Sugarcane Leaf Scald Distribution, Symptomatology, and Effect on Yield in Louisiana

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ABSTRACT

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Sugarcane leaf scald, caused by *Xanthomonas albilineans,* was first observed in Louisiana in November 1992. During 1993, surveys were conducted to determine the geographic distribution of the disease and which cultivars were affected. Symptomatology was monitored in fields with diseased plants, and the effect on yield was studied. Leaf scald was detected in commercial fields of five of seven commercial cultivars. The number of fields of cultivars CP 70-321, CP 72-370, and LHo 83-153 affected and the incidence of plants within fields were low. A greater number of affected fields and higher disease incidence within fields were observed for cultivars CP 74-383 and LCP 82-89. The number of affected fields and the incidence of symptomatic plants were highest in areas located near the Gulf of Mexico, over which a severe hurricane passed during August 1992. Leaf scald was detected in numerous clones at the USDA-ARS research farm near Houma, Louisiana; and the disease was detected in yield trials and increase plots associated with the cultivar selection and release programs. Leaf scald was detected in both commercial and cultivar development plantings at a total of 46 sites in 12 of 18 parishes in which sugarcane is grown. Symptoms were present throughout the growing season. Leaf symptoms included bleaching; characteristic narrow, white pencil lines; and necrosis. Shoot and young stalk death and the development of symptomatic shoots from axillary buds of mature stalks also were observed. At one location, high disease incidence and drought stress in CP 74-383 resulted in extensive plant death and severe losses. Disease incidence, quantified as the number of symptomatic shoots or plants, was inversely correlated with yield in one of four fields. Stalk sucrose content was lower in symptomatic compared to asymptomatic stalks in all four fields; and juice purity, fiber content, and stalk weight were lower in three, two, and one field, respectively.

Leaf scald, caused by *Xanthomonas albilineans* (Ashby) Dowson, is a major disease of sugarcane that is known to occur in at least 44 countries (14). The disease caused severe losses in the *Saccharum officinarum* L. cultivars that were grown around the world until the early part of the twentieth century. Losses were reduced after the introduction of interspecific hybrids of *Saccharum* that were resistant to leaf scald. Damage caused by leaf scald in most regions is now limited to indirect losses resulting from the elimination of promising clones from cultivar selection programs because of disease susceptibility, from the removal of susceptible cultivars from production when new disease outbreaks occur, and from increased production costs associated with producing pathogen-free seed cane of susceptible cultivars (2,12,14).

Leaf scald was first observed in the continental United States in 1967 in clones of the sugarcane collection maintained at the USDA-ARS, Sugarcane Field Station near Canal Point, Florida (9). A low incidence of leaf scald continued to be found in breeding plots until 1989, when the percentage of affected clones increased rapidly at the Field Station, and the disease was found in numerous commercial fields (5). In Louisiana, leaf scald was observed in cultivar CP 74-383 and several experimental clones in cultivar development plots on the USDA-ARS research farm near Houma, during November 1992 (7). Shortly thereafter, it was observed in a nearby commercial field of cultivar LCP 82-89.

Leaf scald is known to occur erratically (14). Infections by *X. albilineans* may be latent in sugarcane plants, or infected plants may exhibit a wide range of possible symptoms. Visible symptoms expressed during the most common chronic phase of the disease include the pencil line symptom (one or more narrow, white lines that run longitudinally down the length of the leaf blade into the sheath), bleaching, chlorosis, and necrosis. The pencil lines may become necrotic, and the necrosis can expand to encompass the entire leaf. Young shoots and stalks may die, and shoots exhibiting leaf symptoms may develop from axillary buds on mature stalks. An acute phase of the disease is recognized in which symptomless mature plants, usually exposed to environmental stress, suddenly collapse and die. Damage to plants and resulting yield loss is correspondingly variable. Disease severity is variable within and between countries.

Disease expression is determined by a complex interaction between genetic traits and environmental factors. The level of resistance to leaf scald varies widely among sugarcane clones. Environmental variables, particularly stress in the form of drought, waterlogging, or low temperature, also are important determinants of disease severity (11-14). Observational evidence has suggested that severe damage from leaf scald is more likely in regions with variable climates (14). In Louisiana, sugarcane is grown near the northern limit of its cultivation range, and extreme variation in weather conditions occurs regularly within and between seasons. Hence, the appearance of leaf scald caused concern within the Louisiana sugarcane industry. In addition, very little information was available concerning the levels of susceptibility to leaf scald among the commercial cultivars in Louisiana. As a result, it was imperative to determine the geographic distribution of the disease and which cultivars were affected. In addition, disease symptomatology and effects on yield were studied in naturally diseased fields.

MATERIALS AND METHODS

Surveys for leaf scald. Plots of experimental cultivars and one commercial field of cultivar LCP 82-89, in which leaf scald-affected plants were observed during fall 1992, were monitored for symptom development during late winter and early spring 1993 to determine when to begin surveying for leaf scald in the Louisiana sugarcane industry. By mid-May, visible symptoms of leaf scald were evident; therefore, during May and June, a survey was conducted by cooperating personnel of the Louisiana Agricultural Experiment Station, USDA-Agricultural Research Service, the Louisiana Department of Agriculture and Forestry, the Louisiana Cooperative Extension Service, and the American Sugar Cane League.

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All experiments of the cultivar selection program located on 14 commercial farms were surveyed. Primary cultivar increase plots that are the first stage of the cultivar release program were surveyed at each of four locations, and secondary increase plots of two newly released cultivars, LCP 85-384 and HoCP 85-845, to be distributed to the industry during 1993, were surveyed on 43 farms in 11 parishes. Variable numbers of commercial fields of seven different cultivars were surveyed on at least one farm (usually the farm on which experimental or increase plantings were located) in each of the 18 parishes in which sugarcane is grown.

Table 1. Summary of leaf scald detection from surveys of sugarcane conducted during 1993

Sources	Sites where leaf scald detected/sites surveyed	Parishes where leaf scald detected
CP 65-357	0/24	0
CP 70-321	2/26	2
CP 72-370	3/19	3
CP 74-383	11/37	5
CP 79-318	0/4	0
LCP 82-89	9/46	5
LHo 83-153	1/9	1
LCP 85-384	0/55	0
HoCP 85-845	11/55	6
Experimental clones in plantings on farms	9/14	8

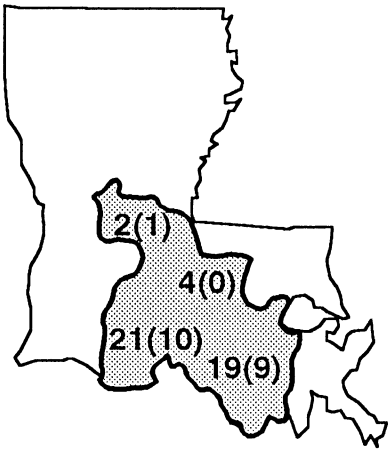

Fig 1. Distribution of sites where leaf scald was detected during 1993 and number of sites at which incidence of symptomatic plants exceeded 1% (number in parentheses) in the areas of Louisiana where sugarcane is cultivated (shaded). The totals for number of sites surveyed in the northwestern, northeastern, southwestern, and southeastern cultivation areas were 25, 43, 64, and 52, respectively.

All plants in research experiments and primary increase plots were observed for characteristic leaf scald symptoms. In secondary increase plots and commercial fields, portions of fields were surveyed for the presence of symptomatic plants. The area surveyed varied among fields. Each member of the surveying party surveyed plants in four rows, for a minimum length of 90 m, or often for the entire length of the rows. The number of surveyors ranged from seven to 10.

Additional surveys were conducted during the remainder of the growing season. Commercial fields were selected based on the observation of plants showing possible leaf scald symptoms in the field to be surveyed or in nearby fields. Research experiments and cultivar increase plots were resurveyed, and additional secondary increase plots were surveyed.

Plants showing possible leaf scald symptoms were noted, and tissue samples consisting of entire young shoots or leaves from young stalks were collected in a plastic bag and placed in an ice chest containing ice packs. In the laboratory, leaf samples were trimmed to portions showing symptoms, and apical meristems were removed from shoots. Tissues were surface disinfested in 1% NaOCl for 3 min and rinsed twice in sterile distilled water. Tissues were cut into small pieces, immersed in sterile distilled water in 5-ml vials, and incubated at room temperature for 2–4 hr or overnight at 4 C. A loop of the resulting suspension was dilution streaked on Wilbrinks agar medium modified to contain 5 g of potassium bromide, 100 mg of cycloheximide, 2 mg of benomyl, 25 mg of cephalexin, 30 mg of novobiocin, and 50 mg of kasugamycin per liter (6).

Plates were incubated at 28 C or room temperature and observed for the development of bacterial colonies each day for 7–10 days. Colonies characteristic of *X. albilineans* appeared 3–5 days after streaking. Tentative identification of an isolate as *X. albilineans* was based on colony characteristics. Isolates were then identified with the Biolog GN MicroPlate System (Biolog, Inc., Hayward, CA) (4).

Disease symptomatology. Symptomatic plants naturally infected with *X. albilineans* were observed periodically following their discovery for the remainder of the growing season. The type, progression, and severity of symptoms were recorded and compared among infected plants of experimental clones and commercial cultivars.

Yield loss estimation. Two fields each of CP 74-383 and LCP 82-89 were found with a high enough incidence of plants exhibiting leaf scald symptoms to allow yield loss experiments to be conducted. Field 1 of CP 74-383 was a third ratoon crop, and field 2 was a plant cane (first year growth) crop. Fields 3 and 4 were LCP 82-89, and both were first ratoon crops.

Twelve 7.5-m single-row plots were laid out on each of four rows for a total of 48 plots. Disease assessment for each plot consisted of counting the number of distinguishable plants showing symptoms of leaf scald in fields 3 and 4 of LCP 82-89 and field 2 of CP 74-383. The number of symptomatic shoots was determined in field 1 of CP 74-383. Disease assessment was not performed at the same time in every field since the disease was discovered at different times during the season. Disease assessments were made in field 1 of CP 74-383 and field 3 of LCP 82-89 on 15 June and 19 October. Disease assessments were made in field 2 of CP 74-383 on 26 July and 27 October, and disease was assessed in field 4 of LCP 82-89 once on 26 July.

During October, the total number of millable stalks (stalks that would be topped and cut by a mechanical harvester) and the number of millable stalks with leaf scald symptoms were determined in fields 1 and 2 of CP 74-383 and one field of LCP 82-89 (field 3). Only millable stalk counts were obtained in the second LCP 82-89 field (field 4) due to severe cane lodging. Five replicates of 10 millable stalks of asymptomatic and symptomatic stalks were collected randomly from each field. These samples were used to determine and compare yield components of asymptomatic and symptomatic stalks, including stalk weight, percent fiber, percent sucrose,

Table 2. Effect of leaf scald on sugarcane stalk yield components

		Component means for asymptomatic (−) and symptomatic (+) stalks[a]							
		Weight (kg)		Fiber (%)		Sucrose (%)		Juice purity	
Field no.	Cultivar	−	+	−	+	−	+	−	+
1	CP 74-383	1.3	1.3	12.1	11.5	12.6	11.7*	84.7	82.9
2	CP 74-383	1.8	1.8	11.0	10.6	13.5	10.9*	86.5	80.1*
3	LCP 82-89	1.5	1.3	12.1	9.7*	14.0	10.3*	86.6	78.8*
4	LCP 82-89	2.0	1.3*	12.3	11.4*	15.3	12.1*	89.6	83.9*

[a] Yield component means for symptomatic stalks that are followed by an asterisk were significantly different ($P = 0.05$) from the mean for asymptomatic stalks for that yield component in the same field.

and juice purity (10). Stalk weight and sucrose content estimates determined from the randomly collected samples in each field and counts from individual plots for each stalk type were used to calculate yield estimates for cane tonnage and kilograms of sucrose per hectare for each plot in the different fields.

Linear regression analysis according to SAS (15) was used to determine if the incidence of symptomatic plants was correlated with the yield estimates for millable stalks, tons of cane, and kilograms of sugar per hectare in each field. Stalk yield components for symptomatic and asymptomatic stalks in each field were compared with a *t* test.

RESULTS

Surveys for leaf scald. In the initial survey conducted from 6 May to 18 June 1993, a total of 80 commercial sugarcane fields of seven cultivars were checked for plants exhibiting symptoms of leaf scald. The disease was not detected in any of 12, 10, four, and seven fields surveyed of cultivars CP 65-357, CP 70-321, CP 79-318, and LHo 83-153, respectively. Leaf scald symptomatic plants were observed in two of five, five of 16, and one of 26 fields of CP 72-370, CP 74-383, and LCP 82-89, respectively. Visible disease incidence was very low in all fields except for two: a field of CP 74-383 with the number of infected shoots estimated at 19,430 per hectare and the field of LCP 82-89 with the number of infected plants estimated at 6,580 per hectare.

Symptomatic plants were observed in numerous clones at the USDA research farm near Houma and in clones introduced from the USDA farm to the Louisiana Agricultural Experiment Station Branch Experiment Station at St. Gabriel, Louisiana. No symptomatic plants were observed in research plots on 14 commercial farms or in cultivar increase plots on four primary increase stations and 11 secondary increase stations on commercial farms.

In subsequent surveys conducted through August 1993, leaf scald symptomatic plants were detected in two of four, one of one, six of nine, six of eight, and one of one fields surveyed of CP 70-321, CP 72-370, CP 74-383, LCP 82-89, and LHo 83-153, respectively. Leaf scald was detected in clones at six of 14 (43%) cultivar selection program experiments on farms, four of four primary cultivar release stations, and 11 of 43 (26%) secondary cultivar release stations. A summary of the survey results is presented in Table 1. Combining observations from commercial and experimental plantings, symptomatic plants were observed at 46 sites in 12 of 18 (67%) of the parishes in which sugarcane is grown. The number of affected fields and the incidence of infection within fields were greatest in areas of surgarcane cultivation closest to the Gulf of Mexico (Fig. 1).

X. albilineans was consistently isolated from symptomatic plants. No *X. albilineans* was isolated in sporadic attempts to isolate bacteria from asymptomatic plants. A total of 29 isolates obtained from symptomatic plants with colony characteristics typical of *X. albilineans* was tested for identification with the Biolog bacterial identification system. For 11 (38%) of the isolates, *X. albilineans* was the most likely species identification provided. The mean degree of similarity for these isolates with the Biolog database for *X. albilineans* was 0.673 ± 0.043 (standard error) with a range of 0.827–0.350. For 15 (52%) of the isolates, *Xanthomonas oryzae* pv. *oryzae* was the most likely species identification provided. The mean degree of similarity for these isolates with the Biolog database for *X. albilineans* was 0.44 ± 0.001. Three isolates (10%) showed no similarity with the Biolog database for *X. albilineans.*

Disease symptomatology. The full range of symptoms associated with the chronic phase of leaf scald was observed in experimental clones and commercial cultivars. Leaf symptoms observed included bleaching, pencil lines, and limited and extensive necrosis. Shoot and young stalk death and the development of symptomatic shoots from axillary buds on mature stalks also were observed in affected clones. Plant death was only observed in a few experimental clones and CP 74-383. Symptoms resembling the acute phase of the disease were observed at one location in CP 74-383.

The final severity of symptoms expressed varied between locations and among cultivars. Variability was greatest for fields of CP 74-383. The incidence of shoots with visible symptoms decreased from 14% on 15 June to 2% on 19 October in field 1. In contrast, disease incidence and symptom severity increased throughout the season in field 2, and extensive plant death occurred at another location in plant cane of CP 74-383.

Yield loss estimation. A comparison was made between stalk yield components of asymptomatic and symptomatic stalks collected from two fields each of CP 74-383 and LCP 82-89 (Table 2). Stalk weight was lower for symptomatic stalks only in field 3 of LCP 82-89. Stalk fiber content was lower in symptomatic stalks in both LCP 82-89 fields. Percent sucrose content was lower for symptomatic stalks in all four fields, and juice purity was lower in all but field 1 of CP 74-383.

Disease incidence was inversely correlated with yield components only in field 2 of CP 74-383 (Table 3 and Fig. 2A and B). In field 2, the degree of correlation was greatest between each of the three yield components (millable stalk number, tons of cane per hectare, and kilograms of sucrose per hectare) and the number of symptomatic plants observed on 27 October (at harvest) (Table 3). The same yield components were not correlated with visible disease incidence in the other fields (Table 3, Fig. 2 C and D).

DISCUSSION

The results of surveys conducted during 1993 suggested that leaf scald was widely distributed but limited in occurrence in the Louisiana sugarcane industry. The surveys were designed to determine the distribution of leaf scald and the cultivars affected. They were not conducted in a random manner to obtain an accurate estimate of leaf scald incidence. As a result, the incidence of fields with leaf scald symptomatic plants determined from these surveys probably represents an overestimate of disease incidence in the industry.

The explanation for the higher frequency of leaf scald in cultivars CP 74-

Table 3. Correlation of sugarcane yield components and leaf scald incidence in fields of two cultivars with natural infection

		Correlation coefficients from linear regression analysis[a]					
		Millable stalks/ha		Cane (tons/ha)		Sucrose (kg/ha)	
Field no.	Cultivar	Infected plants	Infection (%)	Infected plants	Infection (%)	Infected plants	Infection (%)
1	CP 74-383	0.03	−0.14	0.03	−0.14	0.03	−0.15
2	CP 74-383	−0.31*/−0.56**	−0.46**	−0.32*/−0.56**	−0.47**	−0.36*/−0.58**	−0.55**
3	LCP 82-89	−0.12	−0.09	−0.13	−0.11	−0.13	−0.16
4	LCP 82-89	−0.25	ND	−0.25	ND	−0.25	ND

[a] Three yield components were regressed on the number of visibly infected plants (number of infected shoots in field 1) per plot and the infection percentage per plot determined from counts of symptomatic and total millable stalks at harvest. Correlation coefficients are presented for mid- and end-of-season infected plant counts determined in field 2. Coefficients for field 2 were significant at $P = 0.05$ (*) and $P = 0.01$ (**). An end-of-season infection percentage per plot was not determined (ND) for field 4.

383 and LCP 82-89 is not clear. The results of the first experiment to evaluate resistance in plants inoculated with *X. albilineans* suggest that the cultivars planted over the greatest area in Louisiana, CP 70-321, CP 65-357, and CP 72-370, are susceptible to leaf scald (M. P. Grisham, *unpublished*).

Hurricanes are an effective means of spreading leaf scald and have been associated with new disease outbreaks (12–14). In Louisiana, the number of fields in which leaf scald was detected and the incidence of disease within fields were greatest in areas near the Gulf of Mexico over which a severe hurricane passed during August 1992.

An evaluation of symptoms expressed by diseased plants during the season indicated that severe leaf scald symptom development is possible in susceptible cultivars under Louisiana environmental conditions. Severe leaf symptoms and young shoot mortality were observed in all four fields in which yield loss experiments were conducted. However, the number of millable stalks and yield were inversely correlated with visible disease incidence in only one field. Observational evidence suggests that there is an inconsistent relationship between symptom expression and yield loss for this disease (14). The results of this study document the lack of consistency in this relationship. Sugarcane has an indeterminate growth habit, and the most severe form of leaf scald, death of entire plants, may be necessary before consistent yield losses occur. Plant death was observed in the field in which yield was inversely correlated with disease. Plant death was so extreme in another plant cane field of CP 74-383 that the crop was plowed under.

Severe symptom development is associated with the occurrence of stress conditions (11–14). Drought stress occurred in the field that was plowed under, and the field in which yield was adversely affected by leaf scald was also in the area that received erratic rainfall. The other three fields in which yield loss experiments were conducted were located in areas that received adequate to abundant rainfall.

Early reports of crop loss caused by leaf scald provided only rough estimates of the magnitude of losses (1,3,11,14,16). The impact of the disease often was described in terms of the susceptible cultivars that had to be removed from production. In one study (8), yield loss was attributed to slow growth of infected stalks, reduction in stalk number, and a reduction in plant weight. Reductions in millable stalk number and stalk sucrose content were factors contributing to yield loss in the field of CP 74-383 in which yield was adversely affected by leaf scald. The weight of symptomatic stalks was not lower in this field; although stalk weight was lower for symptomatic stalks collected from one field of LCP 82-89. Reductions in symptomatic stalks for stalk yield components, sucrose content, and juice purity were documented previously (1,8). Our results were similar; and additionally, fiber content was decreased in one of two cultivars.

During 1993, it was determined that leaf scald is widely distributed and that the disease has the potential to cause severe symptoms and yield losses under Louisiana environmental conditions. Susceptible cultivars are now grown on nearly all of the area under cultivation with sugarcane. As a result, leaf scald represents a possible threat to the Louisiana sugarcane industry. However, an immediate severe impact on the industry is unlikely since disease incidence is generally low and severe losses appear to result only from a combination of high disease incidence and severe stress. Indirect losses to leaf scald may be more severe. One cultivar released during 1993, HoCP 85-845, was not distributed due to the occurrence of leaf scald in cultivar release plots. Another immediate impact will be the alteration of breeding strategies and the loss of promising clones in the cultivar selection program.

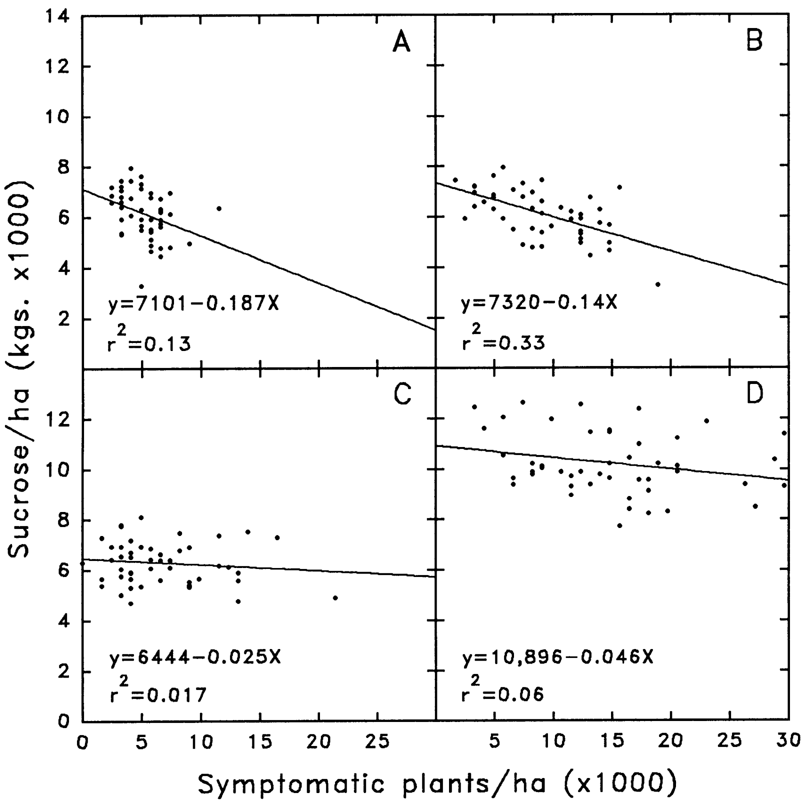

Fig. 2. Relationship of yield to the incidence of leaf scald symptomatic plants in naturally diseased sugarcane fields. **(A)** Yield related to midseason symptomatic plant counts in a plant cane field (field 2) of cultivar CP 74-383. **(B)** Yield related to end-of-season symptomatic plant counts in the same field of CP 74-383. **(C)** Yield related to midseason symptomatic plant counts in a first ratoon field (field 3) of cultivar LCP 82-89. **(D)** Yield related to midseason symptomatic plant counts in another first ratoon field (field 4) of LCP 82-89.

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