Effect of Rust on Sugarcane Growth and Biomass

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ABSTRACT

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The sugarcane rust pathogen, *Puccinia melanocephala*, caused significant growth and biomass reductions of sugarcane plants in a replicated pot study. Disease severity, estimated as the percent area infected on the top visible dewlap leaf, was 53.5% on the highly susceptible cultivar B 4362, 6.9% on the moderately susceptible cultivar CP 78-1247, and 2.3% on the resistant cultivar CP 70-1133. In contrast, the level of rust on uninoculated control plants was 1.3% for cultivar B 4362. Uninoculated control plants of the two other cultivars were free of rust. Stalk height reductions caused by rust were 32.6% in cultivar B 4362, 20.1% in cultivar CP 78-1247, and 15.1% in cultivar CP 70-1133. Wet weights were reduced by 40.9% in cultivar B 4362 and 12.3% in cultivar CP 78-1247 because of rust. Correspondingly, dry weights also were reduced in these two cultivars. Wet weight loss was not observed on the rust-resistant cultivar CP 70-1133, although its dry weight decreased by 3.1%. The experimental design allowed for detection of small yield losses.

Sugarcane (*Saccharum* interspecific hybrid) rust, caused by *Puccinia melanocephala* Syd. & P. Syd., was first reported in Florida in 1979 (3). The disease has effectively eliminated the cultivation of several susceptible cultivars of sugarcane and has mandated that the U.S. Department of Agriculture (USDA) sugarcane variety development program select against rust susceptibility in Florida (12).

Yield losses in sugarcane attributable to rust have generally been documented by making comparisons to historical yields (7). Replicated yield-loss tests in the field have met with only limited success because of difficulties encountered in maintaining disease-free controls. Chemical control using fungicides has been partially successful in controlling rust, however, many applications are required during the long growing season (4,10,13). Application of fungicides to experimental plots also is complicated by the physical size of the sugarcane plant, which precludes the use of ground equipment after the crop is 4–5 mo old.

Yield losses of up to 33% were reported on the highly susceptible cultivar B 4362 in the Dominican Republic, where rust first appeared in the Caribbean in 1978 (1). As the disease spread, losses of 50% were estimated in Mexico during 1981–1982 (6). More recently, yield loss estimates averaged 39.3% on cultivar CP 78-1247 during 1988, based upon comparisons with CP 72-1210 and historical yield data of the two cultivars in replicated yield trials (7). Replicated yield tests verifying these losses have not been reported in Florida. The effect of rust on yield of current commercial cultivars in comparison to rust-susceptible cultivars has not been determined. Our objective was to verify reported yield losses and to determine the effect of rust on a resistant cultivar.

MATERIALS AND METHODS

Experimental design. A test was conducted to measure the influence of rust on growth rate and biomass of two rust-susceptible cultivars, on which substantial losses had previously been reported, and on one rust-resistant cultivar, currently grown commercially. The 2 × 3 factorial experiment consisted of two treatments and three cultivars arranged in a randomized complete block design with 24 replications. The experimental unit was a single potted plant. The two treatments were inoculated and uninoculated plants.

Sugarcane plants. Single-bud seed pieces of sugarcane cultivars B 4362, CP 78-1247, and CP 70-1133, which were highly susceptible, moderately susceptible, and resistant to rust, respectively, were propagated in flats on 23 October 1989 in the greenhouse. Plants were transplanted in Terra ceia muck soil on 12 December 1989 to plastic pots (27 cm diameter × 24 cm high) that were sufficiently large so that plant growth was not restricted at the end of the experiment. The plants were fertilized biweekly throughout the experiment with soluble 20-20-20 fertilizer containing minor elements. The uninoculated plants were maintained in a healthy state by preventing leaf wetness, an environmental requirement for rust infection. Plants were placed on two carts (2.7 × 7.5 m), each holding 72 pots. The minimum distance between pots was 0.45 m. At night, the carts were moved into a photoperiod house maintained at 25 C. During the light hours, plants were moved outdoors. Carts were returned to the house if rain was imminent. The light intensity was 1.6 $\mu E \cdot m^{-2} \cdot s^{-1}$ when plants were in the photoperiod house during the daylight regime. A 12-hr daylight regime was maintained throughout the experiment. This method was reported effective in similar studies in preventing rust infection of uninoculated plants (11).

Inoculation of plants. Plants were moved into the photoperiod house and covered with polyethylene bags before inoculation. A suspension of 8–10 × 10^4 urediniospores per milliliter of *P. melanocephala* was sprayed onto the leaves with a compressed gas atomizer (Spra-Tool, Crown Industrial Products Co., Hebron, IL) by reaching up into the bag covering the plants and spraying 0.5–0.75 ml per plant. The bags were left on the plants overnight and removed the next morning before moving the plants out of the photoperiod house. Plants were inoculated two times each week to ensure that new leaves became infected throughout the experimental period from 12 January to 6 June 1990. The isolate of *P. melanocephala* used in the test was collected from B 4362 plants at Canal Point in July 1989 and was increased on this cultivar. The prevention of dew and careful watering successfully kept rust from occurring on most uninoculated plants.

Rust severity evaluation. Rust severity was determined 1 wk before termination of the experiment. The percent area infected of the top visible dewlap (TVD) leaf was estimated visually, and the severity of rust on the entire plant was rated on a scale of 1–9 where 1 = no symptoms, 2 = necrotic flecks, 3 = a few sporulating pustules on plant, 4 = a few pustules on upper leaves and abundant pustules on lower leaves, 5 = numerous pustules on upper leaves and slight necrosis on lower leaves, 6 = abundant pustules on upper leaves with more necrosis on lower leaves, 7 =

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Table 1. Average rust severity rating and average estimate of percent leaf area infected of the top visible dewlap leaf of sugarcane plants inoculated with *Puccinia melanocephala* and uninoculated for the highly susceptible, moderately susceptible, and resistant cultivars B 4362, CP 78-1247, and CP 70-1133, respectively, 1 wk before harvest

	Inoculated		Uninoculated	
Cultivar	Rating[a]	Severity (%)	Rating	Severity (%)
B 4362	6.8	53.5	2.46	1.33
CP 78-1247	3.3	6.9	1.00	0.04
CP 70-1133	2.0	2.3	1.00	0.00
$LSD_{0.05}$	0.369	4.44	0.309	0.488

[a] Means based on 24 observations per treatment rated on a scale of 1–9 where 1 = no symptoms and 9 = severe rust (2).

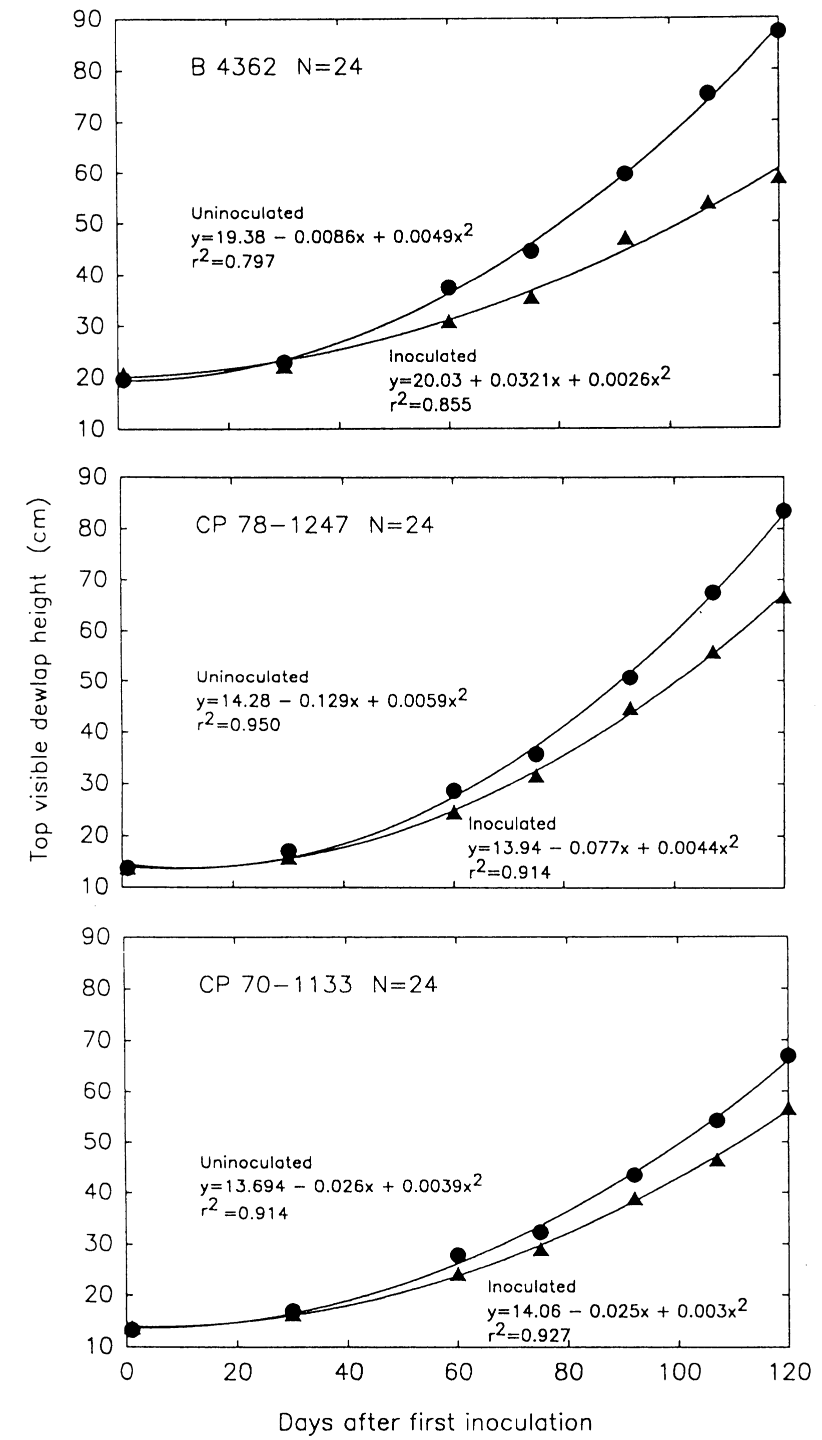

Fig. 1. Plant height (cm) to the top visible dewlap leaf of rusted and healthy sugarcane plants of the highly susceptible, moderately susceptible, and resistant cultivars B 4362, CP 78-1247, and CP 70-1133, respectively.

abundant pustules on upper leaves, lower leaves necrotic, 8 = some necrosis on upper leaves, and 9 = leaves necrotic with plant near death (2).

Plant growth and biomass measurements. The height of the primary shoot from the soil surface to the collar of the TVD leaf was measured. Measurements were taken at 4-wk intervals for 3 mo then measurements were made at 2-wk intervals until completion of the experiment. At the termination of the experiment, whole individual plants were harvested above the soil surface and immediately weighed for their wet weight. The material was dried at 40 C until constant sample weights were obtained for each individual plant.

Data analysis. Differences in disease intensity (rating) and severity among cultivars within treatments (inoculated vs. uninoculated) were determined with LSD. Significance of differences in biomass among treatments within cultivars were identified with analysis of variance. Regression analysis of plant heights over days after inoculation was performed to derive growth curves. Analysis of variance was used to determine differences in growth response to treatments (9).

RESULTS

Rust severity. For both the inoculated and uninoculated treatments, rust severity differed among cultivars (Table 1). The susceptible cultivar B 4362 developed the most rust (53.5%) on the TVD leaf, followed by the moderately susceptible cultivar CP 78-1247 with 6.9%, and the resistant cultivar CP 70-1133 with 2.3% severity (Table 1). Whole plant rust severity ratings on a scale of 1–9 gave the same rankings. Correlation between visual estimation of leaf area infected and whole plant rating of disease severity was high ($r = 0.91$). The resistant cultivar CP 70-1133 had a response rating of 2, indicating necrotic flecks but no sporulating pustules, whereas cultivar CP 78-1247 had a 3.3 rating, indicating a small number of sporulating pustules, and cultivar B 4362 had a 6.8 rating, indicating severe rust symptoms and numerous pustules with necrotic lower leaves. Only 1.33% of the TVD leaf area was infected on plants of the uninoculated susceptible cultivar B 4362, which differed significantly from uninoculated plants of the other two cultivars. This slight amount of infection was considered unimportant for biomass analysis. Sporulating rust pustules were not observed on uninoculated plants of either cultivar CP 70-1133 or CP 78-1247. The uninoculated plants had not been protected from inoculum falling on them from adjacent plants except during inoculation.

Plant growth and biomass measurements. Differences in growth between inoculated and uninoculated treatments were significant ($P = 0.01$) for each cultivar (Fig. 1). Final height reductions

Table 2. Wet and dry biomass of rust inoculated (I) and uninoculated (U) sugarcane plants of the highly susceptible, moderately susceptible, and resistant cultivars B 4362, CP 78-1247, and CP 70-1133, respectively, with percent biomass losses given for inoculated plants

Cultivar	Wet weight (g)			Dry weight (g)		
	I	U	Loss (%)	I	U	Loss (%)
B 4362	450	761	40.9*[a]	99	166	40.4*
CP 78-1247	688	796	12.3*	159	186	14.5*
CP 70-1133	733	733	0.0	158	163	3.1

[a] Asterisk indicates significant difference at $P = 0.01$ between inoculated and uninoculated treatments within a cultivar.

attributable to rust infection were 32.6, 20.1, and 15.1% in cultivars B 4362, CP 78-1247, and CP 70-1133, respectively. The percent biomass loss attributable to rust infection was significant ($P = 0.01$) within cultivars B 4362 and CP 78-1247. The wet biomass loss attributable to rust was 40.9% for B 4362 and 12.3% for CP 78-1247 (Table 2). Dry biomass loss was 40.4 and 14.5% for these respective cultivars. Wet and dry weights were statistically similar in inoculated and uninoculated plants for CP 70-1133. The coefficient of variation for dry weight was 12.9%, compared with 17.4% for wet weight measurements.

DISCUSSION

Dry and wet biomass data gave comparable percent biomass reductions. The biomass losses reported herein for B 4362 are consistent with observations made in commercial production fields in 1978 (1,6). Yield losses of 17.5% cane tonnage with a sugar loss of 23.5% was detected in 1990 field tests on the major commercial cultivar CP72-1210 in south Florida (8). CP 78-1247 had comparable yields to CP 72-1210 until increased rust susceptibility was detected in 1988 when its sugar yield per acre was 39.3% less than CP 72-1210 (7). The severe reaction of cultivar CP 78-1247 to rust caused its subsequent removal from commercial production.

Inoculated plants of the resistant cultivar CP 70-1133 had a dry weight 3.1% less than that of uninoculated plants but the difference was not significant ($P >$ 0.25). The reduction in height, however, was significant ($P < 0.01$). The reason for the apparent discrepancies in reduction in height but not weight loss is not known. Although, essentially, no pustules were observed on the leaves of CP 70-1133 plants, minute flecks from aborted infections were present in abundance in the leaves. It is not known if the high level of leaf flecking caused by continual inoculation caused this reduction of dry weight and reduced growth rate of the primary shoot. The use of the photoperiod house gave experimental evidence quantifying losses attributable to sugarcane rust with a high level of precision in a replicated test. These methods may be appropriate for determining slight differences in resistance among cultivars, as well as for detecting differences in virulence of rust isolates.

Rust infection was successfully controlled in this experiment by preventing leaf wetness. Rust did not develop on plants of uninoculated moderately susceptible cultivar CP 78-1247 and only a slight amount occurred on uninoculated plants of the highly susceptible cultivar B 4362. Although the level of rust on uninoculated plants of B 4362 was significantly different from plants of the other uninoculated cultivars, due to the low level, it was considered unimportant. Fungicidal control of sugarcane rust in earlier field experiments was not as complete as the control of rust obtained in this experiment (4,10,13).

The method of inoculation used in this experiment gave comparable disease ratings and levels of leaf area infected as are observed on plants grown in the field in south Florida. The age of the plants in this test was optimal because rust development is more on plants 3–6 mo of age (2,5). Overall, the experiments appeared to simulate field conditions and are in general agreement with field results.

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