Incidence-Severity Relationships for Common Maize Rust on Sweet Corn

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ABSTRACT

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Incidence and severity relationships for common maize rust on sweet corn were determined using the cultivar Jubilee grown in selected commercial fields in western New York State from 1986 through 1988. The relationships between incidence (percent diseased leaves) and severity (percent leaf area diseased or number of uredinia per leaf) were similar during the 3 yr of study. Incidence was under 80% when disease severity was 1–2% leaf area diseased and about six uredinia per leaf. Severity significantly increased after 80% incidence was reached. We propose the use of the 80% incidence parameter as an action threshold for initiation of fungicide applications prior to tasseling on the cultivar Jubilee to prevent development of damaging levels of disease.

Additional keywords: action threshold, critical disease level, *Puccinia sorghi, Zea mays.*

Common maize rust caused by *Puccinia sorghi* Schwein. is a serious disease of processing sweet corn (*Zea mays* L.) in New York State. Although low levels of common maize rust are normally present in sweet corn fields, disease incidence and severity have increased in recent years. Several factors may be responsible. Sweet corn is planted in New York from May through June to allow processing facilities to operate efficiently over an extended period of time. The staggered planting schedules result in large quantities of inoculum becoming available for late-planted fields, and disease severity is greatest in those fields. The increased production of winter corn crops in southern areas also provides an early source of initial inoculum (6).

The sweet corn hybrid Jubilee, which is the most common cultivar grown for processing in New York State, has been classified as moderately susceptible (17) to moderately resistant (7). Sweet corn hybrids with Rp resistance genes or partial resistance to common maize rust are available (6,14,15), but they have not achieved the popularity of Jubilee among processors. Fungicides are available for control of common maize rust, but proper timing of the fungicide applications and estimates of quantities of incoming inoculum have been difficult to determine (5,6,20). Monitoring spore movement is not considered practical or economical, and forecasts based on environmental parameters are useful for predicting infection periods but do not provide information on initial inoculum levels and time of arrival.

Preliminary research conducted in 1984 in New York State demonstrated the efficacy of the fungicide mancozeb for control of common maize rust (1) and the need for precise timing of initiation of fungicide applications. Since processing sweet corn fields in New York are regularly monitored for presence of insect pests, we proposed inclusion of fungal pathogens in the scouting procedure. In 1986, research was initiated on development of an action threshold for common maize rust on sweet corn, and preliminary results were reported (2,3). This paper summarizes the results obtained in 1986, 1987, and 1988 on the relationships between common maize rust incidence and severity on Jubilee, and the use of those relationships to develop an action threshold for initiation of fungicide applications.

MATERIALS AND METHODS

In 1986, 1987, and 1988 common maize rust incidence and severity data were collected from naturally infected processing sweet corn plants in commercial fields in western New York. The sweet corn hybrid Jubilee was evaluated for rust incidence and severity in three different fields each test year (Table 1).

Field size varied from 6 to 12 ha. For the convenience of the commercial pesticide applicator, each field was arbitrarily divided in half to establish two treatments: treated, or not treated with fungicides for control of common maize rust. Analysis of the fungicide-treated portions of the field are presented in a companion paper (4), which assesses the validity of the action threshold proposed in this manuscript and analyzes yield-loss relationships associated with common maize rust outbreaks.

TABLE 1. Year, location, planting, and evaluation dates for common maize rust incidence and severity on the sweet corn cultivar Jubilee in New York State

Year	Field	Location[a]	Planting date (climatological day)[b]	Evaluation dates (climatological day) and growth stage[c]
1986	A	LeRoy	119	145-EW, 159-MW, 187-S, 209-M
1986	B	LeRoy	119	145-EW, 159-MW, 187-S, 208-M
1986	C	LeRoy	119	145-EW, 159-MW, 187-S, 206-M
1987	D	Corning	113	143-EW, 153-MW, 165-LW, 177-S, 198-M
1987	E	LeRoy	112	146-EW, 160-LW, 174-S, 193-M
1987	F	LeRoy	110	145-EW, 160-LW, 173-S, 195-M
1988	G	Corning	107	129-EW, 147-MW, 161-T, 177-S, 190-M
1988	H	LeRoy	110	135-EW, 149-MW, 164-T, 175-S, 197-M
1988	I	LeRoy	114	135-EW, 150-MW, 163-T, 176-S, 204-M

[a]Locations in New York State.
[b]Climatological day; 1 March = day 1.
[c]EW = Early whorl, MW = mid whorl, LW = late whorl, T = tassel, S = silk, M = mature, following the description of James (11).

Each half-field portion was divided into 10 blocks. Within each block, 10 plants were randomly selected for evaluation. All living leaves on a plant were evaluated for rust severity using counts of uredinia per leaf when the count was initially estimated to be less than 50 per leaf. Visual estimates of percent leaf area diseased per leaf were made using the Horsfall-Barratt rating scale (9). Prior to data analysis, all Horsfall-Barratt ratings were converted to percent leaf area diseased by assigning the midpoint value to each rating interval. Incidence was determined as the percentage of leaves infected per plant. Growth stage of the plant, following the description of James (11), was recorded at each evaluation date (Table 1).

Data were tabulated for each location and treatment by date, block, and plant. The experimental unit was a plant, and values expressed for each plant were average uredinia per leaf, average diseased area per leaf, and percent leaves infected. In order to determine positional importance of disease on the plant, two subsets of the data, representing leaves subtending the ear and leaves above the ear, were also tabulated and analyzed. Incidence and severity relationships were derived from single-plant incidence and severity data pooled over all sampling dates and treatments, after preliminary analysis showed little differences between dates and treatments. Uredinia per leaf and leaf area diseased were both considered severity measurements, and separate relationships for incidence were constructed. Appropriate transformations were made to the severity data in order to linearize the incidence-severity relationship and to make the data more homoscedastic.

RESULTS

In 1986, favorable environmental conditions promoted rapid disease development. Total rainfall (Geneva, NY) for July, August, and September was 158, 63, and 78 mm, respectively. Average monthly temperatures for the same period were 16, 19, and 16 C, respectively. Rust was first detected at the mid whorl growth stage (second evaluation date), and disease severity increased significantly by the silking stage (Fig. 1A). An apparent decrease was detected at the final evaluation (mature growth stage). Further study showed that disease severity on the upper leaves did not change from the silk to the mature growth stage (Fig. 1B), but disease severity on the lower leaves decreased significantly from silking to maturation (Fig. 1C). The apparent decrease in disease severity was due to the presence of fewer leaves to rate because of senescence of the lower leaves.

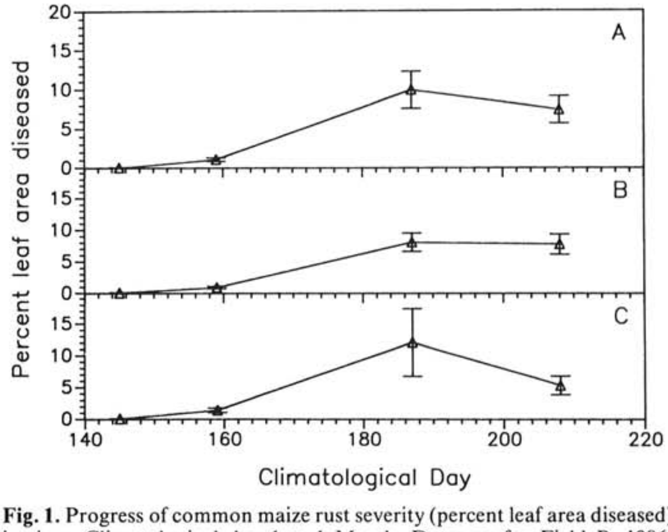

Fig. 1. Progress of common maize rust severity (percent leaf area diseased) in time. Climatological day 1 = 1 March. Data are for Field B, 1986. Bars represent the standard error of the mean. **A,** Disease severity on all leaves. **B,** Disease severity on the upper leaves (leaves above the ear). **C,** Disease severity on the lower leaves (leaves subtending the ear).

As disease incidence increased, disease severity levels generally remained below 2% leaf area diseased until approximately 80% of the leaves were diseased (Fig. 2A). Thereafter, severity levels ranged from 1 to 22% leaf area diseased. An incidence level of 80% corresponded with about 1.3% leaf area diseased. The number of uredinia per leaf increased as disease incidence increased (Fig. 2B). A wide range in the number of uredinia per leaf was present after the 80% incidence level, and the number of uredinia per leaf was frequently too numerous to count. The relationship between incidence and uredinia counts was linear after $\log_{10}$ transformation of uredinia counts, and 80% incidence corresponded with about six uredinia per leaf (Fig. 2B, Table 2). At 80% incidence, the plants were approximately at the late whorl growth stage (Fig. 3A).

In 1987, rainfall totals in July, August, and September were 143, 85, and 130 mm, respectively, and average monthly temperatures for the same period were 22, 19, and 16 C, respectively. Rust was detected at the mid whorl growth stage (second evaluation date). Disease severity increased slowly after the mid whorl growth stage and did not reach levels greater than 2% by maturity (Fig. 4A). As disease incidence increased, disease severity slowly increased. The 80% incidence level corresponded with about six uredinia per leaf (Fig. 5A, Table 2) and 1.2% leaf area diseased. At 80% incidence, the plants were at the late whorl growth stage (Fig. 3B).

Rainfall totals for July, August, and September 1988 were 94, 78, and 57 mm, respectively, and were substantially below normal. Average monthly temperatures for July, August, and September were 23, 22, and 15 C, respectively. Rust was not detected until tasseling (third evaluation date, Fig. 4B). Disease severity increased after tasseling, but remained at low levels. Eighty percent incidence corresponded with about 1.3% leaf area diseased and with five uredinia per leaf (Fig. 5B, Table 2). At 80% incidence, the plants were past the silk growth stage and approaching maturity (Fig. 3C).

DISCUSSION

Puccinia sorghi is a macrocyclic heteroecious fungus. However, infection of the alternate host, *Oxalis* L. spp., is not considered an important component of the disease cycle in temperate areas. The urediniospores initiate infections of sweet corn and are unable to overwinter in northern climates (6). Each spring, the spores move north from southern areas of the United States, and Mexico, following sequential plantings of corn. Because the primary inoculum for initiation of rust epidemics arrives from outside the

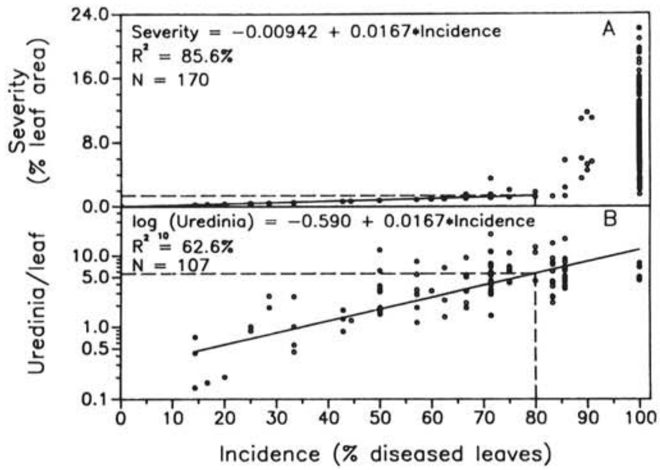

Fig. 2. Relationship between incidence and severity. Data are for Field B, 1986. Points represent the mean severity values for each plant with disease. **A,** Relationship between incidence and percent leaf area diseased. The equation represents the regression line from 0 to 80% incidence. **B,** Relationship between incidence and uredinia per leaf. The equation represents the regression line from 0 to 100% incidence.

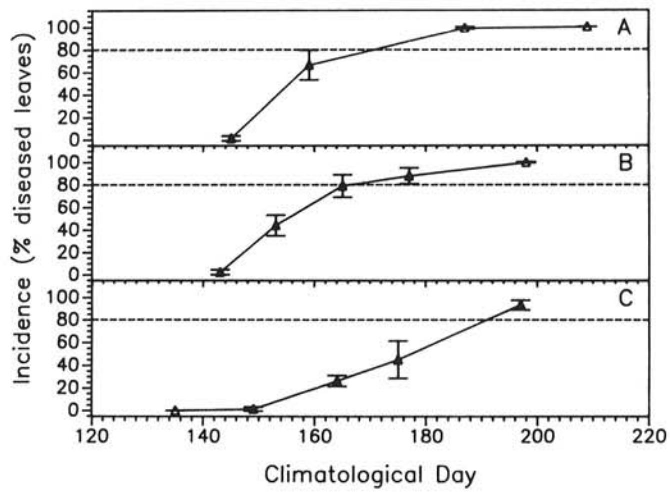

Fig. 3. Progress of common maize rust incidence (percent diseased leaves) in time. Climatological day 1 = 1 March. Bars represent the standard error of the mean. Action threshold is shown at 80% incidence. **A,** Field B, 1986. **B,** Field D, 1987. **C,** Field H, 1988.

TABLE 2. Year, field identification, and regression parameters for common maize rust incidence-severity relationships on the sweet corn cultivar Jubilee in New York State.

Year	Field	Regression parameters[a]			
		b_0	b_1	R^2	s
1986	A	−0.679	0.0180	66.6	0.326
1986	B	−0.590	0.0167	62.6	0.299
1986	C	−0.871	0.0213	78.8	0.272
1987	D	−0.837	0.0207	75.7	0.286
1987	E	−0.920	0.0210	84.3	0.276
1987	F	−0.850	0.0199	73.5	0.336
1988	G	−0.875	0.0189	76.2	0.287
1988	H	−0.875	0.0199	83.7	0.288
1988	I	−0.939	0.0200	81.6	0.288

[a]Severity = $b_0 + b_1$ (incidence). Severity is expressed as $\log_{10}$ uredinia per leaf, and incidence is expressed as percent diseased leaves. The regression equations are for the range of incidence 0–100%. R^2 is the coefficient of determination adjusted for degress of freedom, and s is the standard error about the regression line.

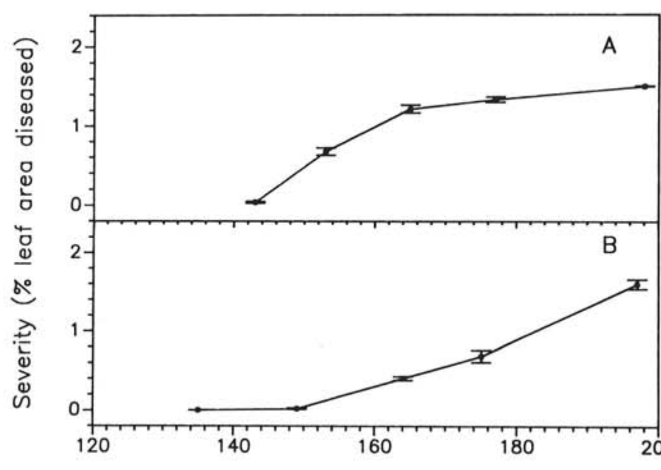

Fig. 4. Progress of common maize rust severity (percent leaf area diseased) in time. Climatological day 1 = 1 March. Bars represent the standard error of the mean. **A,** Field D, 1987. **B,** Field H, 1988.

immediate area planted to corn, it has been difficult to determine when susceptible hybrids should receive a prophylactic fungicide treatment. In New York State, late-planted susceptible sweet corn hybrids show greater incidence and severity levels at harvest than early planted hybrids. This is due in part to greater inoculum levels in the immediate area when late-planted hybrids are in susceptible growth stages. Our objective was to utilize incidence and severity relationships for common maize rust on sweet corn to determine an action threshold that would indicate when a critical disease level had been reached.

The relationships between common maize rust incidence (percent of infected leaves) and severity (percent leaf area diseased or number of uredinia per leaf) were similar during the 3 yr of study (Table 2). Disease severity was 1–2% leaf area diseased and about six uredinia per leaf until 80% incidence was reached. The severity levels substantially increased as incidence increased from 80 to 100%. These relationships are similar to those reported for a susceptible (Florida Staysweet) and a partially resistant (Sugar Loaf) sweet corn hybrid (16).

We believe the rating scale used to assess percent leaf area diseased was insensitive to low levels of disease compared to uredinia per leaf measure of severity. In fact, lack of sensitivity created an artifact in the incidence-severity relationship. If severity on all leaves of a plant did not exceed 1%, the rating was equivalent to incidence (i.e., if a leaf had no disease, it was assigned a severity rating of 0 and the incidence was 0; if a leaf was diseased but had less than 1% leaf area covered with uredinia, it was assigned a severity of 1, and the corresponding incidence value for the leaf was also 1). Thus, when computing the mean incidence and severity of the plant, the two values were identical and the relationship produced a perfect linear relationship between 0 and 1% (Fig. 2A). After one or more leaves developed disease greater than 1% severity, the relationship assumed the more typical form of an incidence-severity curve (10,12,18,19). The problem can be minimized by creating several additional severity classes between 0 and 1%. The severity measurement of uredinia per leaf provided greater sensitivity in this range and thus was the preferred severity measure to relate to incidence.

The relationship between disease incidence and severity as measured by uredinia per leaf was stable over the 3 yr of the study (Table 2). The regression of $\log_{10}$ uredinia on percent incidence was very similar in 1987 and 1988 (Fig. 5) but had a slightly shallower slope and lower intercept in 1986 (Fig. 2) in two of the fields (Table 2). At 80% incidence, the expected number of uredinia per leaf was about six, six, and five for 1986, 1987, and 1988, respectively. Under these conditions, incidence can be used as an accurate predictor of uredinial severity.

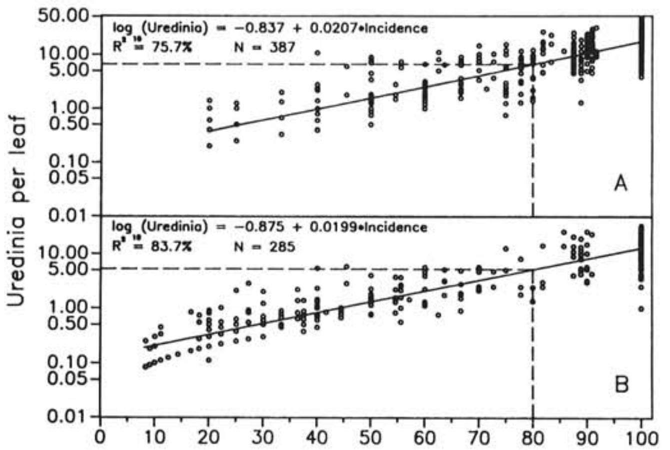

Fig. 5. Relationship between incidence and uredinia per leaf of common maize rust. Points represent the mean severity values for each plant with disease. The equation represents the regression line from 0 to 100% incidence. **A,** Field D, 1987. **B,** Field H, 1988.

We propose the use of the 80% incidence parameter as an action threshold or critical disease level that, when reached, would indicate that a fungicide treatment is necessary to prevent the development of damaging disease levels. The 80% incidence action threshold is only valid if reached prior to tasseling, as previous research has shown that susceptible and resistant hybrids become more resistant to *P. sorghi* as the plants approach anthesis (7). The 80% incidence action threshold also is only valid for the cultivar Jubilee and perhaps sweet corn hybrids in the moderately resistant category. Highly susceptible sweet corn hybrids will require a lower action threshold to avoid yield and quality reductions (16).

It has been suggested that action thresholds are inappropriate for polycyclic diseases (5). For common maize rust on sweet corn, the threshold can be justified because of low rates of increase in severity (Figs. 1A, 4A, and 4B). Based on the Gompertz model and disease severity, Headrick and Pataky (8) reported that the average rates for the susceptible sweet corn hybrid Florida Staysweet were $k = 0.02–0.06$/day and $k = 0.009–0.019$/day for the partially resistant sweet corn hybrid Sugar Loaf. We measured the rate of increase in severity for the moderately susceptible cultivar Jubilee in 1986 at 0.0236/day based on the Gompertz model, using disease severity recorded on climatological days 159 and 187. At this rate, it would take nearly 7 days for disease to increase from 1 to 2% severity. The time from infection to production of mature uredinia is 16 days at 10 C (constant temperature), 10 days at 15 C, 7 days at 20 C, and 5 days at 25 C (13). A fluctuating temperature regime of 20 C and 10 C (12 hr each) resulted in a generation time of 9 days, and a regime of 25 C and 15 C for 12 hr each resulted in a generation time of 6 days (13). Thus, at temperatures common to the growing season in New York (15–25 C), the rate of increase in severity is sufficiently slow for the threshold to be used. Our data suggest that fungicidal control of the disease can be achieved after reaching the threshold before a substantial increase in severity occurs.

The 80% incidence threshold can be readily incorporated into existing integrated pest management scouting procedures because incidence can be easily measured. Obtaining counts of uredinia per leaf is time consuming, and evaluations of percent leaf area diseased tend to vary with the individual recording the data. The 80% incidence action threshold is currently being implemented on a trial basis by Cornell Cooperative Extension county agents.

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