CONTROLLING COMMON RUST IN SWEET CORN

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Common rust, caused by *Puccinia sorghi*, can be a yield-limiting disease of sweet corn. Sweet corn yield is reduced about 6% for each 10% rust severity (leaf area infected) at harvest (Fig. 1). Severity of rust is affected by the growth stage at which plants are first infected, weather, and host resistance. Severe infection must be prevented in order to avoid yield reductions due to rust. There are no curative control measures for rust.

Two types of rust spores occur on corn. During most of the season, rust-colored urediniospores are produced in uredinia (rust pustules). Urediniospores re-infect corn causing rust to become more severe as a greater portion of the leaf area becomes infected. Dark-colored teliospores replace urediniospores in rust pustules as corn matures. Teliospores do not infect corn. Teliospores germinate to produce basidiospores which infect several species of *Oxalis* on which the aecial stage (i.e., the sexual stage of the rust fungus) occurs. The aecial stage does not occur naturally in the United States. Therefore, urediniospores are the only important inocula of common rust for corn in the Midwest.

**PRIMARY INFECTION AND INITIAL INOCULUM**

Urediniospores do not overwinter in most corn fields because teliospores replace urediniospores in rust pustules near the end of the growing season. Urediniospores spread northward in the Corn Belt from the south where *P. sorghi* survives the winter, presumably in Mexico. During most of the 20th century, urediniospores arrived in the Midwest near the middle of the growing season; and rust was primarily a problem on late-planted sweet corn crops. For the past 15 years, a few rust pustules have been observed on sweet corn in the Midwest in early-June. In 2000, a few pustules were seen May 20 on sweet corn grown in Champaign, IL. Presumably, earlier plantings and more acreage of field corn in the southern US (e.g., Texas) has hastened the arrival of urediniospores in the Midwest causing rust to be prevalent in the Midwest earlier in the season. Nonetheless, earliest-planted sweet corn usually escapes damage from rust because the amount of inocula present is not sufficient to cause rust to be severe.

When urediniospores are present, infection usually occurs in leaf whorls where moisture accumulates. Tissue infected in the whorl often can be identified one or two weeks later by bands of rust pustules that occur across corn leaves. The first four or five leaves on a corn plant (juvenile leaves) are more susceptible to rust infection than subsequent leaves (adult leaves) probably because of different types and amounts of leaf waxes, leaf hairs, and other morphological differences between juvenile and adult leaves. Infection of lower leaves has little or no direct effect on yield; however, these infections are the main source of secondary inocula responsible for problematic levels of rust.

**SECONDARY INOCULA, WEATHER, AND RUST DEVELOPMENT**

Secondary inocula (urediniospores produced in rust pustules) usually is abundant unless temperatures are above 92 F and drought conditions occur. Urediniospores form in rust pustules seven days after infection. Over a period of about four weeks, as many as 5,000 urediniospores are produced in each pustule. Thus, a million urediniospores can be produced on three or four lower leaves of a plant that has as few as 50 to 70 pustules per leaf (about 5% severity).

Moisture and temperature greatly influence the rate at which rust develops. Urediniospores remain viable for long periods under dry conditions.
conditions, but about 6 hr of moisture is required for urediniospores to germinate and infect. The rate and amount of infection increases with longer periods of moisture. Rates of germination, infection, and sporulation are optimal at cool temperatures (60 to 75 F), but P. sorghi can infect and sporulate at temperatures from 38 to 92 F. Thus, rust can occur nearly any time during the growing season when moisture is adequate, but infection is most severe when weather is cool and wet.

In the Corn Belt, rust generally develops most abundantly in the later part of the season when urediniospores are plentiful, air is humid, and temperatures drop overnight resulting in the formation of dew. Heavy rain tends to wash urediniospores from leaves.

**Rust Resistance and Reactions of Sweet Corn Hybrids**

Resistance is the ability of the host to restrict the growth, reproduction, or disease-producing capacity of the pathogen, which results in fewer symptoms and less adverse affects on yield. Reactions of sweet corn hybrids to rust range from highly resistant to highly susceptible. There are two distinct types of resistance to common rust: general and Rp-resistance.

Hybrids with general rust resistance (sometimes called partial resistance) are infected less severely than susceptible hybrids, but there is no distinct, qualitative difference in the type of rust symptoms on hybrids with partial resistance.

Rust reactions of sweet corn hybrids that are not Rp-resistant vary continuously from partially resistant to susceptible. These hybrids can be classified as resistant (R), moderately resistant (MR), moderate (M), moderately susceptible (MS), and susceptible (S) based on consistent responses of a hybrid over several trials. This type of classification produces statistically “overlapping” groups (e.g., the hybrid with the least severe symptoms in the MR class is not different from the hybrid with the most severe symptoms in the R class). Nevertheless, this type of classification ranks the reaction of a hybrid relative to all other hybrids, and it provides a reasonable estimate of the effect of rust on yield based on probabilities of how severe rust may be on a particular hybrid (Table 1). For example, hybrid reactions to rust have been assessed in disease nurseries at the University of Illinois for 15 years. In 9 of 15 years (i.e., 60% of the trials, $P = 0.60$), rust severity was below 10% on hybrids classified as resistant (Table 1). In the other 6 years ($P = 0.40$), rust severity ranged from 10 to 20% on partially resistant hybrids. For hybrids that were classified as susceptible (S), rust severity was never below 20%; severity ranged from 20 to 30% in 3 of 15 trials ($P = 0.13$), severity ranged from 30 to 40% in 5 of 15 trials ($P = 0.33$), severity ranged from 40% to 50% in 3 of 15 trials ($P = 0.33$), and severity was above 50% in 2 of 15 trials ($P = 0.13$) [Table 1]. Yield reductions due to rust can be estimated for hybrids in each class by multiplying rust severity by 0.6.

**Table 1.** Probability* of different levels of rust severity (and estimated yield reductions) on sweet corn hybrids the rust reactions that range from resistant (R) to susceptible (S)

<table>
<thead>
<tr>
<th>Rust severity % and (estimated yield reductions)</th>
<th>Probability* of severity of rust</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reactions of sweet corn hybrids</td>
</tr>
<tr>
<td></td>
<td>R</td>
</tr>
<tr>
<td>0-10% (3%)</td>
<td>0.6</td>
</tr>
<tr>
<td>10-20% (9%)</td>
<td>0.4</td>
</tr>
<tr>
<td>20-30% (15%)</td>
<td>0</td>
</tr>
<tr>
<td>30-40% (21%)</td>
<td>0</td>
</tr>
<tr>
<td>40-50% (27%)</td>
<td>0</td>
</tr>
<tr>
<td>&gt;50% (&gt;30%)</td>
<td>0</td>
</tr>
</tbody>
</table>

* probability based on 15 years of evaluations in University of Illinois sweet corn hybrid disease nurseries
When weather conditions are cooler and wetter than in most of the UI disease nurseries, rust will be more severe for hybrids in each category and yield reductions will be larger, but relative ranks of hybrids should remain similar.

Nearly 150 commercially available sweet corn hybrids have Rp-resistance to common rust. Rust symptoms are distinctly different on hybrids with Rp-resistance. Chlorotic or necrotic flecks are evident where typical rust pustules would have developed. Urediniospores usually are not produced or rust pustules are extremely small with only a few spores produced. Severity of rust is 0 or 1% and yield is not affected adversely.

Several single, dominant genes convey Rp-resistance. Most, but not all, commercially available sweet corn hybrids have Rp-resistance conveyed by the Rp1-D gene. A few sweet corn hybrids have Rp-resistance based on other Rp genes such as Rp-G, Rp1-E and Rp1-I. Compound rust resistance also has been developed by using molecular techniques to identify multiple Rp genes that are genetically linked (e.g., Rp-GI, Rp1-DJ, Rp1-G5JC, Rp1-JFC). Sweet corn hybrids with compound rust resistance are being developed presently.

Prior to 1999, the Rp1-D gene effectively controlled common rust on sweet corn in North America. In 1999 and 2000, a population of P. sorgii that was virulent against the Rp1-D gene occurred in North America. Rp-resistance based on the Rp1-D gene was not effective against this population. Reactions of Rp-resistant hybrids to this virulent population vary from susceptible to partially resistant. For example, WHT 2801, an Rp1-D version of a rust susceptible hybrid, has a susceptible reaction to the virulent population; Heritage, an Rp1-D version of a moderate hybrid, has a moderate reaction to the virulent population; and Green Giant Code 55, an Rp1-D version of a moderately resistant hybrid, has a moderately resistant reaction to the virulent population.

In most parts of North America in 2000, the Rp1-D-virulent population of P. sorgii was not as common as the avirulent population. Often, a few small pustules were seen on Rp-resistant hybrids, but rust was not as severe on Rp-hybrids as on non-Rp versions of the same hybrid. Conversely, in areas of New York and Canada where weather conditions were extremely favorable for rust, the Rp1-D-virulent population was prevalent, and Rp-hybrids were infected severely.

The new, Rp1-D-virulent population of P. sorgii does not infect hybrids with Rp-resistance based on many other Rp genes, however, rust isolates in the avirulent population may be virulent on some of the other Rp genes. In 2000, sweet corn lines with the Rp-G, Rp1-E, Rp1-I, or Rp1-K genes and lines with compound rust resistance genes (i.e., Rp-GDJ, Rp-GFJ, Rp-GI, Rp-G5, Rp-G5JC, Rp-G5JD, Rp1-JC, or Rp1-JFC) were asymptomatic in Illinois until late-August when a few, small uredinia were seen on most lines. Rust isolates collected from these plants were avirulent against Rp1-D, but they were virulent against some of the other Rp genes.

**CONTROLLING RUST**

Rust can be controlled with resistance or fungicides. The effectiveness of resistance depends on the type of resistance, the population of the pathogen, and weather. The effectiveness of fungicides is affected by reaction of the hybrid, time of application, and weather.

General resistance is effective against all populations of P. sorgii, but control is not complete. The level of control depends on the reaction of the hybrid and weather. Rust severity usually does not exceed 20% on hybrids classified as resistant, whereas 20 to 30% severity which reduces yield about 12 to 18% is relatively common on hybrids classified as moderately resistant or moderate (Table 1). When weather is rust-conducive, one or two applications of fungicides may be economical on MR and M hybrids. For hybrids with MS or S reactions, rust severity frequently is above 30%, and fungicide control probably is economical when weather is cool and wet.

General resistance and fungicides are complementary control tactics. Fewer applications of fungicide are needed to control rust on hybrids with general resistance than on susceptible hybrids, or rust control is better on hybrids with general resistance than on susceptible hybrids when the same amounts of fungicide are applied to all hybrids. As a rule of thumb, the amount of control provided by each level of general resistance (R, MR, M, MS to S) is equivalent to one application of fungicide.
**Rp resistance** provides nearly complete control of rust, but it is not effective against all populations of *P. sorghii*. For the next few years, it will be very difficult to predict the performance of Rp-resistant hybrids because virulence in populations of *P. sorghii* may vary. Hybrids with Rp-resistance will be completely effective if virulence is absent. They will provide moderate levels of control if virulent isolates comprise only a small portion of the rust population. They will be ineffective if virulent isolates are abundant.

In the near future as various Rp-genes are used in sweet corn hybrids, it is not unlikely that one Rp-resistant hybrid will be completely resistant while another Rp-resistant hybrid will be severely infected because the hybrids have different Rp-resistance genes. Similarly, it is possible now for an Rp-resistant hybrid to be completely resistant at one location but severely infected in another area because virulence differs among rust populations in different areas. Also, an Rp-resistant hybrid may be completely resistant at one planting but infected at a later planting because virulence is introduced to an area during the season. For example, sweet corn breeding lines with the *Rp-G* gene were completely resistant in trials in Urbana, IL in 2000 until late-August when isolates with virulence against *Rp-G* occurred at low levels and a few small pustules occurred on lines with *Rp-G*.

When resistance is not adequate to control rust, fungicides are applied to prevent severe rust infection. Fungicides are NOT curative. They are of little benefit after infection is severe.

Fungicide applications are more crucial when plants are young than after tassels emerge. Juvenile tissue is more susceptible than adult-plant tissues, and moisture accumulates in leaf whorls of seedlings creating excellent conditions for urediniospores to germinate and infect. Application of fungicides to younger plants also is important to prevent the production of large amounts secondary inocula. Two or three well-timed applications of fungicides before rust becomes severe will provide better control than multiple applications after rust is severe. If rust severity reaches 10 or 20% on lower leaves, urediniospores are so abundant that subsequent applications of fungicides may only retard rust development rather than effectively controlling rust. Fungicide applications after pollination are of minimal value since the latent period for *P. sorghii* is seven days, and sweet corn harvest usually is only 2 or 3 weeks away.

Scouting fields for rust can provide useful information when deciding whether or not to apply fungicides. Early-planted sweet corn can be an indicator of increasing rust populations and late-planted crops that are at risk. While it may be too late to protect early-planted crops, significant amounts of rust near harvest of early-planted crops serve as a good warning to protect later-planted crops especially if weather is favorable for rust and susceptible hybrids are planted. Also, later-planted fields can be scouted directly. If weather is wet and cool, a 6-pustule-per-leaf action threshold has been recommended in New York for seedlings of susceptible hybrids. This threshold will be slightly higher for each level of general resistance and with each subsequent growth stage as plants mature.

**IMPORTANT INFORMATION**

In order to control rust, be informed. Know the reactions of the hybrids you are growing. For hybrids with Rp-resistance, know which Rp gene is used and know the background reaction (R, MR, M, MS, S) of the hybrid in case the population of *P. sorghii* is virulent against the Rp gene being used. For non-Rp hybrids, know whether the reaction to rust is R, MR, M, MS or S. Sweet corn hybrid reactions to diseases are reported annually in the Midwestern Vegetable Variety Trial Report and in the Midwest Food Processors Association Crops Manual.

Monitor early-planted crops for levels of rust and for virulence against Rp-resistance. When rust is present in earlier-plantings, be prepared to protect later-planted crops with fungicides especially if the crop is at an early seedling growth stage, the hybrid reaction to rust is moderate to susceptible, and rust-favorable weather conditions are expected. Two or three well-timed applications of fungicides can reduce rust severity and protect at-risk crops from substantial yield reductions.

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