Smut Expression and Resistance of Corn to Sphecelotheca reilianan in Minnesota

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ABSTRACT


Head smut caused by Sphecelotheca reiliana occurred in 1980-1983 in only four counties in north central Minnesota. In resistance trials in 1981 and 1982, 56% of 238 inbreds and hybrids had at least 5% smut-damaged plants. Of 168 elite hybrids, 113 were resistant or moderately resistant to S. reiliana. Planting date within a given year did not significantly affect smut incidence; however, more plants were smutted in 1982 than in 1981. Twice as many ears as tassels were smutted and about half of the smutted plants were stuntted. Leaf infection and phylloclade occurred sporadically. Single crosses were intermediate in smut incidence between their resistant and susceptible inbred parents. Applying teliospore-infested soil to kernels at planting was an effective method to evaluate resistance of inbreds and hybrids in the field.

Head smut of corn (Zea mays L.) is caused by Sphecelotheca reiliana (Kühn) Clint., or according to Langdon and Fullerton (8), by Sporisporium reiliana (Kühn) Langdon & Fullerton. This smut was first discovered in Minnesota in Wadena County in 1980 by Stromberg (11), and it was subsequently identified as occurring sporadically in about 1,200 ha in four counties (Ottertail, Stearns, Todd, and Wadena) (11). Surveys made from 1981 through 1983, however, detected no spread from the four original counties (R. M. Sushak, unpublished).

This smut attracted attention partly because of an outbreak in 1979 in Ontario (9), a first report for Canada, and a seed corn directive dated 10 December 1980, issued by B. E. Hopper, Associate Director, Plant Quarantine, Food Production and Inspection Branch, Agriculture Canada, restricting seed corn importation.

Previously, head smut of corn had been known to occur in river deltas and intermountain valleys of the Pacific Coast states and Mexico (5,6,10,12). In 1975, however, it was reported for the first time in seven counties in Texas, with losses in some fields reaching 30-50% (4).

Details of signs, symptoms, and worldwide geographic distribution were given by Halisky (5,6) and Frederiksen et al (4), and factors affecting infection were reported by Krüger (7) and Baier and Krüger (1).

Because of an incidence of head smut in the University of Minnesota field plots at the Area Vocational Technical Institute farm at Staples (Wadena County), all field trials were made there in soil already contaminated with smut teliospores.

Our objectives were to 1) develop a field inoculation technique to ensure uniform infection pressure to evaluate hybrids for resistance, 2) study typical and atypical signs and symptoms of smut, and 3) evaluate resistance of inbreds and hybrids (public and private) to smut.

MATERIALS AND METHODS

All experiments were done at the University of Minnesota plots at Staples in a field where head smut was found in 1980. Three planting dates were chosen: 27-28 April, 11-12 May, and 26-27 May 1981; and 26 April, 11 May, and 24 May 1982. There were three replicates of a randomized, complete-block design at each planting for each year per entry.

Corn kernels were planted singly in 6-m rows with 30 kernels sown per row to give a plant population of 11,300 plants per hectare. Some seed lots had been treated with captan when received and no attempt was made to remove the fungicide. The soil was a sandy loam and was irrigated weekly as needed by overhead sprinklers during the growing season. The herbicide alachlor was applied at planting for weed control.

To prepare inoculum, smutted ears from the previous year were collected, stored in burlap sacks, and hung in a corncrib over the winter. One week before planting, teliospores from the smutted ears were mixed with moist sandy loam from an adjacent field in a concrete mixer using the ratio 200 parts soil to one part teliospores (v/v). About 120 cc of inoculum was placed over each kernel after it was dropped into a hand-jab planter. This effectively covered each kernel with soilborne teliospores.

Plant stand, incidence of smutted tassel and ear (and combinations thereof), stunting, and any other signs or symptoms of smut infection were recorded.

In the 2 yr, 238 public and private inbreds and hybrids were evaluated. Private hybrids and inbreds were contributed by the seed industry; public hybrids were obtained from the Minnesota

Fig. 1. Signs and symptoms of head smut in corn tassels, showing the variation in branching habit from (A-C) compact types to (D) more open branching and (E) excessive proliferation of bracts that subvert the inflorescence.
Fig. 2. Percentage of corn plants infected with Spheclotrichia reiliana in which signs or symptoms of smut were apparent, based on 1,976 smut-infected plants in 1981. Plants with ear smut included those partially smutted and those with tassel smut; similarly, the tassel smut category included plants that also had ear smut.

Crop Improvement Association. The 25 inbreds evaluated in 1982 included 20 of the 25 most popular public lines in 1979, as listed by Zuber and Darrah (13). Inbreds A554, A654, A665, CO109, ND203, W59E, W117, and W182B are popular early lines and were the parents of the diallel set of 28 F1 single-cross hybrids tested in 1982.

RESULTS

Tassel smut. Typically, head smut is characterized by sori that appear in the microgametophyte inflorescence (tassel) in which florets are replaced by teliospores without the formation of a gall that characterizes common smut (Ustilago maydis (DC.) Cda.). This may result in a compact inflorescence (Fig. 1A–C), some proliferation of spikelets on the rachis and branching (Fig. 1D), and infrequently, some proliferation of bracts or leaves that subduct the inflorescence (Fig. 1E). Where there are multiple tillers, one or more, but not necessarily all, may have signs and symptoms of tassel smut.

Infected tassels occurred in 134 of 168 smutted hybrids (80%) and in 37% of smutted plants (Fig. 2). Tassel infection may be accompanied by ear infection. Both signs were found on the same plant in 128 of the 168 hybrids (76%) and in 28% of the smutted plants (Fig. 2).

Ear smut. Ear infection is a conspicuous sign of head smut and occurred in 164 of 168 hybrids (98%) and on 91% of the smutted plants (Fig. 2). Most often, a single ear was smutted (Fig. 3A), but not infrequently, two or more ears on the same stalk were smutted (Fig. 3B) or one ear was smutted and one was not. Ears that were partially smutted (Fig. 3C) were seen in 22 of 168 smutted hybrids (32%) and on 5% of smutted plants (Fig. 2). Instead of a sorus, there may be a proliferation of leaves or husks at the node (Fig. 3D), with scant appearance of teliospores in the tissues. Ear proliferation (Fig. 3B,D) attributable to smut infection occurred in 79% of the 168 infected hybrids and on 30% of smutted plants (Fig. 2).

Another less frequently occurring variation in symptoms is the substitution of tubular leaves (phylloidy) for kernels on the cob (Fig. 3E,F). Teliospores were not always present in those tissues. These symptoms superficially resemble vivipary as described for Diplodia ear rot (2); however, the structures in Figure 3E,F were not plummules of germinating kernels.

Leaf smut. In fewer than 1% of smutted plants, smut sori appeared on the distal ends of leaf blades, not as a gall but as an open eruption of teliospores along the veins accompanied by some tissue necrosis (Fig. 4). Confirmation as S. reiliana was determined by microscopic examination of teliospores. Leaf smut did not occur as a sole sign of disease but mainly in association with ear or tassel smut.

Stunted plants. Often, infected plants can be recognized in the field by stunted growth; however, smutted tassels and ears are sometimes found on plants of normal height. Stunted plants were observed in 151 of the 168 infected cultivars (90%) and in 56% of the infected plants (Fig. 2). Stunting is frequently
associated with multiple tillers in which one or more show both tassel and ear smut.

**Genotype reaction.** During 1981 and 1982, 238 hybrids or inbred lines of corn were evaluated for resistance to *S. relliana* and 136 (58%) sustained no more than 5% incidence of smutted plants (Table 1). Of 168 private hybrids, 64% had no more than 5% smutted plants, whereas 38% of the inbreds and 25% of the single-cross hybrids were in this group (Table 1). Of 38,928 plants in 152 smutted private hybrid lines tested in 1981, 4.9% of the plants were smutted.

**Private hybrids.** A list of 168 hybrids were classified as resistant (no smutted plants), moderately resistant (0.1–5.0% smutted plants), moderately susceptible (5.1–10.0% smutted plants), and susceptible (>10.0% smutted plants) and are listed by their brand-variety designation as follows:

- Resistant. Conex 2203, 3015, 3139; Dekalb XL14A; Funk’s G4256; Lester Pfister 1430; McCurdy Big M-X956; and Northrup, King & Co. PX37.
- Moderately susceptible. Blaney B607, S3242; Conex 3139; Dekalb EX1112, XL11, XL314; Kaltenberg KX33, KX55, KX58, KX390; Lester Pfister 1222, 1428; Midland M-1051TY, M-2087, M-3080; Northrup, King & Co. PX11; Payco SX-411-N, SX-555-N, SX-637-N, SX-711-N; Pfizer T-9X0, T-930; Ramy X-16, X-150, X-200; RBA Super 4+, Super 80; Stauffer 101, 302wx, 2010wx, 2202, 4402, 5062; and Wilson 1100B, 1300.
- Susceptible. Blaney S4800; Conex 2159; Dekalb XL6, XL12, XL13; Funk’s G5048; Kaltenberg KX362; Northrup, King & Co. PX7, PX24, PX449, PX485; Payco SX-155-N, SX-227-N, SX-599-N; Pioneer 3975A; Ramy EX14739, X-135; Stauffer 3242, S260; and sweet corn hybrids Green Giant Code 7 and Code 47.

**Planting date effect.** The smut ratings and resistance classifications of private hybrids represent averages of three planting dates. These values were combined because there were no significant differences among the three dates. This is illustrated with public inbreds and hybrids to show the amount of variation (Table 2). Although the average for smut incidence is greater in the first than in subsequent planting dates, this was not consistent for each hybrids tested. Therefore, we averaged data for the three planting dates.

**Season effect.** Only seven inbreds and six hybrids were evaluated in both years, and the incidence of smutted plants was consistently greater in 1982 than in 1981 (Table 3). Smut incidence among inbreds was not greatly increased in 1982 although some doubled (W117) or tripled (A654). Because the inoculation method and location were the same in both years, the difference was attributed to the environment. Although naturally occurring inoculum might have been greater in the second year, the amount of inoculum added to each kernel sown would have been much greater than the possible difference in naturally occurring inoculum.

**Inbreds and derived hybrids.** In 1982, 25 public inbreds and 28 F1 single-cross hybrids using eight of these inbreds for parents were evaluated. The contribution to resistance by the inbred is shown by comparing inbreds and hybrids (Table 4). For example, in B584 had 8% smutted plants and A665 had 24%, whereas the hybrid of these two inbreds gave 24% smutted plants. A554 combined with A665 gave only 1% smutted plants, however. Note also that A654 (24% incidence) crossed with A665 (1%) resulted in a hybrid with 10% smutted plants. Other comparisons show the inbred contribution to hybrid resistance (Table 4). In general, smut incidence among the derived hybrids was less than that of the more susceptible inbred but
more than that of the more resistant
inbred.

DISCUSSION

The signs and symptoms we described
and illustrated are similar to and more
complete than those shown by Halisky
(5,6), Frederiksen et al (4), and Lynch (9).
Both Halisky (5,6) and Frederiksen et al
(4) also reported independent infections
of tassels and ears. The predominance of
ear over tassel smut was striking in that
more than twice as many ears as tassels
were smutted. With 91% of the ears in
infected plants with smut, the loss in yield
can be substantial. Tassel infection has
greater visibility than ear infection in the
field so its presence tends to be
overemphasized in detection compared with
ear smut. Linear sori on leaves, reported by
Halisky (6), were found occasionally (<1%)
in smutted plants in Minnesota.

Stunting to half the normal height was
cited by Halisky (6) but this degree of
severity was not usually found by
Frederiksen et al (4). We observed
considerable variation in stunting; some
plants were slightly below normal in
height and others were less than half
normal in height. Stunting occurred in
about half of all smutted plants.

The fact that all signs and symptoms
were not present in each infected plant
suggests, as it has to several others (4-7),
that systemic infection by smut hyphae
depends on the stage of meristem
differentiation at the time of infection.
Soil factors may also be an important
determining factor (1,5-7).

Soil moisture and temperature were
reported to be critical factors affecting
smut incidence (1,5). Soil texture,
however, apparently has little or no
influence because head smut was severe in
clay or clay-loam soil in Ontario (9),
occurring in peat soil in California (5,6),
and was present in sandy-loam soil in
Minnesota.

Inbreds reported by Frederiksen (3) to
be resistant to head smut in Texas (B73,
Mol7, and W64A) were also resistant in
Minnesota, whereas inbred Va26 proved
susceptible in both states. Several other
inbreds also showed good resistance in
our evaluation (Tables 2-4). Of the crosses
made from inbreds (Table 4), the
percentage of smutted plants in the
single-cross hybrid was almost always
intermediate between that of the parent
inbreds. This is not consistent with
Frederiksen's finding (3), where resistance
was reported to be dominant or partially
dominant.

We have identified resistances in
popular inbreds and public and private
hybrids that enable farmers to reduce
losses to head smut in the irrigated sandy
loam soils of Minnesota and perhaps
elsewhere. It is not likely that a field
evaluation of such a number of hybrids
and inbreds will be tried again soon
because of the considerable amount of
inoculum required (8.4 t in 1981) for such
an evaluation.

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