Effect of Genes with Slow-Rusting Characteristics on Southern Corn Rust in Maize

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ABSTRACT

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Eight experimental maize (*Zea mays*) inbreds previously identified as having slow-rusting resistance to southern corn rust (*Puccinia polysora*) on the basis of reduced pustule number, smaller pustules, and delayed pustule rupture were crossed with a susceptible inbred, CI21. Crosses between some of the slow-rusting inbreds were also made. These two groups of crosses were compared with each other and with resistant and susceptible hybrids under field inoculations. Compared with susceptible hybrids, crosses among inbreds with slow-rusting characteristics had fewer and smaller pustules that ruptured later. On resistant genotypes, the direct effect of fewer and smaller pustules was that smaller areas of leaf were destroyed and the indirect effect was that fewer urediniospores were produced and their dispersion was delayed because pustule rupture was delayed.

Additional keywords: disease development, disease resistance

Southern corn rust (*Puccinia polysora* Underw.) has caused yield losses in maize in the southern part of the United States, particularly on late-planted maize. Rodriguez-Ardon et al (5) evaluated near-isogenic crosses and found that this fungus reduced grain yield by up to 45%. Melching (3) reported yield reductions of 50% in a greenhouse test and from 24 to 37% in one field test. Raid et al (4) recently reported that grain yields were reduced 18 and 39% by *P. polysora* at a Pennsylvania and a Maryland field site, respectively. They suggested that temperature may be the most limiting factor in the development of southern rust of maize in northern areas of the United States.

A hypersensitive type of rust resistance, conditioned by a single dominant gene, *RppRpp*, is very effective in preventing yield losses in crop plants and essentially eliminates the production of secondary inoculum (3,8,9). A number of researchers have reported single gene resistance for races of *P. polysora* (2,7–10). The limitation of wide usage of host genotypes with hypersensitive resistance, such as *RppRpp*, is that they may in effect select for other virulent races in the pathogen population that in time can become the prevalent race. The slow-rusting characteristics (reduced infection sites, smaller pustule size, extended latent period) should reduce the rate of rust development without drastically affecting the rust population.

Ru-Hong et al (6) reported differences for pustule number and urediniospore production among genotypes inoculated with *P. polysora* in the greenhouse. Zummo (11) found that a susceptible maize genotype inoculated with *P. polysora* consistently had a greater number of pustules that were significantly larger and more tumid and that ruptured earlier than those produced on resistant maize genotypes. Bailey et al (1) evaluated maize single crosses and inbreds for slow-rusting characteristics as measured by the area under the disease progress curve and found differences among genotypes.

Slow rusting can be the effect of one or more characteristics that reduce the growth and development of the fungus. Thus, slow rusting can result from many effects, including fewer pustules, smaller pustules, or increased latent period. The objective of this study was to determine if maize inbreds previously identified as having slow-rusting attributes contributed characteristics of reduced pustule number, smaller pustules, and/or delayed pustule rupture to their hybrids.

MATERIALS AND METHODS

Corn genotypes for this study were selected on the basis of their observed reaction to *P. polysora* in earlier field trials (*unpublished*). B37R (a recovered B37 with a single dominant gene for

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resistance to *P. polysora*) was chosen for its hypersensitive type of resistance. Eight experimental inbreds (Mp77:136, Mp77:179, Mp77:309, Mp77:394, Mp77:429, Mp78:25, Mp78:38, and Mp78:116) with apparent slow-rusting characteristics were chosen and crossed onto the susceptible genotype CI21. In addition, crosses between some of the slow-rusting lines were made. Four susceptible × susceptible hybrids (Ab24E × SC343, CI21 × Mo12, GT106 × Mp462, and T226 × T232) were included as checks.

This material was grown in the field during 1983 and 1984 in a randomized complete block design with four replications. Single-row 5-m plots were grown with 0.96 m between rows. Thirty-five seeds were planted per row, but later the stand was thinned to 20 plants per row.

Inoculum for each trial was prepared from urediniospores collected from corn leaves in the field at Starkville the preceding year. Spores were air-dried at 21 C for 4 days on sheets of aluminum foil, sealed in glass vials, and stored in liquid nitrogen until used. The glass vials with urediniospores were immersed in 500 ml of H_2O at 40 C for 10 min immediately after removal from liquid nitrogen. Percentage of urediniospore germination was determined on 2% water agar. Urediniospore concentration was adjusted so that about 0.125 g of viable urediniospores per liter of water containing two drops of Tween 20 added as a wetting agent was used.

Inoculations were made when the plants were approximately at the midsilk stage of growth. Before the evening inoculation, a sprinkler irrigation system was used to wet the plants. Inoculum was applied using a 4.24-L yard and garden tank sprayer with the nozzle directed downward toward the top and slightly to the side of the plants. Approximately 50 L of inoculum was applied per hectare.

Rust ratings were taken 18 days after inoculation on the second or third leaf above the ear on all plants in each plot. The rating scale for 1983 indicated relative pustule incidence, pustule size, and percentage of pustules ruptured. Pustule incidence was evaluated according to the following scale for erumpent pustules: 1 = no pustules, 2 = a few isolated pustules, 3 = up to 5% of the leaf area affected, 4 = 6–15% of the leaf area affected, and 5 = 16% or more of the leaf area affected. Pustule size was determined by measuring the length of at least five pustules and converting the average to the following scale: 1 = 0.2 mm or less, 2 = 0.3–0.5 mm, 3 = 0.6–0.8 mm, 4 = 0.9–1.1 mm, and 5 = over 1.2 mm. Percentage of pustule rupture (outer layer or layers of the pustules break and spores can be released) was evaluated using the following scale: 1 = no pustules ruptured, 2 = some but less than 50% of the pustules ruptured, and 3 = more than 50% of the pustules ruptured.

The rating scale used in 1984 was a modification and expansion of the scale used in 1983 and is described by Zummo (11).

Plot mean ratings for pustule incidence, size, and percentage of pustules ruptured were used in the analysis of variance. Orthogonal comparisons were used to compare different groups of hybrids.

Table 1. Ratings for pustule incidence, size, and rupture of *Puccinia polysora* on maize single crosses in field trials during 1983 and 1984

Type of cross and pedigree[a]	1983 Pustule incidence[b]	1983 Pustule size[c]	1983 Pustule rupture[d]	1984 Pustule incidence	1984 Pustule size	1984 Pustule rupture
Resistant						
B37R × Mp78:5273-1	1.8	1.0	1.3	1.0	1.0	1.0
B37R × Mo18W	1.5	1.5	1.5	1.5	1.3	1.0
Mean	1.7	1.3	1.4	1.3	1.2	1.0
SR × SR						
Mp77:309 × Mp77:136	2.5	1.3	3.0	3.8	3.8	4.5
Mp78:25 × Mp77:136	2.8	1.0	3.0	4.0	2.3	2.5
Mp77:309 × Mp77:179	2.5	1.3	2.8	4.0	2.0	2.8
Mp77:378 × Mp77:179	2.8	1.0	2.3	3.3	2.0	3.8
Mp78:116 × Mp77:179	2.8	1.3	1.8	3.8	2.3	3.8
Mp78:25 × Mp77:309	2.5	1.0	2.3	3.0	2.5	3.5
Mp78:116 × Mp77:309	2.3	1.5	2.3	3.3	2.3	3.5
Mp78:38 × Mp77:394	3.3	2.0	2.5	3.8	3.5	3.3
Mp78:116 × Mp77:394	2.0	1.3	1.8	2.3	1.5	1.8
Mean	2.6	1.3	2.4	3.5	2.5	3.3
SR × S						
CI21 × Mp77:136	3.8	2.3	3.0	4.3	4.0	4.0
CI21 × Mp77:179	4.3	2.5	2.8	4.5	3.3	4.0
CI21 × Mp77:309	3.5	2.0	2.5	4.5	2.3	3.8
CI21 × Mp77:394	3.5	2.3	2.5	4.5	3.0	3.0
CI21 × Mp77:429	3.8	1.5	2.5	4.5	3.0	3.0
CI21 × Mp78:25	4.0	2.8	2.8	4.5	3.5	4.0
CI21 × Mp78:38	4.0	1.8	2.8	4.5	3.5	4.0
CI21 × Mp78:116	2.8	1.8	3.0	4.0	2.8	4.0
Mean	3.7	2.1	2.7	4.4	3.2	3.7
S × S						
Ab24E × SC343	4.3	3.0	2.8	4.0	3.8	4.5
CI21 × Mo12	5.0	1.8	3.0	5.0	3.8	3.5
GT106 × Mp462	4.0	2.3	3.0	5.0	3.5	3.8
T226 × T232	4.8	2.3	3.0	5.8	3.5	3.3
Mean	4.5	2.4	3.0	5.0	3.7	3.8

[a] R = resistant, SR = slow rusting, S = susceptible.
[b] Rated on a scale where 1 = no pustules, 2 = a few isolated pustules, 3 = up to 5% of leaf area affected, 4 = 6–15% of leaf area affected, 5 = 16% or more of leaf area affected.
[c] Rated on a scale where 1 = 0.2 mm or less, 2 = 0.3–0.5 mm, 3 = 0.6–0.8 mm, 4 = 0.9–1.1 mm, and 5 = over 1.2 mm.
[d] Rated on a scale where 1 = no pustules ruptured, 2 = some but less than 50% of pustules ruptured, 3 = more than 50% of pustules ruptured.

Table 2. Mean squares from analysis of variance of ratings for pustule incidence, size, and rupture of *Puccinia polysora* for 23 hybrids grown during 1983 and 1984

Source of variation[a]	df	Means squares for ratings 1983 Pustule incidence	1983 Pustule size	1983 Pustule rupture	1984 Pustule incidence	1984 Pustule size	1984 Pustule rupture
Replications	3	0.09	0.29	0.07	0.25	0.20	1.01
Hybrids	22	3.67**[b]	1.40**	1.09**	4.86**	3.05**	3.70**
Among groups	3	22.72**	6.29**	5.14**	29.61**	13.97**	17.09**
R vs. rest	1	22.22**	2.10*	11.09**	59.13**	24.07**	46.53**
(SR × SR) vs. (SR × S) and (S × S)	1	38.89**	16.25**	3.81**	26.68**	15.50**	4.72*
(SR × S) vs. (S × S)	1	7.04**	0.51	0.51	3.01*	2.34	0.01
Within groups	19	0.66*	0.63	0.45*	0.95**	1.32*	1.59
Error	66	0.34	0.37	0.22	0.43	0.67	0.95

[a] R = resistant, SR = slow rusting, S = susceptible.
[b] * = Significance at the 0.05 level of probability, ** = significance at the 0.01 level of probability.

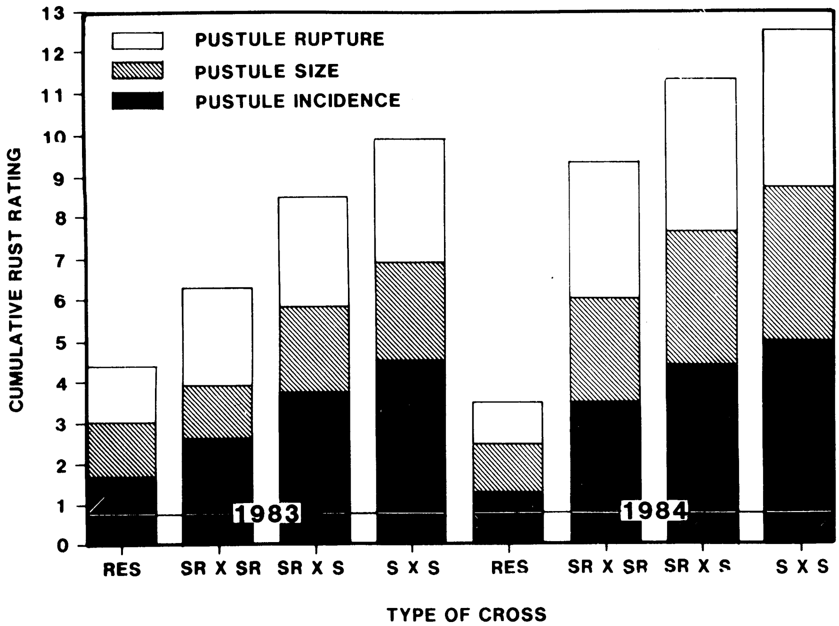

Fig. 1. Cumulative ratings for pustule incidence, pustule size, and percentage of pustules ruptured for resistant (RES), slow-rusting (SR× SR), slow rusting× susceptible (SR× S), and susceptible× susceptible (S× S) crosses of maize inoculated with urediniospores of *Puccinia polysora* in the field in each of 2 yr.

RESULTS AND DISCUSSION

Little rust developed on the two resistant crosses (Table 1). Both crosses had at least a single dominant gene for resistance from the common parent, B37R. The small amount of pustule development on these crosses may have been caused by a virulent race of *P. polysora* present at a low frequency in the rust population.

Crosses among slow-rusting (SR) inbreds had fewer pustules than either the SR× susceptible (S) or the S× S crosses (Table 1). As indicated by the orthogonal comparison of the SR× SR crosses with the mean of the SR× S and S× S crosses, the differences were highly significant (Table 2). Although it was not one of the orthogonal comparisons made, the difference between the means for SR× SR and the SR× S crosses was highly significant in both years.

The pustules that did develop on the SR × SR crosses were significantly smaller than those on crosses in which the SR lines were crossed onto a susceptible tester (CI21) as well as on susceptible crosses. The percentage of pustules that had ruptured on the date of evaluation was less in SR × SR crosses, indicating that the latent period was somewhat longer in these crosses than in the more susceptible crosses.

The SR × S crosses had significantly fewer pustules than did the S × S crosses in both years. However, no significant differences were detected between these two groups for pustule size or percentage of pustules ruptured.

Each slow-rusting characteristic can have an effect on reducing rate of disease development. If maize genotypes have genes for resistance for more than one slow-rusting characteristic, then the total effect will be cumulative. That is, if the rating scale used to classify slow-rusting characteristics reflects rust development, the cumulative rating should indicate the total effect of the slow-rusting characteristics on the plant. The sums for ratings over three characteristics of slow rusting (Fig. 1) illustrate the differences among the groups of crosses. The cumulative sum for ratings of pustule incidence, pustule size, and percentage of rupture for the SR× SR crosses were 36 and 26% less than that for the S× S crosses in 1983 and 1984, respectively.

The slow-rusting characteristics in these maize genotypes of reduced number and size of pustules and extended latent period each contribute to less plant damage and a reduction in secondary inoculum. Thus, as genes for resistance for these slow-rusting characteristics are incorporated into commercial hybrids, they should reduce the extent of yield reductions caused by this fungus.

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