A Comparison of Monogenic and Polygenic Resistance to Helminthosporium turcicum in Corn

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ABSTRACT

Both monogenic and polygenic resistance to infection by *Helminthosporium turcicum* are present in corn germplasm. Monogenic resistance is characterized by small necrotic lesions surrounded by distinct and extensive chlorotic halos. Little, if any, sporulation occurs in the necrotic lesions. Polygenic resistance is expressed as a reduction in numbers of lesions without marked diminution in size over those developed on susceptible genotypes.

In comparative yield trials conducted for 3 years, single crosses possessing polygenic resistance averaged, respectively, 57.1, 27.3, and 58.0 bushels/acre more than the average yields of fully susceptible single crosses in the presence of epiphytotics of northern corn leaf blight. The corresponding average yield increases of single crosses bearing monogenic resistance, over the average yield of the susceptibles, were 38.0, 20.9, and 37.6 bushels/acre. The extensive chlorosis accompanying infection of genotypes carrying monogenic resistance may have a debilitating effect which is reflected in lower grain yield. Severity of leaf blight was positively associated with yield reduction. Phytopathology 60:1597-1599.

Additional key words: northern corn leaf blight, disease resistance.

During 1939 to 1943, northern corn leaf blight caused by *Helminthosporium turcicum* Pass. became prevalent and severe in some localities from Indiana eastward to the Atlantic Coast. The relatively mild temp and ample moisture over this general area during these years favored development of the disease. During this time, hybrid corn, *Zea mays* L., was gaining rapidly in popularity, but most of the hybrids, if not all, were highly susceptible. A third factor, although not related to its severity and prevalence but focusing attention on the disease, was that farmers who had paid $8.00 to $10.00/bu for hybrid seed became much more observant of their crop than in earlier years when seed was gathered from their own fields. Any untoward performance of the hybrid corn, such as blighted leaves, insect damage, excessive lodging, or unsatisfactory yields, was usually quickly noticed and reported to the State Agricultural Experiment Stations or to the seed producers from whom the seed was purchased.

In response to demands for control of the disease, breeding programs were initiated at several State Agricultural Experiment Stations and at the Crops Research Division, USDA, Beltsville, Maryland. The type of resistance first found and used in these early breeding programs was polygenic (3). This type of resistance is expressed primarily as a reduced number of lesions with little decrease in lesion size or amount of sporulation. A number of leaf blight-resistant and high-yielding inbred lines were developed which were released to growers and are still used in hybrid combinations.

In 1959, a distinctly different kind of resistance was observed in a popcorn (P.I. 217407) which, according to the Plant Introduction Station at Ames, Iowa, was collected in Peru (4). The reaction of this genotype to infection by *H. turcicum* is characterized by small necrotic lesions surrounded by pronounced chlorotic halos. This type of resistance was shown to be governed by a single dominant gene (1), although the sources of this resistance were identified then as an unnamed variety of popcorn from Peru (Source B) and a selection of the variety Hastings Prolific (Source A). Later, Source A was identified as GE440 and the unnamed variety as Ladyfinger (2). It is not clear whether the Ladyfinger variety was sent to Peru and then later collected there and assigned a Plant Introduction designation, or whether the accession P.I. 217407 and Ladyfinger derive from the same source in Peru. It has also been pointed out that sporulation of the pathogen on the necrotic lesions is markedly suppressed (2). This would be a decided impediment to the spread of *H. turcicum* because of reduction of inoculum. The single dominant gene determining this type of "chlorotic lesion" reaction has been designated *Ht* and is located on chromosome 2 (5). This gene has now been transferred to a large number of inbred lines currently used in breeding programs.

The distinct, and often extensive, chlorosis surrounding the small necrotic areas in genotypes with monogenic resistance has raised some question as to the possible debilitating effect it might have on the host. The purpose of the experiments reported here was to measure, by means of grain yields, the "protection" against the disease incited by *H. turcicum* conferred upon the host by the monogenic type of resistance.

Materials and Methods.—Single-cross hybrids were used in all yield trials. Where the monogenic resistance was used, the gene *Ht*, because of its dominance, could be introduced from only one of the two parent inbred lines. In some hybrids, however, both parents carried this gene. In some hybrids, the original genotypes in which the *Ht* gene was found were used as parental inbred lines; in others the *Ht* gene had been transferred into some of the released inbred lines currently used in hybrid seed corn production. The inbred lines used were GE440; Pr1; H84, a recovery of B37; H91, a recovery of B14; H93, a recovery of B37; and W64A(*Ht*), the latter being W64A into which *Ht* had been transferred.

Polygenic resistant single crosses derived their resistance from both inbred parents because of lack of complete dominance. The parental inbred lines used were H49, a recovery of Wf9; H52, a recovery of 38-11; H55, a recovery of Hy; H60; and C103. Also used were the inbred lines Syn B254, Syn B256, Syn C86, Syn C94, Syn D304, and Syn D313, which were derived from synthetic varieties B, C, and D developed in the Department of Botany and Plant Pathology, Purdue University, on which strong selection pressure for resistance to *H. turcicum* had been imposed.

The inbred line components of susceptible single crosses were Wf9, Hy, 38-11, B14, B37, W64A, and Oh 07.

In experiments of the kind reported here, in which different levels and different types of resistance are compared, it is necessary to plant two complete blocks of the same materials in order to avoid confounding effects of disease with heritable differences in yield potential between hybrids. For example, the difference in yield between a resistant and a susceptible hybrid when grown only in the presence of a disease would be composed of the differential effects of the disease and also of the differential effects of inherent yield potential. Two components could not be separated under such circumstances. If the hybrids being compared were near-isogenic, and if resistance were determined by a single gene, then direct comparisons between hybrids could be made in the presence of an epiphytotic. A "disease-free" block allows for the evaluation of difference in yield potential between hybrids.

Plots were 1×10 hills in size; 5 kernels were planted/hill and thinned to 3 plants/hill. Plots were replicated 4 times in simple randomized blocks. Every third plot was planted with a highly susceptible double cross, Ind 219 (W64A × A239) × (B14 × A545). In the "disease" block only these plots were artificially inoculated. These then served as "spreader" plots from which secondary inoculum was dispersed naturally to test plots. Two blocks ("disease" and "disease-free") were planted ⅛ to ¼ mile distant from each other. The "disease-free" block was a duplicate of the "disease" block except that the rows of the susceptible double cross were not inoculated. The "disease-free" block was always situated to the windward side of the "disease" block, and the little leaf blight that developed in it occurred late in the season, usually after 10-15 September when the corn was mature, i.e., $< 35\%$ kernel moisture content.

Plants in spreader rows in the "disease" block were inoculated 4 times at 5- to 7-day intervals beginning when plants were 18 to 24 inches tall. An aq suspension of spores and mycelial fragments from pure cultures was sprayed into the whorls of the plants on two occasions. This type of inoculation was alternated with two applications of dry, ground, *H. turcicum*-infected leaves collected the previous year and stored over winter.

The severity of leaf blight was recorded during the 3rd or 4th week of August, about 1 month after silking. The method of scoring was based on an arbitrary, semiquantitative scale of 1 to 5 in which a value of 1 represented few lesions ($<$ 3/leaf below ear) and 5 represented severe infection with most of the leaf tissue necrotic or chlorotic. A value of 0.5 was used for exceptionally resistant genotypes showing only one to four lesions/plant. The relative numbers of necrotic lesions and the chlorosis surrounding them was considered in scoring hybrids with monogenic resistance.

Yield calculations were based on bu per acre of shelled grain at 15.5% moisture content. To evaluate the differential response to leaf blight of the several monogenic resistant genotypes as compared to the polygenic resistant genotypes, the average yield reduction sustained by all of the susceptible hybrids was subtracted from the reduction in yield sustained by each of the test hybrids carrying one or the other types of resistance. This calculation provides a means of determining the real superiority of the resistant hybrids, since any differences between the two blocks in the soil or atmospheric environment and exclusive of leaf blight would probably impinge equally on the susceptible and resistant hybrids.

Results.—The respective increases in yield of the monogenic and of the polygenic resistant hybrids over those of the fully susceptible hybrids for the 3 years were 38.0 bu/acre and 57.1 bu/acre; 20.9 bu/acre and 27.3 bu/acre; and 37.6 bu/acre and 58.0 bu/acre as shown in column 6, Table 1.

A relatively consistent and positive association was evident between mean blight ratings and the differential responses in yield; the higher the blight rating, generally the greater the yield reduction.

In 1967 and 1968, half of the polygenic resistant hybrids yielded more in the presence of the disease than in the "disease-free" block. This was due to the inadvertent higher levels of soil fertility in those 2 years in the "disease" block, which, coupled with resistance, was able to overcome the effects of the disease on yield.

Among the hybrids with polygenic resistance, those from inbred-line parents derived from Synthetics B, C, and D generally were the poorest yielders, yet they showed the lowest leaf blight scores, which in turn was reflected in the least yield reduction.

Discussion.—The generally greater average reduction in yield sustained by the monogenic resistant hybrids may be due to the extensive chlorosis that surrounds the small necrotic lesions. The amount of necrosis is much less in the individual lesions on genotypes where the gene *Ht* is present than in lesions on genotypes carrying polygenic resistance. The combined leaf area composed of a small amount of necrosis and extensive chlorosis in the monogenic resistant hybrids was often greater than the necrosis in some polygenic resistant hybrids. The cause of the chlorosis is not known, but it is associated with the presence of the pathogen, which is arrested in its progression through the leaf tissue although not killed by whatever factor(s) is responsible for resistance.

The suppression of sporulation in lesions on plants bearing the *Ht* gene is considered an important factor in reducing the amount of inoculum of *H. turcicum*. Theoretically, if all the corn over a wide area carried this single gene, the cyclic increase in inoculum would be virtually eliminated. However, many of the epiphy-

TABLE 1. Mean yields in the absence of "disease-free" block and in the presence of northern corn leaf blight ("disease" block) of monogenic resistant, polygenic resistant, and susceptible single crosses over a 3-year period

(1) Year	(2) Type of resistance and no. of single crosses tested	(3) Mean yield in "disease-free" block	(4) Mean yield in "disease" block	(5) Difference[a]	(6) (Difference)-(Avg difference of all susceptible crosses)
	Monogenic	*bu/acre*	*bu/acre*	*bu/acre*	*bu/acre*
1967	3	111.5	89.9	−21.6	(−21.6) − (−59.6) = 38.0
1968	4	116.4	109.5	− 6.9	(− 6.9) − (−27.8) = 20.9
1969	8	136.5	97.5	−38.9	(−38.9) − (−76.5) = 37.6
	Polygenic				
1967	6	126.8	124.3	− 2.5	(− 2.5) − (−59.6) = 57.1
1968	8	116.1	115.6	− 0.5	(− 0.5) − (−27.8) = 27.3
1969	10	154.9	138.0	−16.9	(−16.9) − (−76.5) = 58.0
	Susceptible				
1967	3	128.6	69.0	−59.6	
1968	4	130.2	102.4	−27.8	
1969	10	149.1	72.6	−76.5	

[a] Mean differences between monogenic hybrids and polygenic hybrids are statistically significant at the 10% level, and between these and that of susceptible hybrids at the 1% level.

totics of northern corn leaf blight are characterized by a sudden onset, suggesting that large volumes of inoculum are carried on air currents to the host. When such "spore showers" occur, lesions are often numerous. Under such circumstances, where abundant inoculum is blown into an area, extensive chlorosis accompanying the small necrotic lesions might have an adverse effect on the host as has been indicated in the experiments reported here.

The results of these comparative yield tests suggest that the *Ht* gene confers less "protection" to the host than polygenic resistance under conditions of heavy epiphytotics of northern corn leaf blight.

Two biases are probably operative in these experiments. One is the possible differential response of hybrids to different levels of fertility that are to be expected between the two blocks. This, if it does exist, is probably small and would not confound the results obtained. A second bias probably occurs as a result of early onset of debility and death of plants in the spreader rows in the "disease" block. Loss of these plants would reduce competition for soil water and nutrients among the test plants and thus increase their yield. This is a "positive" bias affecting the plants in an opposite direction from that imposed by the leaf blight.

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