Winter Wheat Genotype Responses to *Cephalosporium gramineum* Inoculum Levels

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ABSTRACT

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Environmental factors influence grain yield and reactions of winter wheat to the soilborne fungus *Cephalosporium gramineum*. As a result, resistance of winter wheat genotypes can vary from trial to trial. One reason may be that genotypes respond differently to varying inoculum levels. Six genotypes ranging in susceptibility to *C. gramineum* were tested for their responses to varying levels of inoculum. Lenore, Winridge, Marias, MT 7579, PI 094424, and PI 278212 were inoculated with five levels (0, 5, 10, 15, and 30 g/3 m of row) of oat kernel inoculum in a replicated trial at Bozeman, MT, in 1983 and 1984. The genotypes responded differentially to increasing levels of inoculum. PI 278212 and PI 094424 were least susceptible and Marias was most susceptible. Lenore showed less yield reduction than Winridge and MT 7579, despite infection levels equal to or greater than those in these two genotypes. Resistance was not overcome at the inoculum levels used in this study, suggesting that the high yield reduction in resistant lines in some years is influenced more by an unknown environmental component than by inoculum level.

Cephalosporium stripe disease of winter wheat is caused by the soilborne fungus *Cephalosporium gramineum* Nisikado & Ikata (*Hymenula cerealis* Ell. & Ev.). The pathogen enters the host through root wounds and subsequently colonizes vascular bundles (4,8). Mycelia, gums, and gels are produced in colonized vascular bundles that disrupt the water economy of infected plants (12). Early visual symptoms include longitudinal stripes on leaves, sheaths, and culms. The discrete stripes ultimately coalesce, causing necrosis and premature senescence of foliar tissue. Grain yield may be reduced as much as 70% in extremely susceptible winter wheat genotypes (10).

Mathre and Johnston's oat kernel inoculation technique (9) has been used to evaluate genotypes for their reactions to *C. gramineum*. Genetic differences as measured by yield reduction have been observed (6,10). Although a constant amount of inoculum has been used in all trials, environmental factors influence yield levels and disease severity. As a result, genotypes often show a change in rank order or relative performance for disease resistance from trial to trial. One reason for the interaction with environments may be that genotypes respond differently to varying levels of inoculum. In other vascular diseases, resistance has sometimes been overcome by use of high inoculum densities (3), e.g., Fusarium wilt of tomatoes (2), Fusarium wilt of radish (13), and Verticillium wilt of mint (5).

In 1982, we observed that the disease was extremely severe, and genotypes with some resistance to *C. gramineum* were severely infected. We were concerned that resistance to the disease might be overcome at high inoculum levels. This research was initiated to measure the responses of six genotypes ranging in susceptibility to *C. gramineum* to varying inoculum levels.

MATERIALS AND METHODS

Six winter wheat genotypes, Lenore (CI 17726), Winridge (CI 17902), Marias (CI 17595), MT 7579, PI 094424, and PI 278212, were chosen to study genotype responses to increasing inoculum levels because our evaluations have shown that they represent a range of reactions to *C. gramineum*. PI 094424, PI 278212, and Lenore are least susceptible; MT 7579 and Winridge are intermediate; and Marias is most susceptible as measured by grain yield reduction. The six genotypes were planted as whole plots with five levels of oat kernel inoculum (0, 5, 10, 15, and 30 g/3 m of row) as subplots in a split-plot design with three replicates. Each plot was a single 3-m row; rows were 30 cm apart. Seed and inoculum were added simultaneously through a plot cone seeder (9). All plots received 30 g of oats, with 0, 16.67, 33.3, 50, or 100% colonization of the oat kernels by *C. gramineum*. A sample of the oat kernels was plated out on acidified cornmeal agar to determine the degree of colonization by *C. gramineum*. The level was higher than 80% for both years. All plots were seeded at 76 kg/ha. Identical experiments were planted on 17 September 1982 and on 15 September 1983 at the Arthur H. Post Field Research Laboratory near Bozeman, MT. Percent infection was determined as the proportion of tillers showing visible symptoms in 45 cm of row in mid-July of both years. Grain yield was measured from the center 2.3 m of each plot.

Analysis of variance combined over years was performed on percent infection and grain yield data. Regression methods were used to partition the main effect of inoculum level into linear and quadratic sum of squares to establish the type of relationship between the response variables and inoculum level. Regressions for individual genotypes were computed using data from both years. The significance of regression coefficients was tested using the error mean square from the combined analysis of variance.

RESULTS AND DISCUSSION

Differences among genotype and inoculum level means were detected for both percent infection and grain yield, but year means differed only for percent infection (Tables 1 and 2). Increases in percent infection became progressively smaller, whereas average grain yield decreased with increasing levels of inoculum (Table 1). Percent infection was greater at comparable inoculum levels in 1983 than in 1984 (Table 1). Across all genotypes, grain yields were nearly the same in the two years for the 0- and 30-g inoculum levels (Table 1), but grain yields were higher at intermediate inoculum levels in 1984 than in 1983. Genotype interactions with years were not significant. That is, the six genotypes performed relatively the same between the two years. Therefore, responses for individual genotypes were examined using data combined over both years. The genotypes showed different linear responses to increasing inoculum level for grain yield as evidenced by a significant ($P < 0.05$) genotype × inoculum level linear interaction. This same interaction was significant ($P = 0.01$) for percent infection (Table 2). In all instances, interaction mean squares were small relative to mean squares for main effects of inoculum level and genotypes, which means differential genotype response to inoculum level is much less important than overall

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differences among genotypes and inoculum levels in explaining variation in grain yield and percent infection.

A small amount of infection (<5%) was noted in all genotypes with no added inoculum (Fig. 1). This probably represents contamination of seed during planting operations and/or lateral movement of the pathogen from adjacent inoculated rows. Percent infection increased linearly with increasing inoculum level for all genotypes except Marias and Winridge, which had a curvilinear relationship. Percent infection was highest in Marias and lowest in PI 094424 and PI 278212 at all inoculum levels (Fig. 1).

A statistical relationship was observed between percent infection and inoculum level for all six genotypes. The relationship, however, failed to account for all fluctuations in percent infection. For example, increasing inoculum level accounted for 64 and 78% of the variation in percent infection for PI 278212 and PI 094424, respectively (Fig. 1). Part of the variation in percent infection may be because pathogen presence may not always be expressed as visual symptoms, particularly in genotypes with some resistance.

Table 1. Effect of inoculum level of *Cephalosporium gramineum* on percent infection and grain yield of six winter wheat genotypes[a] at Bozeman, MT, in 1983 and 1984

Inoculum level[b]	Percent infection			Grain yield (mg/ha)		
	1983	1984	Mean	1983	1984	Mean
0	5.8	1.4	3.6	5.29	5.42	5.35
5	26.1	7.4	16.8	4.26	4.46	4.36
10	33.7	16.7	25.2	3.60	4.33	3.96
15	38.4	19.1	28.7	3.40	3.78	3.59
30	40.7	28.3	34.5	2.67	2.64	2.65
SE	3.2	3.2	2.3	0.17	0.17	0.12

[a] Lenore, Winridge, Marias, MT 7579, PI 094424, and PI 278212.
[b] Grams of oat kernel inoculum per 3 m of row.

Table 2. Selected mean squares from the combined analysis of variance of six winter wheat genotypes with five levels of *Cephalosporium gramineum* inoculum during two years at Bozeman, MT

Source	df	Mean square	
		Percent infection	Grain yield
Year	1	9,288**[a]	3.50
Genotype (G)	5	1,668**	21.78**
Level (L)	4	5,190**	35.49**
Linear (lin)	1	16,710**	132.42**
Quadratic (quad)	1	3,837**	7.35**
G × L	20	193	1.43
G × L (lin)	5	378	4.33*
G × L (quad)	5	234	0.65

[a] * = Significant at $P = 0.05$ and ** = significant at $P = 0.01$.

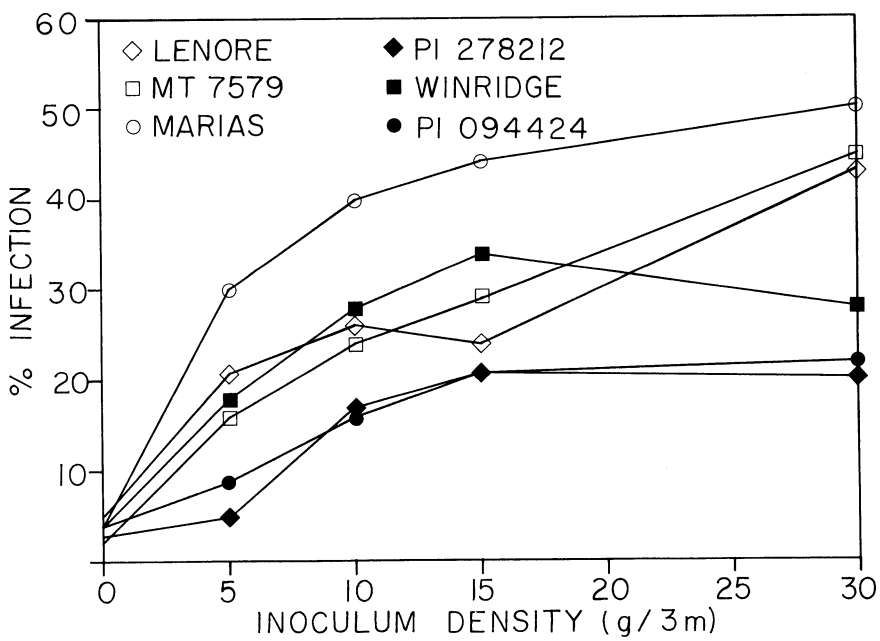

Fig. 1. Relationship between percentage of infected tillers and level of *Cephalosporium gramineum* inoculum for six winter wheat genotypes averaged over 1982 and 1983. Regression equations: Lenore, $y = 10.3 + 1.1x$, $r^2 = 0.89$; PI 278212, $y = 6.0 + 0.6x$, $r^2 = 0.64$; MT 7579, $y = 7.4 + 1.3x$, $r^2 = 0.95$; Winridge, $y = 3.8 + 3.3x - 0.03x^2$, $r^2 = 0.99$; Marias, $y = 7.4 + 4.0 - 0.09x^2$, $r^2 = 0.96$; PI 094424, $y = 7.2 + 0.6x$, $r^2 = 0.78$.

The range in grain yields among the six genotypes was similar at all inoculum levels (Fig. 2); however, relative differences and rankings among genotypes did change with increasing inoculum level. For instance, although Lenore and Winridge suffered a greater percent yield loss with increasing inoculum than the two most resistant genotypes, PI 278212 and PI 094424, they still produced more grain at the highest inoculum level than these two genotypes.

These results corroborate those of an earlier study in which PI 278212 and PI 094424 were least susceptible, MT 7579 was intermediate, and Marias was most susceptible to infection by *C. gramineum* (11). Grain yield results from previous comparative experiments also have shown that Lenore, Winridge, PI 094424, and PI 278212 suffered less yield reduction from *C. gramineum* than did MT 7579 or Marias (7,10). Morton and Mathre (11) attributed the reduced susceptibility of PI 278212 and PI 094424 to some mechanism that may limit ingress by the pathogen into the host. Resistance in MT 7579, which was rated as having an intermediate reaction, differed in that pathogen movement was restricted after ingress into the host. Thus, fewer tillers were infected per plant. The grain yield response of Lenore is interesting because it showed a smaller grain yield reduction than MT 7579 and Winridge despite infection levels equal to or greater than found in these two genotypes. Lenore may be able to maintain grain yield under high infection via some tolerance mechanism. Resistance in PI 278212 and PI 094424 was maintained despite increasing inoculum level. The response of these two genotypes represents a partial resistance, since the plants escape infection.

The response of winter wheat to varying levels of inoculum of *C. gramineum*, whether measured as percent infection or grain yield reduction, was linear over a range of inoculum levels for the most resistant genotypes and curvilinear for the susceptible genotypes (with one exception, MT 7579 and percent infection). This seems unusual. With many other vascular diseases, the response (percent infection and/or yield reduction) is usually curvilinear regardless of the degree of resistance of the host (1,5,13,14). The reasons for this linear response of winter wheats resistant and/or tolerant to *Cephalosporium* are unknown

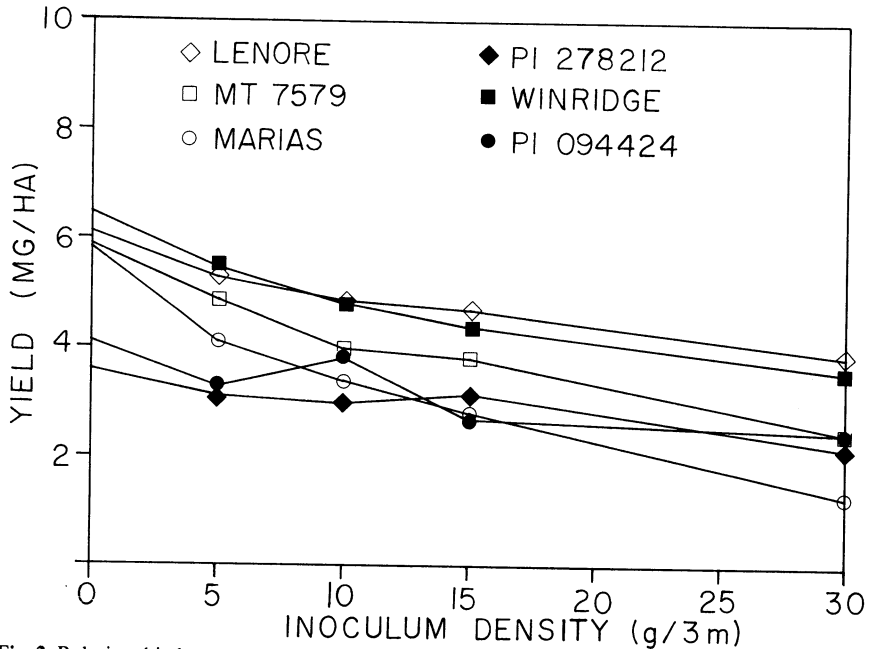

Fig. 2. Relationship between grain yield and level of *Cephalosporium gramineum* inoculum for six winter wheat genotypes averaged over 1982 and 1983. Regression equations: Lenore, $y = 5.78 - 0.07x$, $r^2 = 0.93$; PI 278212, $y = 3.51 - 0.04x$, $r^2 = 0.85$; MT 7579, $y = 5.82 - 0.19x + 0.003x^2$, $r^2 = 0.98$, Winridge, $y = 6.48 - 0.2x + 0.003x^2$, $r^2 = 0.99$; Marias, $y = 5.65 - 0.26x - 0.004x^2$, $r^2 = 0.98$; PI 094424, $y = 3.9 - 0.05x$, $r^2 = 0.73$.

but may be related to the mechanism by which wheat resists this pathogen. D. E. Mathre (*unpublished*) has noted that the resistance appears to function by restricting pathogen movement through the plant crown.

The resistance observed in PI 278212 and PI 094424 as well as the possible tolerance mechanism observed in Lenore represent a means to maintain grain yield under diseased conditions. The ideal situation would be to combine genes for resistance and tolerance into the same adapted genotype. Our results show that resistance was not overcome at the inoculum levels used in this study. The high yield reduction in resistant lines in some years, i.e., PI 278212 in 1982, is influenced more by an unknown environmental component than by inoculum level.

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