Mexican Oat Germ Plasm as a Source of Resistance to Stem Rust and Crown Rust

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ABSTRACT

One hundred and three lines and cultivars of oat used as progenitors in the oat breeding programs in Chihuahua and Chapingo, Mexico, were tested for resistance to stem rust and crown rust. Each line or cultivar was evaluated in the seedling stage to races NA8, 16, 25, 26, 27, 28, and 55 of Puccinia graminis f. sp. avenae (stem rust), and isolates CR13, 20, 36, 50, 152, and 169 of P. coronata f. sp. avenae (crown rust). Additional tests were performed on crown rust resistant lines with isolates CR185 and CR225. The same material was tested in the adult plant stage in field nurseries inoculated with a composite of the above rust isolates, except for NA26. Of the 103 lines evaluated in the seedling stage to stem rust, 32 were resistant to all races except NA28, indicating the presence of gene Pg7. The presence of genes Pg2 + Pg9, Pg4 + Pg9, Pg4, and Pg13 were indicated in 15, 9, 1, and 4 lines, respectively. In the remaining 41 lines, the identity of possible resistance genes could be determined from the seedling tests. The field tests indicated the presence of the adult plant resistance gene Pg11 in 22 of the lines. Twenty-eight lines were detected with seedling resistance to crown rust. Of these, 8 lines may contain gene Pc59. The results indicate the presence of potentially useful sources of resistance, warranting further genetic studies to confirm these preliminary findings.

Stem rust, caused by Puccinia graminis Pers.:Pers. f. sp. avenae Eriks. & E. Henn., and crown rust, caused by P. coronata Corda f. sp. avenae Eriks., are two important diseases in the oat (Avena sativa L.) growing areas of Mexico. Geographically, the northern oat-growing area of Mexico through the Great Plains of the U.S. to the eastern Canadian prairies constitutes a single epidemiological area for oat stem rust (14). The P. graminis f. sp. avenae population in this region is asxual and relatively stable, and has been dominated since 1963 by a single virulence phenotype, race NA27 (5).

There is less information available regarding virulence in P. coronata f. sp. avenae in northern Mexico. Collections from this region have not been included in the North American virulence surveys. The Great Plains population normally would include northern Mexico, but the epidemiology for this fungus is more complex because of the occurrence of the alternate host, Rhamnus cathartica L., in this region. Virulence in the Great Plains population of P. coronata f. sp. avenae is highly variable (2,3).

The Mexican oat-breeding program was initiated in 1959 by introducing germ plasm from the United States. The original material was late maturing and susceptible to several pathogens, and thus was unsuitable for direct use by growers. In 1967, the first Mexican-developed oat cultivars, Cuauhtemoc and Chihuahua, were released and distributed. The emphasis in this program has been on developing cultivars with earliness, stem rust resistance, and high yield. Oat workers at Cd. Cuauhtemoc, Chilt., Mexico, recently have become more interested in identifying the rust resistance genotypes in their breeding lines. This study reports the initial results of evaluating the resistance in Mexican oat-breeding lines to a range of virulence phenotypes of P. graminis f. sp. avenae and P. coronata f. sp. avenae.

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RESULTS AND DISCUSSION
Stem rust. The seedling and field reactions of the Mexican oat germ plasm lines to stem rust are summarized in Table 1. The lines were divided into groups depending on their reactions to the seven races of P. graminis f. sp. avenae, and the field reactions for the same groupings of lines are included. One of the lines was the diploid Avena strigosa Schreb. var. Saia. This line was resistant to all races, and was not included in Table 1.

Group A in Table 1 consisted of 32 lines resistant to all races except NA28. The near immune infection types and pattern of reactions of the lines in this group to the seven races are consistent with resistance
conferred by gene \textit{Pg6}. In the field test of adult plants, however, 14 of the lines in this group were classified as MS-S. \textit{Gene Pg6} was reported by Martens et al. (8) as originating from the cross of Kyto (which also carries gene \textit{Pg12}) with an \textit{A. steriliis} L. line, S-666AB667. The \textit{Pg6} line, which also is referred to as the "Omega" line, may be a complex of \textit{Pg12} and resistance from \textit{A. steriliis}. This line is highly resistant to all known stem rust races in North America except NA17 and NA28 in the seedling stage, but is less resistant in the adult stage (8). This may account for the higher susceptibility of some of the lines in the field. The presence of the \textit{Pg6} resistance in most of these lines is not apparent from their pedigrees. However, CI 9221, a source of \textit{Pg8} (8) occurs in this group. Since this group constitutes the largest group of lines in this test, it is likely that through breeding and/or out-crossing and subsequent selection, the \textit{Pg6} resistance has become quite widely distributed in the Mexican germ plasm. The \textit{Pg6} resistance has not been used as a resistance source in oat breeding elsewhere in North America.

Eighteen of the lines in group A in Table 1 were R-MR or MR-MS in the field test, indicating the presence of adult plant resistance. The resistant adult plant reactions in these lines could have been due to the presence in these lines of gene \textit{Pg Kl}, which is effective only in adult plants. CI 3034, the source of \textit{Pg11} (11), occurs in the pedigrees of the Mexican cultivars Huamantla \(S\), Jal, and Tulancingo. Tulancingo and Jal in turn have been used as parents for a number of other germ plasm lines, thus gene \textit{Pg11} could occur extensively in this germ plasm.

The lines in group B were resistant to races NA8 and NA16 but susceptible to all other races. This pattern of reactions is consistent with resistance conferred by gene \textit{Pg2}. \textit{Gene Pg2} is widespread in North American germ plasm (6). The cultivars Richland and Hajira, known sources of \textit{Pg2} (16,17), and derivatives of these cultivars (e.g., Indo), have been used as parents in the Mexican program. These lines were expected to be susceptible in

### Table 1. Groups of Mexican breeding lines of \textit{Avena sativa}, their infection type reactions in the seedling stage to seven races (NA) of \textit{Puccinia graminis} \(f.\) sp. \textit{avenae} and field reactions to a composite of the same races, except race NA26

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of lines</th>
<th>Race and infection type</th>
<th>Field reactions and no. of lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>32</td>
<td>NA8: 0; NA16: 0; NA25: 0; NA26: 0; NA27: 0; NA28: 0; NA55: 0</td>
<td>R-MR: 4; MS-S: 14</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>NA8: 0; NA16: 0; NA25: 0; NA26: 0; NA27: 0; NA28: 0; NA55: 0</td>
<td>R-MR: 1; MS-S: 3</td>
</tr>
<tr>
<td>C</td>
<td>9</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 3</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>F</td>
<td>1</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>G</td>
<td>9</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>H</td>
<td>1</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>J</td>
<td>5</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>K</td>
<td>2</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
<tr>
<td>M</td>
<td>1</td>
<td>NA8: 1; NA16: 1; NA25: 1; NA26: 1; NA27: 1; NA28: 1; NA55: 1</td>
<td>R-MR: 1; MS-S: 1</td>
</tr>
</tbody>
</table>

1. The number segregated into infection types 2 and 4 to NA28.
2. Two lines segregated into infection types 2 and 4 to NA28.
the field test, because most races used in this test were virulent to this gene. However, of the 15 lines in this group, one was MR and three were MR-MR. There appears to be additional adult plant resistance in some of these lines. As in group A, parentage with the adult plant resistance gene 
Pg11 occurs in this group.

In group C the lines were resistant to races NA8 and NA16, moderately resistant to NA27 and NA28, and susceptible to NA25, NA26, and NA55. A combination of genes 
Pg2 and 
Pg9 would cause this result. A possible source of gene 
Pg9 is CI 7114 (9), which occurs in the pedigrees of the Mexican cultivars Romulo and Tarambarumara. This gene also has been identified in several introductions into the U.S. (4), and occurs in numerous breeding programs (10). This gene is associated with a gene for crown rust resistance (9). Although gene 
Pg9 is not known to be present in most registered oat cultivars, it occurs in some Canadian cultivars, in some cases together with genes 
Pg2 and 
Pg13, as in the cultivar Dumont (1). Gene 
Pg9 confers a moderate level of resistance to most of the Great Plains population of 
P. graminis f. sp. avenae.

The lines in group D were susceptible only to race NA26, indicating the possible presence of gene 
Pg13. This gene was isolated from A. sterilis (13), and was first deployed in the cv. Fedler, released in Canada in 1981 (12). There is no known source of gene 
Pg13 in the Mexican oat germ plasm.

The one line in group F, with resistance only to race NA16, may contain gene 
Pg8. This gene also occurs in Hajira (16.17), and is common in North American oat cultivars.

The reaction of the single line in group K could be explained by the presence of genes 
Pg2 and 
Pg9. The reactions of the lines in the remaining groups could not be explained by known resistance genotypes. There are new, rare or unusual sources of resistance known in North American germ plasm, and the resistance may be due to gene combinations not revealed by the races used. For all of the lines in this preliminary screening test, further genetic evaluations are required to ascertain the identity of resistance genotypes.

Crown rust. The seedling reactions of the 103 lines tested in the greenhouse to six isolates of 
P. graminis f. sp. avenae are summarized in Table 3. Any lines that showed resistance to any of these isolates were additionally tested with CR185 and CR225 to help differentiate possible resistance genotypes (these isolates were chosen because of the specific virulence of CR185 to 
Pe58 and Pe59, and of CR225 to 
Pe68, Table 2).

Fifteen groups of lines (A to N in Table 3) could be differentiated based on infection type reactions to the eight isolates used. Seventy-six of the lines were susceptible to all isolates (the lines in group A were not tested with isolates CR185 and CR225). The five lines in groups B, C, and D were resistant to the first six isolates, and were further differentiated by isolates CR185 and CR225. The line in group E also was resistant to all isolates, but was differentiated by higher infection types to CR50. The remaining lines were differentiated by one or more of the eight isolates. The nine lines in group F were resistant to CR13, CR20, CR36, CR50, and CR152, but were susceptible to CR169 and CR185. The line in group G reacted generally similarly to those in group H, except that the group H lines were less resistant to CR13. The two lines in group I were susceptible to CR13, CR169, and CR185, and the line in group J was susceptible to CR36, CR152, and CR225, and was moderately susceptible to CR169. The line in group K is the diploid A. strigosa var. Saia, and it was susceptible to CR152.

In the field test, 89 of the lines were moderately susceptible to six

### Table 2. Avirulence/virulence formulae for isolates of 
P. graminis f. sp. avenae (NA) and 
P. coronata f. sp. avenae (CR)

<table>
<thead>
<tr>
<th>Race</th>
<th>Avirulence/virulence combination (Pg or Pc genes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA8</td>
<td>1, 2, 8, 16, a/3, 4, 9, 13, 15</td>
</tr>
<tr>
<td>NA16</td>
<td>2, 4, 9, 13, 15, 16, a/1, 3, 8</td>
</tr>
<tr>
<td>NA25</td>
<td>8, 13, 16, a/1, 2, 3, 9, 15</td>
</tr>
<tr>
<td>NA26</td>
<td>8, 16, a/1, 2, 3, 9, 14, 15</td>
</tr>
<tr>
<td>NA27</td>
<td>9, 13, 15, 16, a/1, 2, 3, 4, 8</td>
</tr>
<tr>
<td>NA55</td>
<td>8, 13, a/1, 3, 4, 9, 15 (b)</td>
</tr>
<tr>
<td>CR13</td>
<td>35, 38, 50, 56, 58, 59, 61, 62, 63, 64, 67, 68/39, 40, 45, 46, 48, 54, 55, 60</td>
</tr>
<tr>
<td>CR20</td>
<td>35, 38, 39, 40, 45, 46, 48, 54, 55, 58, 59, 60, 61, 62, 63, 64, 67, 68/50, 56</td>
</tr>
<tr>
<td>CR36</td>
<td>35, 39, 45, 46, 50, 54, 55, 56, 58, 59, 60, 61, 62, 63, 64, 68/38, 40, 63, 67</td>
</tr>
<tr>
<td>CR50</td>
<td>38, 39, 40, 45, 46, 48, 54, 55, 58, 59, 60, 61, 62, 63, 64, 67, 68/35, 50, 56</td>
</tr>
<tr>
<td>CR152</td>
<td>35, 38, 39, 40, 45, 46, 48, 50, 54, 55, 56, 58, 59, 60, 61, 62, 63, 64, 67, 68</td>
</tr>
<tr>
<td>CR169</td>
<td>38, 45, 48, 50, 54, 56, 58, 60, 61, 62, 63, 64, 67, 68/35, 39, 40, 46, 55, 59</td>
</tr>
<tr>
<td>CR185</td>
<td>38, 39, 45, 46, 50, 54, 55, 56, 58, 60, 61, 62, 63, 64, 67, 68/35, 40, 46, 58, 59</td>
</tr>
<tr>
<td>CR225</td>
<td>35, 39, 45, 46, 48, 54, 55, 56, 58, 59, 60, 62, 63, 64, 68/38, 40, 50, 60, 61, 67, 68</td>
</tr>
</tbody>
</table>

### Table 3. Groups of Mexican breeding lines of 
*Avena sativa* and their seedling reactions to eight isolates of 
P. coronata f. sp. avenae and their adult plant field reactions to a composite of isolates CR13, CR20, CR36, CR50, CR152, and CR169

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of lines</th>
<th>CR13</th>
<th>CR20</th>
<th>CR36</th>
<th>CR50</th>
<th>CR152</th>
<th>CR169</th>
<th>CR225</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>76</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
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<tr>
<td>D</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
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<td>0</td>
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<tr>
<td>E</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>10</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>0</td>
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<td>4</td>
<td>3</td>
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<td>H</td>
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<td>0</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>3</td>
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<td>3</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>J</td>
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<td>0</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>K</td>
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<td>0</td>
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<td>4</td>
<td>3</td>
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<td>0</td>
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<td>4</td>
<td>3</td>
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</tr>
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<td>0</td>
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<td>3</td>
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</tr>
<tr>
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<td>0</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

### Notes

* The lines in each of the groups are as follows: Group A - all susceptible, not listed; Group B - CR4 (K); Group C - CR48 (A), CR49 (A), CR78 (E); Group D - CB97; Group E - CB101 (A); Group F - CR8 (A); CB24 (A), CR28 (A), CR41 (A), CR47 (A), CR59 (A), CR79 (E), CR80 (A), CR100 (A), CR103 (A); Group G - CR46 (A); Group H - CR25 (A), CR28, CR81 (A); Group I - CR23 (L), S126 (G); Group J - CR32 (A); Group K - CR2 (Saia); Group L - CR52 (A); Group M - CB55 (B); Group N - CB65 (A); The pedigrees for each of the lines are shown in Table 1. The letters in parentage refers to the groups in Table 1 for ease of cross-referencing.

* CB100, CB103.

* S126.
were moderately resistant to moderately susceptible, and seven were resistant to moderately resistant (Table 3).

The identity of crown rust resistance genes could not be ascertained for any of the lines. It is likely that for most of the resistant lines, there are combinations of genes that could not be identified by the isolates used.

This study has shown that there are potentially useful sources of stem rust and crown rust resistance in the Mexican oat germ plasm. For stem rust, the putative resistances conferred by the \( P_{g9} \) resistance and genes \( P_{g9} \) and \( P_{g11} \) are the most important. The \( P_{g9} \) resistance appears to occur widely in the Mexican breeding lines. Although this gene appears less effective in the adult plant stage than in the seedling stage (8), further analysis may show a useful protective effect in the field. Gene \( P_{g11} \) has not been used as a resistance source in Canada or the U.S., possibly because of deleterious physiologic effects associated with this gene (6,11). It is important that this gene be identified with certainty, and that agronomic performance of lines with this gene be analyzed carefully. Gene \( P_{g9} \) confers moderate resistance to most of the Great Plains population of \( P. graminis f. sp. avenae \), and could usefully be incorporated into commercial cultivars. Genetic analysis is required to ascertain the genotypes of the undetermined lines, and to determine their potential usefulness. For crown rust, the 3 lines in group C and the line in group E (Table 3), resistant to all eight isolates in the seedling stage and in the field, may provide usable resistance, pending elucidation of their resistance genotypes.

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**LITERATURE CITED**