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

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ABSTRACT

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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 *Pga*. The presence of genes *Pg2* + *Pg9, Pga* + *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 asexual 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, Chih., 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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MATERIALS AND METHODS

One hundred and three lines and cultivars from the Mexican oat-breeding program at Cd. Cuauhtemoc and Chapingo were evaluated in greenhouse and field tests at the Agriculture and Agri-Food Canada Cereal Research Centre, Winnipeg. The pedigrees for the lines tested may be found in Table 1.

In the greenhouse tests, 15 plants of each line were inoculated with urediniospores suspended in a light mineral oil (Dustrol, Ciba-Canada Ltd., Winnipeg, MB). Inoculum of *P. graminis* f. sp. *avenae* consisted of 7 NA races (nomenclature of Martens et al.) (7) and that of *P. coronata* f. sp. *avenae* consisted of eight isolates (designated as CR-isolates) (Table 2). The inoculated plants were incubated overnight at 100% relative humidity, then grown in a greenhouse with an average temperature of 22°C and supplemental fluorescent lighting to provide an 18:6 h light/dark period. The plants were evaluated for stem rust and crown rust resistance 12 to 14 days after inoculation. Infection types were recorded using the Stakman et al. (15) scale, in which infection types ranging from 0; to 3^- were considered resistant, and infection types 3 and 4 susceptible. The test was repeated to verify the infection types.

In the field tests the lines were planted in separate stem rust and crown rust nurseries on 23 May 1991 and on 20 May and 3 June 1993 in single 1-m rows. A mixture of susceptible lines was planted every sixth row as a rust spreader. The spreader rows were inoculated at the five- to six-leaf stage by dusting them with a urediniospore/talcum powder mixture. The inoculum consisted of a composite of races NA8, 16, 25, 27, 28, and 55 of *P. graminis* f. sp. *avenae*, and isolates CR13, 20, 36, 50, 152, and 169 of *P. coronata* f. sp. *avenae* (Table 2). Rust severities were evaluated late July to mid August. For both rusts they were classified as resistant to moderately resistant (R-MR), moderately resistant to moderately susceptible (MR-MS), and moderately susceptible to susceptible (MS-S) (based on infection types). The MS-S classification was considered susceptible.

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 *Pga*. In the field test of adult plants, however, 14 of the lines in this group were classified as MS-S. Gene *Pga* was reported by Martens et al. (8) as originating from the cross of Kyto (which also carries gene *Pg12*) with an *A. sterilis* L. line, S-66AB667. The *Pga* line, which also is referred to as the "Omega" line, may be a complex of *Pg12* and resistance from *A. sterilis*. 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 test. The presence of the *Pga* resistance in most of these lines is not apparent from their pedigrees. However, CI 9221, a source of *Pga* (8) occurs in the pedigree of one of the lines, CB102, in this group. Since this group constitutes the largest group of lines in this test, it is likely that through breeding and/or outcrossing and subsequent selection, the *Pga* resistance has become quite widely distributed in the Mexican germ plasm. The *Pga* 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 could have been due to the presence in these lines of gene *Pg11*, which is effective only in adult plants. CI 3034, the source of *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 *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 *Pg2*. Gene *Pg2* is widespread in North American germ plasm (6). The cultivars Richland and Hajira, known sources of *Pg2* (16,17), and derivatives of these cultivars (e.g., Indio), 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 *Avena sativa*, their infection type reactions in the seedling stage to seven races (NA) of *Puccinia graminis* f. sp. *avenae* and field reactions to a composite of the same races, except race NA26

		Race and infection type							Field reactions and no. of lines		
Group[a]	No. of lines	NA8	NA16	NA25	NA26	NA27	NA28	NA55	R-MR	MR-MS	MS-S
A	32	0;	0;	0;	0;	0;	4	0;	4	14	14
B	15	1	1	4	4	4	4	4	1	3	11
C	9	;1	;1	4	4	1 to 2	2 to 3^-	4		4	5
D	4	1	;1	1	4	1	2	;1	1	2	1
E	3	1	;1	1	4	1	4[b]	;1		3	
F	1	4	1	4	4	4	4	4			1
G	9	1	;1^-	4	4	1	4	2 to 3	5	2	2
H	19	1	;1	4	4	1 to 2^+	2 to 3[c]	1 to 3	1	4	15
I	2	1	;	4	4	4	4	1 to 2	2		
J	5	1	;	4	;	;	4	;	3	2	
K	1	0;	0;	0;	0;	0;	1 to 3	0;	1		
L	1	1	;	1	4	4	4	4			1
M	1	;1	;	4	;1	4	1 to 2	4		1	

[a] The groups, identification of the lines in each group, and their pedigrees are as follows: *Group A*: **CB 8** - Cauhtemoc (AB 177/Putnam 61); **CB 24** - Xochi/Coker-79-CP 84; **CB 25** - IORN/CI 3655/Hajira/Joanette/LMHJA/CI 8091; **CB 26** - Tulancingo-227131; **CB 28** - Tulancingo/Diamante "S"/79AB-369-79GH-133; **CB 29** - Tulancingo/Diamante "S"/79AB-369-79GH-133; **CB 30** - Santa Fe/4-58-44-Wis//79AB-361-79GH-133; **CB 32** - Xochi/Coker79/CP 84; **CB 35** - Tarahumara/Sierra/Severionin/IORN 78-S72); **CB 38** - Yuca/Diamant-R31/79AB-361-79GH-79; **CB 41** - Xochi/Coker CO-79-CP 84; **CB 42** - Tarahumara/Yubiheyumiy/IORN 80-48; **CB 46** - Pioneer/Mutica/CI 1904/IORN78-33; **CB 47** - Yuca/Diamante "S"/Boyeros; **CB 48** - Tulancingo/Romulo; **CB 49** - Xochi/Coker/CO-79-CP84; **CB 52** - 11630/Nuprime/Diamante "s"/Hajira/Joanette/LMJA/CI 8091; **CB 59** - Boni/Jal; **CB 60** - V1 E1/Ber-762/Minsky-17; **CB 61** - Tarahumara//Sierra/Severionin/IORN 78-72; **CB 62** - Tulancingo/Opalo; **CB 65** - 1630/Nuprime/Diamante "S"/Hajira/Joanette//LMHJA/CI 8091; **CB 66** - 1486/OA-364-663-1-8-47-2-73/77075; **CB 68** - Tulancingo/Romulo; **CB 75** - Tarahumara/Yubileymly/IORN 76-72; **CB 80** - Tulancingo/79Ab-79GH; **CB 81** - Tulancingo/Diamante "S"; **CB 97** - Huamantla "s"; **CB 100** - 81AB-1011-50-SA(79 Bordenave Sel); **CB 101** - 425-ME-1554-Cr-Cpx/76 AB-532-2/Sr-Cpx; **CB 102** - CI 9221/OTTE/2/RL 3038/Dal/3/MN 78142/ND 821456-2; **CB 103** - Bordenave Sel/Kenya Sr Line SA 86-30265. *Group B*: **CB 1** - Burt; **CB 3** - Gema (Arkansas No. 58/AB 177/Curt/ Nodaway*3/Indio/Nodaway/Funl-1169); **CB 6** - Putnam; **CB 7** - Opalo; **CB 9** - Chihuahua (AB 177/Putnam 61); **CB 10** - Guelatao (Curt/Nodaway); **CB 11** - Diamante (Dia "s") (1955-A-39-3-2C/Indio/AB 110/AB 177/Curt); **CB 12** - Huamantla (CI 3034/Tippecanoe/ENA/); **CB 13** - Paramo (AB 177/Curt/Curt/Nodaway*2/AB); **CB 14** - Tarahumara (CI 7114/Curt/Nodaway*3/AB 110/Ab 177/Curt/7939); **CB 15** - Tulancingo (CI 3034/Tippecanoe/Curt/Cuauhtemoc); **CB 16** - Protavena; **CB 55** - MN 859503; **CB 56** - MN 869508; **S 14** - Huamantla "s" *Group C*: **CB 33** - Swan/Romulo; **CB 40** - Val/Lobo N//Jin/Dia "S"/Ena/Dia "S"/Paco/Jal/Romulo; **CB 51** - Val/Lobo/Jim/Dia "s"/Hajira/Joanett/LMHJA/CI 8091; **CB 53** - Gue/Paco/AB 177/C-CN/Ena/Dia "S"/Boyeros; **CB 64** - Boni/Jal; **CB 67** - Valiao/Yuca/Yuca/Dia "S"; **CB 69** - Tulancingo/Romulo; **CB 71**- Tulancingo/Romulo; **CB 72** - Yuca/Diamante "S". *Group D*: **CB 27** - Oji/777131; **CB 57** - Tulancingo/Diamante-R31/79AB-384-79GH-270; **CB 58** - Tulancingo/Jal; **CB 74** - Gutierrez-77694. *Group E*: **CB 77** - Tarahumara/Sierra/Severionin/IORN-Cv76-S72; **CB 78** - Xochi/Coker Co-79CP84; **CB 79** - Kenya S59-1C. *Group F*: **CB 5** - Tam-0-386. *Group G*: **CB 63** - Pan-777131; **S 9** -Diamante "S"; **S 10** - Diamante "S"; **S 18** - Huamantla "S"; **S 22** - Huamantla "S"; **S 26** - Diamante "S"; **S 29** - Diamante "S"; **S 30** - Romulo (Jim/Inca/Colli/Tippecanoe/MHF/CI 7114/ENA/Indio-N/Inca/F4); **S 126** - Diamante "S". *Group H*: **CB 17** - Papigochi; **CB 18** - Babicora; **CB 19** - Cusihuiriachi; **CB 20** - Raramuri; **CB 21** - Pampas; **CB 22** - Raramuri "S"; **CB 31** - V1-E1/(Ber-762/Misky-17)*2 719; **CB 34** - Swan/Romolo; **CB 36** - Tulancingo/Romulo; **CB 37** - Tulancingo/Diamante R31/79-AB-384-79GH-270; **CB 39** - Boni/Jal; **CB 43** - Val/Lobo/Jin/Diamante "S"/ENA/Diamante "S"/Paco/Jal/Romulo; **CB 44** -; **CB 45** - Tulancingo/Diamante-R31/Jin/Inca/Colli/Tippecanoe/Mhf/7114/Ena/Inca/Jim/Inca; **CB 50** - Boni/Jal; **CB 54** - Pioneer/Mutica 1904/IORN 78-S33; **CB 70** - Boyeros/Romulo; **CB 73** - Val/Lobo-N/Jin/Diamante "S"/Paco/Jal/Frat/Romulo; **S 28** - Diamante "S" *Group I*: **S 15** - Huamantla "S"; **S 16** - Huamantla "S". *Group J*: **S 116** - Huamantla "S"; **S 125** - Diamante "S"; **S 131** - Huamantla "S"; **S 133** - Huamantla "S"; **S 39** - IORN-S48-CV80. *Group K*: **CB 4** - TAM-O-386. *Group L*: **CB 23** - 1482-04-24B-1893-5-1-3-179/Hajira/Joanette. *Group M*: **CB 76** - MI-III-R77-78-CV78-R78-79-CV79-CV80. *Additional notes to the pedigrees:* **Boni** = CI 7919/Opalo/Curt/Impala/ENA; **CI 3034** = Rhodesia selection of resistant plants from oat variety Burt; **CI 7114** = Clinton*2Ark674; **CI 8091** = Hajira/Joanette 2/LMHJA(CI 4023/CI 7048); **CI 9221** = *Avena sterilis*/Kyto; **Colli** = CI 3034/Tippecanoe/Curt; **ENA** = Curt/AB 177/Curt; **Inca** = 7971/o*2/Curt/Indio/AB 110/AB 177/Curt; **Impala** = Indio/AB 110/AB 177/curt; **Indio** = Victoria/Richland/Fulghum/Palestine; **IORN** = International Oat Rust Nursery; **Jal** = Rapida/CL 34/CI 3034/ Tippecanoe/Curt/Nodaway/AB 177/Curt; **LMHJA** = Landhafer/Mindo/Hajira/Joanette/Andrew; **Lobo** = CI 3034/Tippecanoe/ENA; **Oji** = Opalo/Curt/CI 7359 No8/CI 8247/Perla/Cuauhtemoc; **Rapida** = *A. byzantina/A. fatua/A. byzantina*(mono)*2/A. fatua; **TAM-O-301** = Abss/3/Ora/63C 3668-4-2/2/Ora/PI-295919; **TAM-O-386** = Coker 75-1214/Coker 227/Coker 234/3/TAM-O-301/TAM-O-312/2/CI 9221/TAM-O-312/2/Coker 227; **TAM-O-312** = Abss/3/Ora/63/Ora/63 C 3868-4-2/Alamo-X/PI 296244; **Xochi** = Impala/ENA/Putnam/7359/7359/O-C; **Yuca** = Tippecanoe/MHF/CI 7114/Indio-N/CI 8247/Perla/AB 177/Putnam-61.

[b] One line segregated into infection types 2 and 4 to NA28.

[c] Two lines segregated into infections 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-MS. 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 Tarahumara. 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. Fidler, 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 *Pg4*. 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 *Pga* and *Pg9*. The reactions of the lines in the remaining groups could not be explained by known resistance genotypes. There are no new 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 *Pc58* and *Pc59*, and of CR225 to *Pc68*, 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 susceptible, six

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

Race	Avirulence/virulence combination (*Pg* or *Pc* genes)
NA8	1, 2, 8, 16, a/3, 4, 9, 13, 15
NA16	2, 4, 9, 13, 15, 16, a/1, 3, 8
NA25	8, 13, 16, a/1, 2, 3, 4, 9, 15
NA26	8, 16, a/1, 2, 3, 4, 9, 13, 15
NA27	9, 13, 15, 16, a/1, 2, 3, 4, 8
NA28	9, 13, 15, 16/1, 2, 3, 4, 8, a
NA55	8, 13, a/1, 2, 3, 4, 9, 15, 16
CR13	35, 38, 50, 56, 58, 59, 61, 62, 63, 64, 67, 68/39, 40, 45, 46, 48, 54, 55, 60
CR20	35, 38, 39, 40, 45, 46, 48, 54, 55, 58, 59, 60, 61, 62, 63, 64, 67, 68/50, 56
CR36	35, 39, 45, 46, 48, 50, 54, 55, 56, 58, 59, 60, 61, 62, 64, 68/38, 40, 63, 67
CR50	38, 39, 40, 45, 46, 48, 54, 55, 58, 59, 60, 61, 62, 63, 64, 67, 68/35, 50, 56
CR152	35, 38, 39, 40, 45, 46, 48, 50, 54, 55, 56, 58, 59, 60, 61, 62, 63, 64, 67, 68
CR169	38, 45, 48, 50, 54, 56, 58, 60, 61, 62, 63, 64, 67, 68/35, 39, 40, 46, 55, 59
CR185	38, 39, 45, 48, 50, 54, 55, 56, 60, 61, 62, 63, 64, 67, 68/35, 40, 46, 58, 59
CR225	35, 39, 45, 46, 48, 54, 55, 56, 58, 59, 62, 63, 64/38, 40, 50, 60, 61, 67, 68

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

		Isolate and infection type								Field reactions and no. of lines		
Group[a]	No. of lines	CR13	CR20	CR36	CR50	CR152	CR169	CR185	CR225	R-MR	MR-MS	MS-S
A	76	4	4	4	4	4	4	–	–			76
B	1	;	0;	0;	;	0;	;1	4	4			1
C	3	0;	0;	0;	;	0;	;	;	;	3		
D	1	;	;	0;	;	0;	;1	3	1	1		
E	1	;	0;	0;	1 to 2	;	;1	;	;	1		
F	10	; to ;1	0;	0;	; to ;1	0;	4	4	1		2[b]	8
G	1	;	0;	0;	4	0;	4	3	;			1
H	3	;2 to 3	;1	;	4	; to ;1	4	4	;		3	
I	2	3	;	;	;1	;	4	4	;	1[c]		1
J	1	0;	;1	4	;	4	2 to 3	;1	4		1	
K	1	0;	;	0;	0;	4	;	;1	0;	1		
L	1	3	4	;	3	;	4	4	4			1
M	1	3	4	4	;1	4	4	;	4			1
N	1	;	4	0;	4	;	4	4	0;			1

[a] The lines in each of the groups are as follows: *Group A* - all susceptible, not listed; *Group B* - **CB 4** (K); *Group C* - **CB 48** (A), **CB 49** (A), **CB 78** (E); *Group D* - **CB97**; *Group E* - **CB101** (A); *Group F* - **CB 8** (A); **CB 24** (A), **CB 38** (A), **CB 41** (A), **CB 47** (A), **CB 59** (A), **CB 79** (E), **CB 80** (A), **CB100** (A), **CB103** (A); *Group G* - **CB 46** (A); *Group H* - **CB 25** (A), **CB28**, **CB 81** (A); *Group I* - **CB 23** (L), **S 126** (G); *Group J* - **CB 32** (A); *Group K* - **CB 2** (Saia); *Group L* - **CB 52** (A); *Group M* - **CB55** (B); *Group N* - **CB65** (A). The pedigrees for each of the lines are shown in Table 1. The letters in parentheses refer to the groups in Table 1 for ease of cross-referencing.

[b] CB100, CB103.

[c] 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 *Pga* resistance and genes *Pg9* and *Pg11* are the most important. The *Pga* 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 *Pg11* 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 *Pg9* 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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