# Pathogenicity Variations of *Puccinia recondita* f. sp. *tritici* and *P. graminis* f. sp. *tritici* in Wheat-Growing Areas of Mexico During 1988 and 1989

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**ABSTRACT**

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A survey of *Puccinia recondita* f. sp. *tritici* in Mexico during 1988 and 1989 indicated the presence of 23 pathotypes. In the Pacific region and Highland Plateau, pathotype TCB/TD predominated both years, followed by TBD/TM. The population was most variable in the eastern lowlands of Mexico to the Texas border. Predominating pathotypes isolated from the collections made from durum wheats and triticales were different from those on bread wheats. Two extra supplemental host sets are proposed for future use in Mexico. Only six pathotypes of *P. graminis* f. sp. *tritici* were identified.

Additional keywords: leaf rust, stem rust, *Triticum aestivum*

Wheat (*Triticum aestivum* L.) cultivation in Mexico occupies about 1 million ha with an annual production of about 4.5 million t. As indicated in Figure 1, the wheat-growing areas are widely distributed from eastern to northern Mexico. These areas could be separated into three distinct zones by the two mountain ranges. These zones include: 1) the eastern lowlands east of the Sierra Madre Oriental mountain range, 2) the Highland Plateau between the Sierra Madre Oriental and the Sierra Madre Occidental, and 3) the Pacific region.

Areas predisposed to leaf rust (caused by *Puccinia recondita* Roberge ex Desmaz. f. sp. *tritici* (Eriks. & E. Henn.) D. M. Henderson) in the eastern lowlands include those that cross the Texas (USA) border from the Mexican states of Coahuila, Tamaulipas, and San Luis Potosi. The total area is about 22,000 ha. Wheat is planted November through January and harvested April through May.

Leaf rust can occur in various sparsely distributed areas of the Highland Plateau in the states of Chihuahua, Jalisco, Mexico, Tlaxcala, Guanajuato, and Michoacan (total area of about 63,000 ha). Wheat is planted either in May–June or December–January and is harvested in October–November or May. Although this continuous planting is ideal for the survival of rust throughout the year, it is a problem only in summer-sown wheat.

The possible areas for leaf rust infection in the Pacific region include Sinaloa and southern Sonora. Wheat is planted from November to February and harvested from April to June. This is the major wheat-growing region in Mexico with an approximate area of 500,000 ha.

The segregating and advanced generation materials of the breeding programs at CIMMYT are selected for resistance to leaf rust and stem rust (caused by *P. graminis* Pers.:Pers. f. sp. *tritici* Eriks. & E. Henn.) diseases at some of the locations in the three geographic zones under artificially created or natural epidemics. High-yielding and rust-resistant ad-

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vanced lines are then distributed worldwide for multilocational international testing and varietal release in numerous countries. This research was conducted to study the variations in the pathogen population in various parts of Mexico in the belief that accumulated data over years will be useful in the characterization of the epidemiologically similar or different areas in Mexico and the United States. Furthermore, the information on the pathotypes would be useful to the programs in numerous countries receiving CIMMYT wheat germ plasm resistant to leaf rust.

## MATERIALS AND METHODS

Rust trap nurseries were planted during the 1987–1988, 1988, 1988–1989, and 1989 crop cycles at various locations in Mexico. This nursery included near-isogenic Thatcher lines (developed by Canadian Department of Agriculture, Winnipeg) for various leaf rust resistance genes (6), Morocco (an extremely susceptible genotype), and a few current commercial cultivars. Infected leaf or stem samples were collected from this nursery in 1988 (from the 1987–1988 and 1988 crop cycles) and 1989 (from 1988–1989 and 1989 crop cycles) as well as other breeding materials or commercial cultivars grown in the vicinity of those locations exhibiting infections. Collections from CIANO (Sonora), El Batan, and Toluca (Mexico state) were also made from nurseries that were artificially inoculated with rust collected during the past several years from the same area.

Eight- to nine-day-old seedlings of Morocco treated with Maleic hydrazide (5 mg with 50 ml of water per pot) were inoculated with spores collected from each field sample. The treatment with Maleic hydrazide restricts the growth of seedlings and enhances the spore production. Two or three single uredia were isolated from each viable sample. Each isolate was increased on Morocco in separate clear plastic chambers to generate sufficient inoculum.

Eight- to nine-day-old seedlings of the tester host series were inoculated by spraying urediospores suspended in a lightweight mineral oil, placed in a dew chamber overnight at 18–20 C, and transferred to a greenhouse where temperatures varied between 18 and 24 C. Some resistance genes, known to be more effective at lower temperatures than 18–24 C, were tested at 15–18 C (Tables 1 and 2). Infection types were based on a scale of 0–4 (10) after 9–11 days for leaf rust and 12–14 days for stem rust.

Known leaf rust resistance genes (*Lr* genes) included in the host series for leaf rust pathogenicity survey are listed in Table 1, and known stem rust resistance genes (*Sr* genes) for stem rust pathogenicity are given in Table 2. The seeds of these lines were provided by A. P. Roelfs, Cereal Rust Laboratory, St. Paul, MN; and R. A. McIntosh, Plant Breeding Institute, The University of Sydney, Australia.

The nomenclature for *P. r. tritici* pathotypes follows the system described by Long and Kolmer (6) with two supplemental host sets (Table 3) to describe most of the variation occurring in Mex-

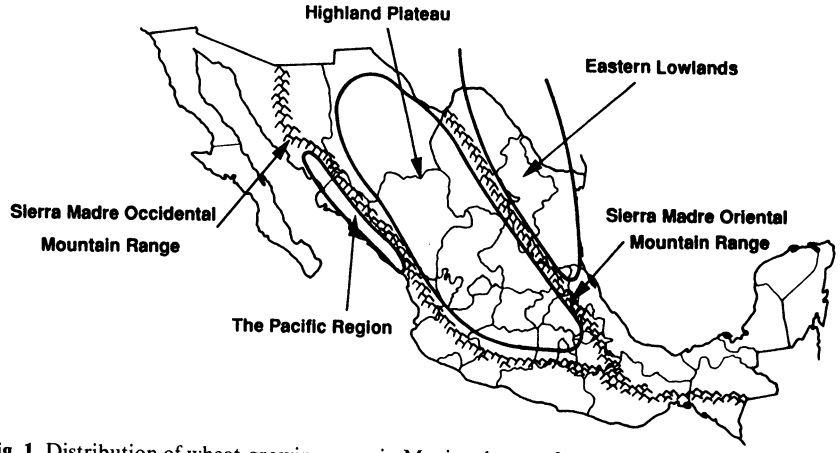


**Fig. 1.** Distribution of wheat-growing areas in Mexico that are favorable to infection by *Puccinia recondita* f. sp. *tritici*.

**Table 1.** Host series with known *Lr* genes included in the leaf rust survey with observed low seedling infection types (0–4 scale) at 18–24 C

| *Lr* gene | Test line | | Low infection type[w] |
|---|---|---|---|
| | Cross | Number | |
| *1* | Tc*6/Centenario | RL6003 | 0; |
| *2a* | Tc*6/Webster | RL6016 | ;, ;1 |
| *2b* | Tc*6/Carina | RL6019 | ;1, 1+ |
| *2c* | Tc*6/Loros | RL6047 | 1, 2+3 |
| *3* | Tc*6/Democrat | RL6002 | 0;, 12 |
| *3ka* | Tc*6/Aniversario | RL6007 | 12 |
| *3bg* | Bage/8*Tc | RL6042 | 0;, 2+ |
| *9* | Transfer/6*Tc | RL6010 | 0; |
| *10* | Tc*6/Exchange | RL6004 | ;1− |
| *11* | Hussar | W976 | 1N[x] |
| *12* | Exchange/6*Tc | RL6011 | APR[y] |
| *13* | Manitou | | X |
| *14a* | Selkirk/6*Tc | RL6013 | X |
| *14b* | Tc*6/Maria Escobar | RL6006 | ?[z] |
| *15* | Tc*6/Kenya 1483 | RL6052 | ;;;1[x] |
| *16* | Tc*6/Exchange | RL6005 | 1+ |
| *17* | Klein Lucero/6*Tc | RL6008 | ; |
| *18* | Tc*7/Africa 43 | RL6009 | 2−[x] |
| *19* | Tc*7/Agatha | RL6040 | 0; |
| *20* | Thew | W203 | ?[z] |
| *21* | Tc*6/RL5406 | RL6043 | 12 |
| *22a* | Tc*6/RL5404 | RL6044 | APR |
| *22b* | Thatcher | CI10003 | APR |
| *23* | Lee310/6*Tc | RL6012 | ;1, 23C |
| *24* | Tc*6/Agent | RL6064 | ;1− |
| *25* | Transec | RL6084 | ; |
| *26* | Tc*6/ST-1-25 | RL6078 | 0;, 1+ |
| *27+31* | Gatcher | W3720 | X− |
| *28* | CS20-2M | | 0; |
| *29* | Tc*6/CS7AG#11 | RL6080 | ;1 |
| *30* | Tc*6/Terenzio | RL6049 | 23− |
| *32* | Tetra Canthatch/*T. tauschii* | RL5497-1 | 2 |
| *33* | Tc*6/PI58548 | RL6057 | 22+ |

[w] 0 = No uredia or other macroscopic signs of infection; ; = no uredia, but hypersensitive necrotic or chlorotic flecks of varying size present; 1 = small uredia often surrounded by necrosis; 2 = small to medium uredia often surrounded by chlorosis or necrosis; 3 = medium-sized uredia that may be associated with chlorosis or rarely necrosis; X = random distribution of variable-sized uredia on single leaf with a pure culture; + = uredia somewhat larger than normal for the infection type; − = uredia somewhat smaller than normal for the infection type; C = more chlorosis than normal for infection type; and N = more necrosis than normal for infection type.

[x] Tested at 15–18 C because of its temperature-sensitive response.

[y] Adult plant resistance.

[z] No low infection type observed.

**Table 2.** Host series with known *Sr* genes included in the stem rust survey with observed low seedling infection types (0–4 scale) at 18–24 C

| *Sr* gene | Test line | Low infection type[y] |
|---|---|---|
| *5* | ISr5-Ra | 0 |
| *6* | W2691Sr6 | ;[z] |
| *7a* | Line G | 2+ |
| *7b* | ISr7b-Ra | 2 |
| *8a* | ISr8a-Ra | 2 |
| *8b* | Barleta Benvenuto, W3502 | X |
| *9a* | ISr9a-Ra | 2– |
| *9b* | W2691Sr9b | 2 |
| *9d* | ISr9d-Ra | 2– |
| *9e* | Vernstein | ;2= |
| *9f* | ISr5-Sb | – |
| *9g* | Chinese Spring (Tc2B)/Line E | – |
| *10* | W2691Sr10 | X |
| *11* | ISr11-Ra | ; |
| *12* | Chinese Spring (Tc3B) | X[z] |
| *13* | W2691Sr13 | 2– |
| *14* | Line A selection | 2–, 2+ |
| *15* | W2691Sr15Nk | – |
| *17* | Little Club/Kenya Hunter | ;[z] |
| *21* | *T. monococcum* derivative | 2– |
| *22* | SWSr22Tb | ;2= |
| *23* | Exchange | 3–N |
| *24* | BtSr24Ag | 2– |
| *25* | Sr25Ars | 2– |
| *26* | Eagle | 2= |
| *27* | Coorong Triticale | ; |
| *28* | W2691Sr28Kt | – |
| *29* | Pusa*4/Etiole de Choisy | ;2– |
| *30* | BtSr30Wst | 2 |
| *31* | Line E/Kvz | 2– |
| *32* | C77.19 | 2– |
| *33* | RL5405 | 2– |
| *34* | Compair | – |
| *35* | W3763 | ; |
| *36* | W2691SrTt1 | ;,X |
| *Dp2* | Medea Ap9d | 2,2+3 |
| *Gt* | BtSrGamut | 2 |
| *Pl* | Peliss | – |
| *Wld* | Baart/Waldron | 2 |
| *H* | H44 derivative | 12– |
| *W3560* | Entrelargo de Montijo, W3560 | 2– |
| *AgI* | Taf-2 | ;2– |

[y] 0 = No uredia or other macroscopic signs of infection; ; = no uredia, but hypersensitive necrotic or chlorotic flecks of varying size present; 1 = small uredia often surrounded by necrosis, 2 = small to medium uredia often surrounded by chlorosis or necrosis; 3 = medium-sized uredia that may be associated with chlorosis or rarely necrosis; X = random distribution of variable-sized uredia on single-leaf with a pure culture; + = uredia somewhat larger than normal for the infection type; – = uredia somewhat smaller than normal for the infection type; = = uredia at the lower size limit for the infection type; C = more chlorosis than normal for infection type; and N = more necrosis than normal for infection type.

[z] Tested at 15–18 C because of its temperature-sensitive response.

ico. The nomenclature for *P. g. tritici* follows the system described by Roelfs and Martens (8). Avirulence/virulence formulae for pathotypes are also given. The pathotypes are reported in this paper after conducting the tests at least three times.

## RESULTS AND DISCUSSION

***P. r. tritici.*** Twenty-three pathotypes were identified (Table 4) for 325 leaf samples infected with leaf rust. The samples were obtained from 10 Mexican states (Tables 5 and 6). From these, 690 single uredia isolates were evaluated on the host series described in Table 1. The avirulence/virulence formulae for the pathotypes are given in Table 4. The usually occurring low infection types associated with each *Lr* gene are given in Table 1. Plants with genes *Lr12*, *Lr14b*, *Lr20*, *Lr22a*, and *Lr22b* displayed consistently high infection type to all isolates. Of these, *Lr12*, *Lr22a*, and *Lr22b* are known to confer low reactions only in adult plants, therefore, virulence status in the pathogen for these genes could not be determined. With regard to *Lr14b* and *Lr20*, it could be inferred that the pathogen population was virtually 100% virulent.

Genes *Lr3Ka*, *Lr9*, *Lr19*, *Lr21*, *Lr25*, *Lr29*, *Lr30*, *Lr32*, and *Lr33* displayed low seedling reactions to all isolates, indicating that virulences for these genes were virtually lacking in the rust population. All other genes listed in Table 4 display variation. Avirulence for *Lr14a* and *Lr28* was rare and observed only in pathotypes BBB/BN and CBJ/QL, respectively. Similarly, virulence for *Lr16* was observed only in pathotype MGB/SM.

Certain *Lr* gene lines displayed two distinct low infection types. These were *Lr2a*, *Lr2b*, *Lr2c*, *Lr3*, *Lr3bg*, *Lr15*, *Lr23*, and *Lr26* (Table 1). The lower of the two infection types associated with these genes may indicate the homozygous avirulence allelic situation in the pathogen, whereas the higher infection type

**Table 3.** Infection type[z] produced on 12 North American and eight Mexican differential hosts (near isogenic *Lr* gene lines) and nomenclature code for *Puccinia recondita* f. sp. *tritici* modified from Long and Kolmer (6)

| | North American host set | | | | | | | | | | | | Mexican host set | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nomenclature | 1 | | | | 2 | | | | 3 | | | | 4 | | | | 5 | | | |
| code | *1* | *2a* | *2c* | *3* | *9* | *16* | *24* | *26* | *3ka* | *11* | *17* | *30* | *3bg* | *13* | *15* | *18* | *10* | *19* | *23* | *27+31* |
| B | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L | L |
| C | L | L | L | H | L | L | L | H | L | L | L | H | L | L | L | H | L | L | L | H |
| D | L | L | H | L | L | L | H | L | L | L | H | L | L | L | H | L | L | L | H | L |
| F | L | L | H | H | L | L | H | H | L | L | H | H | L | L | H | H | L | L | H | H |
| G | L | H | L | L | L | H | L | L | L | H | L | L | L | H | L | L | L | H | L | L |
| H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H |
| J | L | H | H | L | L | H | H | L | L | H | H | L | L | H | H | L | L | H | H | L |
| K | L | H | H | H | L | H | H | H | L | H | H | H | L | H | H | H | L | H | H | H |
| L | H | L | L | L | H | L | L | L | H | L | L | L | H | L | L | L | H | L | L | L |
| M | H | L | L | H | H | L | L | H | H | L | L | H | H | L | L | H | H | L | L | H |
| N | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L |
| P | H | L | H | H | H | L | H | H | H | L | H | H | H | L | H | H | H | L | H | H |
| Q | H | H | L | L | H | H | L | L | H | H | L | L | H | H | L | L | H | H | L | L |
| R | H | H | L | H | H | H | L | H | H | H | L | H | H | H | L | H | H | H | L | H |
| S | H | H | H | L | H | H | H | L | H | H | H | L | H | H | H | L | H | H | H | L |
| T | H | H | H | H | H | H | H | H | H | H | H | H | H | H | H | H | H | H | H | H |

[z] H = High infection type, L = low infection type.

may reflect heterozygosity. Although the nomenclature system of Long and Kolmer (6) does not differentiate between the two situations, it is important to maintain the information, especially for any host-pathogen studies. Therefore, in the avirulence/virulence formulae described in Table 4, *Lr* genes with intermediate phenotypes (or partial avirulence in the pathogen) are given in parentheses.

Linked avirulence, partial avirulence, or virulence on genes *Lr2a*, *Lr2b*, and *Lr2c* were similar to that described by Dyck and Samborski (2), except for pathotype NBJ/GL, which appeared to be partially avirulent for *Lr2a* and virulent for *Lr2b* and *Lr2c*.

Gene *Lr13* has been described to confer only adult plant resistance (3,6,9) but at certain temperature regimes could also confer low seedling reactions to certain pathotypes (4,7). In the present study, *Lr13* conferred low seedling reactions with four pathotypes at the prevailing temperatures (18–24 C).

Certain pathotypes (KBB/JP and TBB/JP, KBB/JM and KBB/JP, TBB/JM and TBB/JP, MBD/SM and MCD/SM, MDB/JM and MDB/JP, and TCB/TB and TCB/TD) differed only for virulence or avirulence for one gene, hence, it could be postulated that the more virulent pathotype of the pair arose by simple mutation from avirulence to virulence.

Only 19 of the 23 pathotypes could be differentiated with the nomenclature system of Long and Kolmer (6). The description of the pathotypes was also felt to be inadequate on other *Lr* genes that have played an important role in Mexican commercial cultivars (R. P Singh, *unpublished*). By including eight supplementary *Lr* gene lines as two additional Mexican sets (Table 3), the description of variation was more complete.

A total of 12 pathotypes were identified in the artificially inoculated areas (Table 5), and 16 pathotypes constituted the natural population (Table 6). The most frequently occurring pathotypes were TCB/TD (found in nine of the 10 states) and TBD/TM (seven of 10) (Table 6). All collections made from the natural infections in the state of Sonora (the Pacific region) were one of these two pathotypes (Table 6). The same two pathotypes also predominated in the collections made from bread wheats in artificially inoculated nurseries. An outbreak of leaf rust epidemic occurred on wheat cultivar Jupateco 73 during 1976–1977 (1). Pathotype TBD/TM possesses virulences for the resistance genes present in Jupateco 73 (R. P. Singh, *unpublished*). Pathotype TCB/TD possesses virulences for the known resistance genes present in four cultivars derived from the Veery cross (Genaro 81, Glennson 81, Ures 81, and Seri 82). These cultivars once occupied a majority of the wheat area in Mexico but now occupy only certain areas of central plateau. This could explain why this pathotype predominated in a number of states.

Seven pathotypes (BBJ/BL, LBJ/BL, LCJ/BN, MBD/SM, MCD/SM, FBD/QL, and TCB/TB) were identified only in collections made from artificially inoculated nurseries at Sonora and Mexico state (Table 5). The inoculum used represents a historical collection from the area. The maximum number of pathotypes (15 of the 16) in natural populations were identified from the collections obtained from the eastern lowlands (states of Veracruz, Coahuila, and San Luis Potosi) (Table 6). These pathotypes appeared to be more similar to those described in the United States by Long and Kolmer (6). This result indicates that this area is epidemiologically distinct from the other two areas with highest variability. Furthermore, it is possible that rust moves freely to and from Texas to the eastern lowlands of Mexico because of the absence of any geographical barrier. Only four pathotypes constituted the identified variation in the highland plateau (states of Mexico, Morelos, Celaya, Tlaxcala, Jalisco, and Michoacan).

Other interesting features were the predominance of pathotypes BBB/BN and MBB/JM in the collections obtained from durum wheats (*Triticum durum* Desf.) and triticales (× *Triticosecale* Wittmack), respectively (Table 5). Pathotype NBJ/GL was also identified from naturally infected triticale in the state of Michoacan (Table 6). Huerta-Espino and

**Table 4.** Avirulence/virulence formulae on *Lr* genes, based on seedling reactions, for 23 pathotypes of *Puccinia recondita* f. sp. *tritici* identified in Mexico during 1988–1989

| Number | Pathotype | Avirulence/virulence formulae[y] |
|---|---|---|
| 1 | BBB/BN | *1,2a,2b,2c,(3)[z], 3bg,11,13,14a,15,16,17,18,24,(26),27+31/10,23,28* |
| 2 | BBJ/BL | *1,(2a),(2b),(2c),3,3bg,13,15,16,18,(23),24,26,27+31/10,11,14a,17,28* |
| 3 | LBJ/BL | *(2a),(2b),(2c),3,3bg,13,15,16,18,(23),24,26,27+31/1,10,11,14a,17,28* |
| 4 | LCJ/BN | *(2a),(2b),(2c),3,3bg,13,15,16,18,24,27+31/1,10,11,14a,17,23,26,28* |
| 5 | CBJ/QL | *1,2a,2b,2c,15,16,18,23,24,26,27+31,28/3,3bg,10,11,13,14a,17* |
| 6 | KBB/JM | *1,(3bg),11,16,17,18,(23),24,26/2a,2b,2c,3,10,13,14a,15,27+31,28* |
| 7 | KBB/JP | *1,(3bg),11,16,17,18,24,26/2a,2b,2c,3,10,13,14a,15,23,27+31,28* |
| 8 | TBB/JM | *(3bg),11,16,17,18,(23),24,26/1,2a,2b,2c,3,10,13,14a,15,23,27+31,28* |
| 9 | TBB/JP | *(3bg),11,16,17,18,24,26/1,2a,2b,2c,3,10,13,14a,15,23,27+31,28* |
| 10 | TDB/JP | *(3bg),11,16,17,18,26/1,2a,2b,2c,3,10,13,14a,15,23,24,27+31,28* |
| 11 | NBJ/GL | *2a,3,3bg,(15),16,18,23,24,(26),27+31/1,2b,2c,10,11,13,14a,17,28* |
| 12 | MBB/JM | *2a,2b,2c,(3bg),11,16,17,18,(23),24,26/1,3,10,13,14a,15,27+31,28* |
| 13 | MBD/SM | *2a,2b,2c,11,16,18,(23),24,(26)/1,3,3bg,10,13,14a,15,17,27+31,28* |
| 14 | MCD/SM | *2a,2b,2c,11,16,18,(23),24/1,3,3bg,10,13,14a,15,17,26,27+31,28* |
| 15 | FBD/QL | *1,(2a),(2b),(2c),11,15,16,18,23,24,26,27+31/3,3bg,10,13,14a,17,28* |
| 16 | MGB/SM | *2a,2b,2c,11,17,18,(23),24,26/1,3,3bg,10,13,14a,15,16,27+31,28* |
| 17 | MDB/JM | *2a,2b,2c,(3bg),11,16,17,18,(23),26/1,3,10,13,14a,15,24,27+31,28* |
| 18 | MDB/JP#1 | *2a,2b,2c,(3bg),11,16,17,18,26/1,3,10,13,14a,15,23,24,27+31,28* |
| 19 | MDB/JP#2 | *2a,2b,2c,(3bg),11,16,17,18,(26)/1,3,10,13,14a,15,23,24,27+31,28* |
| 20 | MFB/SP | *2a,2b,2c,11,16,17,18/1,3,3bg,10,13,14a,15,23,24,26,27+31,28* |
| 21 | TBD/TM | *11,16,(23),24,26/1,2a,2b,2c,3,3bg,10,13,14a,15,17,18,27+31,28* |
| 22 | TCB/TB | *10,11,16,17,(23),24,27+31/1,2a,2b,2c,3,3bg,13,14a,15,18,26,28* |
| 23 | TCB/TD | *10,11,16,17,24,27+31/1,2a,2b,2c,3,3bg,13,14a,15,18,23,26,28* |

[y] All pathotypes were avirulent in seedling for genes *Lr3ka, 9, 19, 21, 25, 29, 30, 32,* and *33* and were virulent for genes *Lr12, 14b, 20, 22a,* and *22b.*

[z] Genes in parentheses indicate partial avirulence.

**Table 5.** Distribution of *Puccinia recondita* f. sp. *tritici* pathotypes in inoculated areas of the states of Sonora and Mexico during 1988–1989

| | Sonora | | | Mexico State | | | | |
|---|---|---|---|---|---|---|---|---|
| Pathotype | BW[x] | DW[y] | Tcl[z] | BW | DW | Tcl | Total | Percentage |
| BBB/BN | 1 | 69 | | | 14 | | 84 | 25.1 |
| BBJ/BL | 1 | 2 | | | | | 3 | 0.9 |
| LBJ/BL | 1 | 5 | 12 | | | | 18 | 5.4 |
| LCJ/BN | 3 | | | | | | 3 | 0.9 |
| CBJ/QL | | | | 3 | | | 3 | 0.9 |
| MBB/JM | 1 | | 28 | | | 16 | 45 | 13.4 |
| MBD/SM | 6 | | | | | | 6 | 1.8 |
| MCD/SM | 7 | | | 3 | | | 10 | 3.0 |
| FBD/QL | 2 | | | | | | 2 | 0.6 |
| TBD/TM | 66 | 6 | 3 | 12 | | | 87 | 26.0 |
| TCB/TB | 4 | | | 2 | | 1 | 7 | 2.1 |
| TCB/TD | 38 | 3 | 5 | 18 | | 3 | 67 | 20.0 |
| Total | 130 | 85 | 48 | 38 | 14 | 20 | 335 | |

[x] Bread wheat.

[y] Durum wheat.

[z] Triticale.

**Table 6.** Distribution of *Puccinia recondita* f. sp. *tritici* pathotypes in naturally infected areas of Mexico during 1988–1989

| Pathotype | Location[z] | | | | | | | | | | Total | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| BBB/BN | | | | | | | | | | 6 | 6 | 1.7 |
| CBJ/QL | | | | | 7 | | | | | 2 | 9 | 2.5 |
| KBB/JM | | | | | | | | | 1 | | 1 | 0.3 |
| KBB/JP | | | | | | | | | 8 | 2 | 10 | 2.8 |
| TBB/JM | | | | | | | | | 1 | | 1 | 0.3 |
| TBB/JP | | | | | | | | | 25 | 3 | 28 | 7.9 |
| TDB/JP | | | | | | | | | 1 | | 1 | 0.3 |
| NBJ/GL | | | | | | | 2 | | | | 2 | 0.6 |
| MBB/JM | | | | | | | | | 1 | 1 | 2 | 0.6 |
| MGB/SM | | | | | | | | | 3 | | 3 | 0.9 |
| MDB/JM | | | | | | | | | 6 | | 6 | 1.7 |
| MDB/JP#1 | | | | | | | | | 3 | | 3 | 0.9 |
| MDB/JP#2 | | | | | | | | | 1 | | 1 | 0.3 |
| MFB/SP | | | | | | | | 5 | | | 5 | 1.4 |
| TBD/TM | 48 | | | | 3 | 1 | | 4 | 4 | 1 | 61 | 17.2 |
| TCB/TD | 70 | 3 | 4 | 13 | 32 | 51 | | 36 | 5 | 2 | 216 | 60.8 |
| Total | 118 | 3 | 4 | 13 | 42 | 52 | 2 | 45 | 59 | 17 | 355 | |

[z] 1 = Sonora, 2 = Mexico, 3 = Morelos, 4 = Celaya, 5 = Tlaxcala, 6 = Jalisco, 7 = Michoacan (collection from triticale), 8 = Veracruz, 9 = Coahuila, and 10 = San Luis Potosi.

**Table 7.** Frequency and avirulence/virulence formulae on *Sr* genes, based on seedling reactions, for six pathotypes of *Puccinia graminis* f. sp. *tritici* identified in Mexico during 1988–1989

| Pathotype | Isolates (no.) | Percentage | Avirulence/virulence formulae[y] |
|---|---|---|---|
| GFC | 35 | 18.5 | *5,6,7a,7b,8b,9b,10,11,14,36,(Dp2)[z], H/8a,9a,9d,17,21* |
| MCC | 22 | 11.6 | *6,8a,9a,9b,9d,11,(14),21,36,Dp2/5,7a,7b,8b,10,17,H* |
| QFC | 41 | 21.7 | *6,7a,7b,9b,10,11,14,(36),(Dp2),H/5,8a,8b,9a,9d,17,21* |
| RKQ | 27 | 14.3 | *7a,10,11,(14),17,Dp2,H/5,6,7b,8a,8b,9a,9d,21,36* |
| RTQ | 51 | 27.0 | *7a,10,(14),17,Dp2,H/5,6,7b,8a,8b,9a,9b,9d,11,21,36* |
| RTR | 13 | 6.9 | *7a,10,14,Dp2,H/5,6,7b,8a,8b,9a,9b,9d,11,17,21,36* |
| Total | 189 | | |

[y] All pathotypes were avirulent in seedling for genes *Sr9e, 12, 13, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 35, Gt, Wld, W3560,* and *Ag1* and were virulent for genes *Sr9f, 9g, 15, 28, 34,* and *Pl.*

[z] Genes in parentheses indicate partial avirulence.

Roelfs (5) have recently shown that the pathotypes occurring on durum wheats were very different from those obtained from bread wheats in different parts of the world. Studies with pathotypes BBB/BN and MBB/JM and NBJ/GL in Mexico have indicated that they possess virulences for some unidentified genes present in durum wheat and triticale germ plasm, respectively (R. P. Singh, *unpublished*).

***P. g. tritici.*** One hundred and eighty-nine single uredia isolates were obtained from 95 collections made from the inoculated nurseries planted at Ciudad Obregon, Sonora, during the 1987–1988 and 1988–1989 crop cycles. Natural infections were not observed at any of the locations planted with the trap nursery. A total of six pathotypes were identified (Table 7). The low infection types displayed by the resistance genes are given in Table 2. Genes *Sr14*, *Sr36*, and *SrDp2* displayed two distinct low infection types. All pathotypes were avirulent on 19 of the 42 resistance genes included in the study (Table 6). Most of these genes are of alien origin. All pathotypes were virulent on plants with genes *Sr9f*, *Sr9g*, *Sr15*, *Sr28*, *Sr34*, and *SrPl.*

Because stem rust has been under control in Mexico for more than 30 yr because of the use of resistant cultivars, the pathotypes identified in this study are perhaps the same as those prevalent 30 yr ago.


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