Physiologic Specialization of *Puccinia triticina* in Canada in 1998

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ABSTRACT

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In 1998, leaf rust of wheat (*Triticum aestivum*), caused by *Puccinia triticina*, was widespread throughout the prairies of western Canada. Warm summer temperatures with frequent dew periods favored spread of the disease in wheat fields in Manitoba and Saskatchewan. The Canada Prairie Spring wheat cultivars (AC Vista, AC Foremost, AC Crystal) were susceptible to leaf rust, while the bread wheat cultivars with leaf rust resistance genes *Lr16* and *Lr13* or *Lr34* (AC Majestic, AC Domain, AC Barrie) had high to moderate levels of leaf rust infections. Bread wheat cultivars AC Cora, AC Minto, Pasqua, and McKenzie had trace to low levels of leaf rust infection. Thirty-four virulence phenotypes of *P. triticina* were identified on 16 Thatcher lines, which are near-isogenic for leaf rust resistance genes. Phenotypes with virulence to *Lr16* increased to 25% of isolates in Manitoba and Saskatchewan in 1998. Forty-three isolates were also tested for virulence to plants with the adult plant resistance genes *Lr12, Lr13, Lr34,* and *Lr13,34*. Most isolates had virulence to *Lr12* and *Lr13*. All isolates had lower infection type on adult plants with *Lr34* compared with Thatcher.

Additional keywords: specific resistance, specific virulence, wheat leaf rust

Wheat leaf rust, caused by the fungus *Puccinia triticina* Eriks., occurs annually throughout the wheat (*Triticum aestivum* L.) growing regions of Canada. Leaf rust can cause yield losses of 5 to 25%, depending on the crop developmental stage when the initial infections occur and the relative resistance of the wheat cultivars. The use of leaf rust resistant wheat cultivars in North America has led to changes in the prevalent virulence phenotypes of the wheat leaf rust fungus (6). Winter wheats grown in the southern Great Plains of the United States can have a selective effect on the *P. triticina* populations that are present in the Canadian prairies of Manitoba and Saskatchewan, since leaf rust urediniospores are carried northward every year from infections that overwinter. The Great Plains region of the United States, and the Canadian prairies, can be thought of as a single epidemiological unit since the same leaf rust virulence phenotypes are usually found throughout the region (3,6,8). However, regional populations of *P. triticina* can also be found in North America. The predominant virulence phenotypes of *P. triticina* found in Ontario and Quebec are distinct from those found in Manitoba and Saskatchewan (6). Similarly, the predominant virulence phenotypes found in the southeastern United States where soft red winter wheats are grown differ from those in the hard red wheat area of the Great Plains (10; J. A. Kolmer, *unpublished data*). Regional populations may arise due to differences in the *P. triticina* virulence phenotypes that are introduced to the regions, overwintering of leaf rust infections within regions and spread of urediniospores between regions, and mutation and selection of virulence phenotypes by specific resistance genes on a regional basis.

Annual surveys of cereal rust virulence phenotypes are conducted in order to detect virulence phenotypes that pose a threat to the currently grown wheat cultivars. In recent years, the frequency of *P. triticina* virulence phenotypes with virulence to resistance gene *Lr16* have increased in Manitoba and Saskatchewan (4,5). Phenotypes with virulence to this gene are particularly important since many spring wheats grown in Manitoba and Saskatchewan have *Lr16*. Leaf rust severities have increased on spring wheats in the Canadian prairies since the resistance conditioned by *Lr16* has been eroded by the increase of isolates with virulence to this gene. Similarly, leaf rust phenotypes with virulence to *Lr13*, which is also present in many Canadian and U.S. spring wheats, has increased to the point where this gene no longer conditions a high level of resistance (4,5). Surveys of virulence phenotypes in cereal rusts can provide information on the effectiveness of currently used resistance genes and on the potential effectiveness of genes that have not yet been widely deployed in commonly grown cultivars.

Surveys of virulence phenotypes are also used to detect virulence phenotypes that may have been introduced to a region. *P. triticina* isolates with virulence to *Lr17, LrB,* and *Lr3bg* have become common since 1996 in Manitoba and Saskatchewan (4,5). These isolates also have very distinct molecular backgrounds as distinguished by the amplified fragment length polymorphism (AFLP) technique (7). It is unlikely that these virulence phenotypes arose by mutation and selection from the previous common isolates since they are distinct for both virulence and molecular phenotypes. The *P. triticina* virulence survey in Canada has been conducted annually since 1931 (1,2) in order to provide information describing the population biology of *P. triticina* and to assist in the development of wheat cultivars with high levels of leaf rust resistance.

MATERIALS AND METHODS

Collections of leaf rust were obtained in 1998, as in previous years, from British Columbia, Alberta, Saskatchewan, Manitoba, and Ontario. Leaf rust collections were obtained from farm fields and uniform wheat nurseries. The collections were increased on seedlings of the wheat cultivar Little Club that had been treated with maleic hydrazide to prevent emergence of secondary leaves and to increase the size of uredinia. One week after inoculation, the leaves were trimmed so that only one uredinium remained on each plant. Spores from single uredinia were collected with a cyclone spore collector into a size 00 gelatin capsule when secondary rings had formed. Dustrol (Novartis Canada Ltd., Winnipeg) light industrial oil (330 µl) was added to each capsule, and the spore suspensions were atomized onto 1-week-old seedling differential sets composed of 16 near-isogenic lines of Thatcher wheat, each with a different gene for resistance. The 12 Thatcher differentials in the letter code nomenclature designed to describe virulence phenotypes of *P. triticina* (9) were used along with isogenic lines with *LrB, Lr10, Lr14a,* and *Lr18*. After the oil was allowed to evaporate (approximately 1 h), the seedling flats were placed in a 100% humidity chamber for 16 h. All plants were then maintained in a greenhouse between

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18 and 25°C with supplemental fluorescent lighting. Two to three single uredinial isolates from each collection were evaluated for virulence phenotype. Infection types on the differential sets were read 12 days after inoculation. Each single-uredinial isolate was assigned a three-letter virulence phenotype description based on high or low infection type to the differentials and supplemental lines according to the established virulence phenotype nomenclature (9). A four-letter code described low and high infection type to the 16 Thatcher differentials.

Isolates of *P. triticina* based on their virulence phenotypes as determined in the seedling tests were tested for virulence to adult plants of Thatcher lines with the adult plant genes *Lr12*, *Lr13*, and *Lr34*, and a line with *Lr13* and *Lr34*. Five plants (one each of Thatcher lines with *Lr12*, *Lr13*, *Lr34*, and *Lr13,34* and Thatcher) were grown together to maturity in 15-cm-diameter fiber pots in a greenhouse at 18 to 25°C with supplemental fluorescent lighting. Plants were trimmed such that two tillers remained on each plant. The flag

Table 1. Number of isolates of *Puccinia triticina* virulent on 16 lines of Thatcher wheat-near isogenic for leaf rust resistance genes in Canada in 1998

	Ontario		Manitoba/ Saskatchewan		Alberta		British Columbia		Total	
Resistance gene	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Lr1	12	100.0	180	99.4	35	100	40	100.0	267	99.6
Lr2a	0	0.00	45	24.9	6	17.1	0	0.00	51	19.0
Lr2c	9	75.0	45	24.9	7	20.0	13	32.5	74	27.6
Lr3	12	100.0	180	99.4	34	97.1	27	67.5	253	94.4
Lr9	0	0	0	0	0	0	0	0	0	0
Lr16	2	16.7	44	24.3	0	0	0	0	46	17.2
Lr24	0	0	22	12.2	9	25.7	6	15.0	37	13.8
Lr26	0	0	35	19.3	10	28.6	4	10.0	49	18.3
Lr3ka	7	58.3	31	17.1	5	14.3	1	2.5	44	16.4
Lr11	0	0	27	14.9	15	42.9	11	27.5	53	19.8
Lr17	4	33.3	107	59.1	5	14.3	1	2.5	117	43.7
Lr30	0	0	31	17.1	2	5.7	1	2.5	34	12.7
LrB	11	91.7	107	59.1	7	20.0	17	42.5	142	53.0
Lr10	12	100.0	179	98.9	35	100.0	40	100.0	266	99.3
Lr14a	4	33.3	181	100.0	34	97.1	27	67.5	246	91.8
Lr18	2	16.7	1	0.6	1	2.9	13	32.5	17	6.3
Total	12		181		35		40		268	

Table 2. Virulence phenotypes of *Puccinia triticina* identified on 16 lines of Thatcher wheat near-isogenic for leaf rust resistance genes in 1998 in Canada

Virulence phenotype	**Virulence combination (ineffective genes)**	**Ontario**		**Man. Sask.[a]**		**Alberta**		**British Columbia**		**Total**	
		No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
BBBD	*14a*	0	0	1	0.6	0	0	0	0	1	0.4
MBBJ	*1, 3, 10, 14a*	0	0	0	0	2	5.7	3	7.5	5	1.9
MBBS	*1, 3, B, 10, 14a*	0	0	0	0	0	0	3	7.5	3	1.1
MBDS	*1, 3, 17, B, 10, 14a*	1	8.3	86	47.5	3	8.6	0	0	90	33.6
MBGJ	*1, 3, 11, 10, 14a*	0	0	0	0	10	28.6	10	25.0	20	7.5
MBQJ	*1, 3, 3ka, 11, 10, 14a*	0	0	0	0	3	8.6	0	0	3	1.1
MBRD	*1, 3, 3ka, 11, 30, 14a*	0	0	1	0.6	0	0	0	0	1	0.4
MBRJ	*1, 3, 3ka, 11, 30, 10, 14a*	0	0	13	7.2	0	0	1	2.5	14	5.2
MCBJ	*1, 3, 26, 10, 14a*	0	0	0	0	4	11.4	3	7.5	7	2.6
MCBS	*1, 3, 26, B, 10, 14a*	0	0	0	0	1	2.9	0	0	1	0.4
MCDS	*1, 3, 26, 17, B, 10, 14a*	0	0	13	7.2	2	5.7	1	2.5	16	6.0
MDBJ	*1, 3, 24, 10, 14a*	0	0	0	0	2	5.7	6	15.0	8	3.0
MDRJ	*1, 3, 24, 3ka, 11, 30, 10, 14a*	0	0	12	6.6	1	2.9	0	0	13	4.9
MFMJ	*1, 3, 24, 26, 3ka, 30, 10, 14a*	0	0	2	1.1	0	0	0	0	2	0.7
MGDS	*1, 3, 16, 17, B, 10, 14a*	2	16.7	7	3.9	0	0	0	0	9	3.4
MHDS	*1, 3, 16, 26, 17, B, 10, 14a*	0	0	1	0.6	0	0	0	0	1	0.4
NBBR	*1, 2c, 3, B, 10, 18*	0	0	0	0	1	2.9	13	32.5	14	5.2
PBBQ	*1, 2c, 3, B, 10*	1	8.3	0	0	0	0	0	0	1	0.4
PBDT	*1, 2c, 3, 17, B, 10, 14a, 18*	1	8.3	0	0	0	0	0	0	1	0.4
PBLG	*1, 2c, 3, 3ka, 10*	1	8.3	0	0	0	0	0	0	1	0.4
PBLQ	*1, 2c, 3, 3ka, B, 10*	5	41.7	0	0	0	0	0	0	5	1.9
PBLR	*1, 2c, 3, 3ka, B, 10, 18*	1	8.3	0	0	0	0	0	0	1	0.4
TBBJ	*1, 2a, 2c, 3, 10, 14a*	0	0	2	1.1	0	0	0	0	2	0.7
TBMJ	*1, 2a, 2c, 3, 3ka, 30, 10, 14a*	0	0	1	0.6	0	0	0	0	1	0.4
TCMJ	*1, 2a, 2c, 3, 26, 3ka, 30, 10, 14a*	0	0	1	0.6	0	0	0	0	1	0.4
TDBJ	*1, 2a, 2c, 3, 24, 10, 14a*	0	0	2	1.1	2	5.7	0	0	4	1.5
TDGJ	*1, 2a, 2c, 3, 24, 11, 10, 14a*	0	0	1	0.6	1	2.9	0	0	2	0.7
TFBJ	*1, 2a, 2c, 3, 24, 26, 10, 14a*	0	0	2	1.1	2	5.7	0	0	4	1.5
TFMJ	*1, 2a, 2c, 3, 24, 26, 3ka, 30, 10, 14a*	0	0	0	0	1	2.9	0	0	1	0.4
TGBJ	*1, 2a, 2c, 3, 16, 10, 14a*	0	0	17	9.4	0	0	0	0	17	6.3
TGBK	*1, 2a, 2c, 3, 16, 10, 14a, 18*	0	0	1	0.6	0	0	0	0	1	0.4
THBJ	*1, 2a, 2c, 3, 16, 26, 10, 14a*	0	0	15	8.3	0	0	0	0	15	5.6
TJBJ	*1, 2a, 2c, 3, 16, 24, 10, 14a*	0	0	2	1.1	0	0	0	0	2	0.7
TKMJ	*1, 2a, 2c, 3, 16, 24, 26, 3ka, 30, 10, 14a*	0	0	1	0.6	0	0	0	0	1	0.4
Total		12		181		35		40		268	

[a] Manitoba and Saskatchewan.

leaves of each pot of five plants were inoculated at anthesis with a single isolate by atomizing 2 to 3 mg of urediniospores mixed with oil (330 µl). Incubation and growth conditions were the same as for the seedling tests. Infection types were read on the two flag leaves of each plant in the same manner as the seedling infection types 14 days after inoculation.

RESULTS AND DISCUSSION

Occurrence and severity. In 1998, wheat leaf rust infections were widespread in Manitoba and eastern Saskatchewan. Warm weather in the spring and early summer facilitated the spread and rapid increase of leaf rust throughout western Canada. The incidence and severity levels of leaf rust in 1998 were similar to those in 1997 (5), which was also a year with widespread leaf rust. Plots of susceptible wheats and the Canada Prairie Spring (CPS) cultivars AC Foremost, AC Vista, and AC Crystal suffered severe leaf rust infections in Manitoba and eastern Saskatchewan. Based on severity levels, yield losses due to leaf rust in CPS wheats would have ranged from 5 to 20%. Only trace levels of leaf rust infection were found on the bread wheat cultivars AC Cora (*Lr13, Lr21*), AC Minto (*Lr11, Lr13, Lr22a*), and McKenzie (*Lr21*, plus adult plant resistance). These cultivars would not have suffered losses due to leaf rust. Moderate amounts of leaf rust were found on the cultivars AC Majestic (*Lr13, Lr16*), AC Domain (*Lr10, Lr12, Lr34*), and AC Barrie (*Lr13, Lr16*). Other cultivars such as Roblin (*Lr1, Lr10, Lr13, Lr34*), Glenlea (*Lr1, Lr34*), AC Karma (*Lr16, Lr34*), and AC Taber (*Lr13, LrTb*) also had moderate levels of leaf rust.

Physiologic specialization. *Seedling tests.* Two hundred sixty-eight single uredinial isolates were evaluated for virulence phenotype in Canada in 1998. Thirty-four virulence phenotypes were identified on the 16 Thatcher near-isogenic differential lines (Table 1). In collections from Ontario, 100% of isolates had virulence to *Lr1, Lr3,* and *Lr10* (Table 1), while none of the isolates had virulence to *Lr2a, Lr9, Lr24, Lr11,* and *Lr30*. Virulence frequencies to the other resistance genes ranged from 16.7 to 91.7%. Seven virulence phenotypes were identified in Ontario from 12 isolates (Table 2). Virulence phenotype PBLQ was the most common at 41.7% of isolates. This has been the most common phenotype in Ontario since 1987 (6).

In Manitoba and Saskatchewan, 100% of the isolates had virulence to *Lr14a,* and virulence to *Lr9* was at 0% (Table 1). Virulence to *Lr1, Lr3,* and *Lr10* was at 99% of isolates, while virulence to *Lr18* was at 0.6%. Virulence to the other resistance genes ranged from 12.2 to 59%. Virulence to *Lr16* increased from 5.9% in 1996 to 16.3% in 1997 to 24.3% in 1998. Leaf rust severities on cultivars with *Lr16* will increase if isolates with virulence to *Lr16* continue to increase in frequency. Twenty virulence phenotypes were identified from 181 isolates collected from Manitoba and Saskatchewan in 1998 (Table 2). MBDS, which has virulence to *Lr17,* was the most common virulence phenotype at 47.5%, followed by TGBJ at 9.4% and MBRJ and MCDS at 7.2% (Table 2). MBDS was also the most common phenotype in Manitoba in 1997 (5), and MBRJ and TGBJ were also common phenotypes in the previous year. MBDS phenotypes were found to have distinct AFLP phenotypes compared with other isolates from Manitoba and Saskatchewan (7).

In Alberta, virulences to *Lr1* and *Lr10* were at 100% of isolates, and virulences to *Lr9* and *Lr16* were at 0% of isolates (Table 1). Virulence to the other resistance genes ranged from 2.9 to 97.1%. Fourteen virulence phenotypes were identified from the 35 isolates from Alberta in 1998 (Table 2). MBGJ was the most common virulence phenotype at 28.6%, followed by MCBJ at 11.4%. In British Columbia, virulences to *Lr1* and *Lr10* were at 100% of isolates, while virulences to *Lr2a, Lr9,* and *Lr16* were at 0% of isolates (Table 1). Virulence to the other resistance genes ranged from 2.5 to 67.5% of isolates. There were eight virulence phenotypes among the 40 isolates from British Columbia in 1998. NBBR was the most common virulence phenotype at 32.5%, followed by MBGJ at 25% and MDBJ at 15% (Table 2). Phenotypes MBGJ and NBBR were also common isolates from Alberta in 1997.

Adult plant tests. Forty-three isolates were tested for virulence to adult plants with resistance genes *Lr12, Lr13, Lr34, Lr13,34,* and the recurrent parent Thatcher.

Table 3. Infection types[a] on adult plants of isogenic Thatcher lines with resistance genes *Lr12, Lr13, Lr34,* and *Lr13,34,* and Thatcher of representative *Puccinia triticina* isolates collected from Canada in 1998

Isolate	Tc*Lr12*	Tc*Lr13*	Tc*Lr34*	Tc*Lr13,34*	Thatcher
BBBD 25-1[b]	11$^-$	;11$^+$	22$^+$3	;2	4
MBBJ 156-1	3$^+$4	;11$^+$	22$^+$3	;1$^-$2	4
MBBJ 155-1	3$^+$4	11$^+$	22$^+$3	;2	4
MBBS 171-3	3$^+$4	1$^+$2	2$^+$3	;1$^-$	4
MBBS 171-2	3$^+$4	;1	2$^+$3	;12	4
MBDS 145-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
MBDS 92-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
MBDS 26-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
MBDS 18-1	3$^+$4	3$^+$4	22$^+$3	22$^+$	4
MBGJ 158-1	11$^+$	3$^+$4	22$^+$3	22$^+$3	4
MBQJ 161-1	22$^+$c	3$^+$4	22$^+$3	22$^+$3	4
MBRD 116-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
MBRJ 91-2	11$^+$	3$^+$4	22$^+$3	22$^+$	4
MBRJ 71-1	1$^+$	3$^+$4	22$^+$3	22$^+$3	4
MBRJ 5-1	11$^+$	3$^+$4	22$^+$3	22$^+$3	4
MCBJ 170-3	3$^+$c4	11$^+$	22$^+$3	;12	4
MCBJ 154-1	3$^+$4	11$^+$	22$^+$3	;12	4
MCDS 87-2	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
MCDS 32-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
MCDS 87-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
MDRJ 2-1	3$^+$4	12$^+$3	22$^+$3	;2	4
MDRJ 34-1	3$^+$4	3$^+$4	22$^+$3	22$^+$	4
MDRJ 14-1	3$^+$4	3$^+$4	22$^+$3	;22$^+$	4
MFMJ 3-1	3$^+$4	3$^+$4	22$^+$3	22$^+$	4
MGDS 86-2	3$^+$4	3$^+$4	22$^+$3	22$^+$	4
MHDS 163-3	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
NBBR 163-1	;11$^-$	;11$^-$	22$^+$3	;1$^-$	4
NBBR 173-3	;11$^-$	;11$^-$	22$^+$3	;1$^-$	4
TBBJ 114-2	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
TCMJ 65-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
TDBJ 33-2	3$^+$4	2$^+$c	22$^+$3	;2	4
TFBJ 81-1	3$^+$4	11$^+$	22$^+$3	;12	4
TFMJ 165-1	3$^+$4	22$^+$	22$^+$3	;22$^+$	4
TGBJ 110-2	3$^+$4	3$^+$4	22$^+$3	22$^+$	4
TGBJ 26-2	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
TGBJ 116-3	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
TGBJ 6-2	3$^+$4	3$^+$4	22$^+$	22$^+$	4
THBJ 23-2	3$^+$4	3$^+$4	22$^+$3	22$^+$	4
THBJ 82-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
THBJ 90-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
THBJ 119-1	3$^+$4	3$^+$4	22$^+$3	22$^+$3	4
TJBJ 5-2	3$^+$4	3$^+$4	22$^+$3	;1$^+$2	4
TKMJ 130-2	3$^+$4	;11$^+$	22$^+$3	22$^+$3	4

[a] Infection type scale: 0 = no necrosis or uredinia, ; = small hypersensitive flecks, 1 = small uredinia surrounded by necrosis, 2 = moderate-size uredinia surrounded by chlorosis, 3 = moderate-size uredinia without chlorosis, 4 = large uredinia without chlorosis, + = larger uredinia than expected for the infection type, – = smaller uredinia than expected for the infection type.

[b] Single pustule isolate number.

All isolates had high infection type (IT) on Thatcher (Table 3). Eight isolates had low IT of 11^{-} to $22c^{+}$ to the Thatcher line with *Lr12*, while 14 were avirulent to *Lr13*. All other isolates had high IT of $3^{+}4$ on lines with *Lr12* and *Lr13*. All isolates had IT of $22^{+}3$ with fewer pustules on the Thatcher line with *Lr34* compared with Thatcher. Isolates that had low IT to *Lr13* also had lower IT on the line with *Lr13,34* compared with the line with only *Lr34*. Isolate TKMJ 130-2 was an exception, however, as it had IT $;11^{+}$ on *Lr13* and IT $22^{+}3$ on *Lr34*. TJBJ 5-2 had low IT of $;12^{+}$ on Tc*Lr13,34* but had high IT of $3^{+}4$ on *Lr13* and IT of $22^{+}3$ on *Lr34*.

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