Letter Code System of Nomenclature for *Puccinia graminis* f. sp. *avenae*

T. G. Fetch, Jr., Cereal Research Centre, Agriculture and Agri-Food Canada, Winnipeg, MB R3T 2M9, Canada; and **Y. Jin,** Cereal Disease Laboratory, United States Department of Agriculture–Agricultural Research Service, University of Minnesota, St. Paul 55108

ABSTRACT

Fetch, T. G., Jr., and Jin, Y. 2007. Letter code system of nomenclature for *Puccinia graminis* f. sp. *avenae*. Plant Dis. 91:763-766.

Current systems that describe the virulence phenotype in *Puccinia graminis* f. sp. *avenae* lack a systematic approach for the naming of races or to provide easily made comparisons of virulence among races. A new nomenclature system that simply and systematically characterizes virulence in *P. graminis* f. sp. *avenae* is described. The new system has the distinct advantage of providing easily seen relationships among races in contrast to previous nomenclature systems. This allows for easier interpretation of virulence relationships in the oat stem rust population and provides a large amount of virulence information with a minimum of written characters. This system uses single-gene differential lines with the resistance genes *Pg1*, *Pg2*, *Pg3*, *Pg4*, *Pg6*, *Pg8*, *Pg9*, *Pg10*, *Pg12*, *Pg13*, *Pg15*, and *Pg16*, grouped into three subsets of four lines in sequential *Pg* gene order. By grouping in sequential gene number order, the relationship of the new system to the "standard" system is easily seen. Each race is designated by a three-letter code, based on the seedling reaction (low or high) on 12 differential lines. The letter code nomenclature system is open ended and can be updated easily as new differential genes are identified. This system simply and precisely describes the virulence phenotypes of isolates of *P. graminis* f. sp. *avenae*, and allows for easily made comparisons of virulence of isolates collected over time and across geographical locations worldwide.

Several nomenclature systems to describe virulence in *Puccinia graminis* f. sp. *avenae* Erikss. & Henning have been developed; however, currently, there is no adequate system that simply describes the virulence phenotypes of isolates of *P. graminis* f. sp. *avenae* or provides easily made comparisons of virulence of isolates from different geographical areas. Physiologic specialization in *P. graminis* f. sp. *avenae* first was described by Stakman et al. in 1923 using the varieties Victory, White Tartar, and Monarch to describe four races of oat stem rust (20). In 1925, Bailey described five races of *P. graminis* f. sp. *avenae*, using White Tartar (=White Russian), Richland, and Jostrain (3). Levine and Smith added races 6 to 10 in 1937, and Newton and Johnson added races 11 to 13 in 1944, using the same three differential varieties (11,16). These first 13 races were used as the standard for describing physiologic specialization in *P. graminis* f. sp. *avenae*.

Subsequent to the description of the 13 "standard" races, additional genes conferring resistance to *P. graminis* f. sp. *avenae* were found and are described in Table 1. Genes originally were designated by using a letter (e.g., gene *A*) but currently are designated by number (e.g., *Pg2*) using a standardized gene nomenclature system (19). Deviations from standard races were described as subraces, adding letters to standard race numbers to identify additional races. In 1965, Green (7) devised a virulence formula nomenclature system for Canada (C-races) using genes from the differential varieties Richland, Rodney, Minrus, Jostrain, CI 4023, and CI 5844-1. In 1970, Stewart and Roberts published the first proposed international system for identifying races of *P. graminis* f. sp. *avenae*, using the same six differential varieties as Green (7) and the diploid oat line Saia to describe the "standard" races, numerous subraces, C-races, and exotic races from several countries, with a total of 97 races identified (21).

The development of backcross-derived lines (Rodney 0 background) with a single gene (*Pg* gene) for oat stem rust resistance led to the development of the North American (NA) nomenclature system in 1979 (14), which currently is used to characterize virulence in *P. graminis* f. sp. *avenae* in Canada and the United States. In contrast, virulence in *P. graminis* f. sp. *avenae* in Australia currently is characterized using a modified Stewart and Roberts system (2). Because there is a lack of continuity across the various nomenclature systems and there appears to be no systematic approach in the naming of races (other than by order of discovery), we describe a new nomenclature similar to existing cereal rust nomenclature systems (4,12,17) that simply and precisely identifies the virulence phenotype (race) of isolates of *P. graminis* f. sp. *avenae*. This system will provide a method to easily and accurately compare virulence of isolates collected over time and across geographical areas.

THE LETTER CODE RACE NOMENCLATURE SYSTEM

Currently, there are 17 numbered *Pg* genes identified, plus the *Pg-a* complex. Genes *Pg5* and *Pg7* are repetitive of genes *Pg4* and *Pg6*, respectively, and are of no use as differential lines (13). Genes *Pg11* and *Pg17* are expressed only at the adult plant stage and would not be useful as differential lines at the seedling stage (10,15). Gene *Pg14* is ineffective to numerous North American and exotic isolates tested thus far (T. Fetch, *unpublished data*) and is not noted for its resistance (13); thus, it is not included in the differential set. All other numbered genes are useful in characterizing virulence and are included in the differential sets.

The differential lines for the new nomenclature system are listed in Table 2. Most (*Pg1*, *Pg2*, *Pg3*, *Pg8*, *Pg9*, *Pg13*, *Pg15*, and *Pg16*) are in a Rodney 0 (CI 9317, no known *Pg* resistance gene) background as described by Martens et al. (14). Comparisons of infection type (IT) between original sources of resistance to their Rodney 0-derived lines were made with several races using previously reported methods (5), and the results are presented in Table 3. IT of infected seedlings was determined using a 0-to-4 scale, where ITs of 0, ;, 1, and 2, or combinations thereof, are classified as low ITs and indicative of resistance, whereas ITs of 3 or

Corresponding author: T. G. Fetch, Jr.
Email: tfetch@agr.gc.ca

This is contribution no. 1943 of the Cereal Research Centre.

Accepted for publication 6 January 2007.

doi:10.1094/PDIS-91-6-0763
Department of Agriculture and Agri-Food, Government of Canada © Minister of Public Works and Government Services Canada 2007

4 are high ITs and indicative of susceptibility (3). Because expression of several *Pg* genes is affected by incubation temperature (6,14), all comparisons were conducted in a growth chamber at 19ºC with a 16-h photoperiod and light intensity of 180 to 220 µmol photon m^2 s^{-1}. Under these incubation conditions, all genes will express their low ITs to avirulent races of *P. graminis* f. sp. *avenae*, which is easily discernable from a susceptible (IT 34 or 4) reaction. For a given *Pg* gene, the observed ITs between the original source and the corresponding Rodney line were comparable (Table 3). However, it was found that several *Pg* gene sources and their Rodney 0 derivatives acquired from the Unites States Department of Agriculture–Agricultural Research Service (USDA-ARS) National Small Grains Collection (NSGC) in Aberdeen, ID were mixed for ITs. Therefore, differential lines in the Rodney 0 background were reselected for the correct phenotype and increased for seed that is available for race identification of *P. graminis* f. sp. *avenae*.

The letter code nomenclature utilizes 12 single-gene *Pg* differential lines, using three subsets of four lines organized into a hexadecimal system that has 16 possible combinations of low (L) or high (H) reaction for each letter (Table 4). This is adapted from the existing nomenclature systems used for other cereal rusts (4,12,17). The advantage of the letter code system is a simple, short, and accurate description of virulence phenotype across most of the described resistance genes, which enables utilization of this system regardless of when and where isolates have been collected. In contrast, comparisons of virulence of isolates identified using the "standard", C number, and NA formula system were difficult and imprecise (8), due to the lack of a systematic approach in numbering of races and to addition of differential lines that occurred over time. Because the order of genes in the new system is sequential, it is relatively easy to make comparisons to the "standard" system originally described (e.g., race 1 = B_ or C_ races, race 2 = D_ races, race 6 group = TG_ or TD_ races, race 7 group = N_ or P_ races, race 8 = J_ races, and race 11 group = G_ or H_ races). Additionally, virulence of isolates collected worldwide cannot currently be compared, because differential sets are not uniform and different nomenclature systems are utilized. The letter code system is flexible in that, as new *Pg* genes are characterized, they can be added as additional subsets and letters appended accordingly. Data on supplemental lines can be added to the letter code using a plus (+) sign (e.g., race TGL+ *Pg-a*). In addition, the letter code system is suitable for international use because it incorporates almost all *Pg* genes to characterize virulence in *P. graminis* f. sp. *avenae*. Virulence information previously reported in North America is presented in Table 5 using the new letter code, NA number designation (14), and avirulence or virulence formula systems. Each NA race reported previously corresponded to a unique letter-code race designation following this system.

The new system uses three seedling *Pg* genes (*Pg6*, *Pg10*, and *Pg12*) that have not been used previously to characterize *P. graminis* f. sp. *avenae*. Gene *Pg6* (from CI 6956) and the resistance gene in the diploid line Saia (which is used in the Stewart and Roberts nomenclature) appear to be identical (18). Although *Pg6* has not yet been transferred into a hexaploid background, it has been shown to be useful in differentiating isolates of stem rust at the Winnipeg Rust laboratory. In testing of 23 common North American races stored at

Table 2. Differential lines used for characterizing virulence in *Puccinia graminis* f. sp. *avenae*[a]

Pg gene	CI no.	CN no.	RL no.	IT at 20ºC[b]	Source of resistance
Pg1	9318	58243	899	11^+	White Russian, CI 551
Pg2	9319	58244	815	;1	Hajira, CI 1001
Pg3	2660	58245	…	;1 to X^-	Jostrain, CI 2660
Pg4	6661	56534	2123	$;1^-$	Hajira, CI 1001
Pg6	6956	56818	…	$0;1^-$	CD 3820, CI 6956
Pg8	9321	58246	903	12^-	Hajira, CI 8111
Pg9	9322	58247	879	11^+	CI 6792
Pg10	8457	58055	…	23n	Illinois Hulless, CI 2824
Pg12	8250	64102	…	;1	Kyto, CI 8250
Pg13	9212	28959	618	11^+	*Avena sterilis*, PI 324798
Pg15	9351	58276	997	11^+	*A. sterilis*, CAV 1830
Pg16	9352	58277	882	12^-	*A. barbata*, D203
Pg-a	…	1947	996	$0;1^-$	Omega, CI 9139

[a] CI is the Cereal Introduction number (United States Department of Agriculture–Agricultural Research Service, Aberdeen, ID), CN is the Canadian Number (Plant Genetic Resources Collection, Saskatoon, SK, Canada), and RL is the Rust Lab accession number (Cereal Rust Lab, Winnipeg, MB, Canada).

[b] Infection types (ITs) are based on a 0-to-4 scale (3).

Table 1. Background information for resistance genes to *Puccinia graminis* f. sp. *avenae*

Pg gene	Letter[a]	Year	Origin	Source	*Avena* sp.	CI number	Temperature[b]
1	D	1925	Russia	White Russian	*sativa*	551	None
1	D	1938	Russia	Minrus	*sativa*	2144	None
2	A	1925	Russia	Richland	*sativa*	787	None
3	E	1925	USA	Sevnothree	*sativa*	3251	21ºC
3	E	1925	France	Jostrain	*sativa*	2660	21ºC
4	B	1954	South Africa	Hajira	*sativa*	1001	26ºC
5	C	1954	South Africa	Hajira	*sativa*	4019	…
6	…	1956	Uruguay	CD 3820	*strigosa*	6956	None
7	…	1956	Uruguay	CD 3820	*strigosa*	6956	…
8	F	1959	North Africa	Hajira	*sativa*	8111	27ºC
9	H	1965	Argentina	Sante Fe selection	*sativa*	5844-1	25ºC
10	G	1965	USA	Illinois Hulless	*nuda*	2824	None
11	…	1968	Rhodesia	Burt	*sativa*	3034	Adult[c]
12	…	1968	Yugoslavia	Kyto	*sativa*	8250	25ºC
13	M	1970	Tunisia	CW490-2	*sterilis*	PI 324798	27ºC
14	N	1972	Wales	Milford	*sativa*	5039	…
15	…	1980	Turkey	CAV 1830	*sterilis*	9351	26ºC
16	R	1979	Israel	D-203	*barbata*	9125	25ºC
17	…	1990	Spain	IB 3056	*sterilis*	…	Adult
Pg-a	X	1981	USA	Omega	hybrid	9139	26ºC

[a] Genes originally were designated by letter, then changed later to a *Pg* gene number (17).

[b] Incubation of lines at or above this temperature renders ineffective the expression of resistance (6). For genes *Pg1, Pg2, Pg6*, and *Pg10,* there is no effect of incubation temperature up to 30ºC.

[c] CI 3034 also has been reported to possess the seedling gene *Pg1* (11).

the Winnipeg Rust Laboratory, only NA1 and NA70 have been found to be virulent on *Pg6* (T. Fetch and Zegeye, *unpublished data*); thus, most North American races were presumed to be avirulent to *Pg6* in Table 5. In contrast, virulence to Saia (= *Pg6*) is observed frequently in isolates of *P. graminis* f. sp. *avenae* in Australia (2).

Gene *Pg10* (from CI 2824) has not been used in previous nomenclature systems due to temperature sensitivity (14). Studies at Winnipeg indicate that the reaction of *Pg10* is intermediate (IT = 23N) at low (15 to 21ºC) temperatures, but becomes more resistant (12+N) at elevated (>24ºC) temperatures (6). Although *Pg10* exhibits an intermediate resistance reaction (IT = 23n), the distinct necrosis associated with its resistance response is unique to this gene (9) and is easily discernable from a susceptible (IT = 3 or 4) reaction. Virulence to *Pg10* has not been observed in North America among several thousand isolates tested at Winnipeg and St. Paul rust laboratories, but virulence to *Pg10* has been found from an isolate obtained from New Zealand (T. Fetch, *unpublished data*).

Gene *Pg12* has not been used previously in nomenclature systems, but the related *Pg-a* complex was used by Martens et al. (14) in the NA nomenclature. Gene *Pg12* is included in the new differential set in lieu of the *Pg-a* complex because (i) it is a single gene, (ii) no differential response (high versus low) between *Pg12* and *Pg-a* has been found among several thousand isolates tested simultaneously on the two lines, and (iii) allelism tests of F_2 progeny from crosses between the *Pg12* source 'Kyto' (CI 8250) and *Pg-a* source 'Omega' (CI 9139) found no susceptible segregants among 4495 F_2 plants (T. Fetch, *unpublished data*). Thus, the low seedling IT observed on the *Pg-a* complex apparently is conditioned by the gene *Pg12* and may be modified by an additional unknown recessive gene. This is in contrast to previously published data that reported that *Pg12* is not involved in the *Pg-a* response (1). The *Pg-a* complex was included in Table 2 as a supplementary line because of historical use, but is not intended as a differential line in this nomenclature system.

The letter code nomenclature system presented here is simple, precise, and describes the virulence spectrum of races of *P. graminis* f. sp. *avenae* on most known seedling resistance genes in oat. This system will be useful in enabling rust workers to uniformly characterize *P. graminis* f. sp. *avenae* isolates for discussion on virulence dynamics and population studies. Limited seed for all differential lines is available from the authors, and also from seed depositories in Plant Gene Resources Canada (PGRC, Saskatoon, SK) and USDA-ARS NSGC in Aberdeen, ID.

Table 4. Letter code designations for races of *Puccinia graminis* f. sp. *avenae* using 12 differential single *Pg*-gene lines in three ordered subsets of four lines each

	Subset	**Classification of infection types (ITs)[a]**			
	1	***Pg1***	***Pg2***	***Pg3***	***Pg4***
	2	***Pg6***	***Pg8***	***Pg9***	***Pg10***
Letter code	**3**	***Pg12***	***Pg13***	***Pg15***	***Pg16***
B	…	L	L	L	L
C	…	L	L	L	H
D	…	L	L	H	L
F	…	L	L	H	H
G	…	L	H	L	L
H	…	L	H	L	H
J	…	L	H	H	L
K	…	L	H	H	H
L	…	H	L	L	L
M	…	H	L	L	H
N	…	H	L	H	L
P	…	H	L	H	H
Q	…	H	H	L	L
R	…	H	H	L	H
S	…	H	H	H	L
T	…	H	H	H	H

[a] Classification of infection types: L = low/resistant (ITs of 0, ;, 1, and 2, or combination thereof) and H = high/susceptible (ITs of 3, 4, or combination thereof) (17).

Table 3. Infection type (IT) comparison of oat lines with original sources of *Pg* gene resistance and equivalent Rodney 0-derived lines to races of *Puccinia graminis* f. sp. *avenae*

			IT at 20ºC[a]				
Pg gene	**CI no.[b]**	**Genetic background**	**NA1**	**NA8**	**NA16**	**NA20**	**NA55**
Pg1	551	White Russian	$2^{\pm}$	12^{-}	$3^{+}4$	$3^{+}4$	34n
	9318	Rodney 0	12^{-}	$1^{\pm}$	$3^{+}4$	4	3^{+}n
Pg2	787	Richland	;1	;1^{-}	;1	4	34n
	9319	Rodney 0	;1	;1	;1	4	34n
Pg3	2660	Jostrain	X^{-}	$X^{=}$	4	0;	$X^{=}$
	9320	Rodney 0	X^{-}	X^{-}	4	0;	$X^{=}$
Pg4	1001	Hajira	;1	33^{+}	;1	4	34n
	6661	Rodney	;1^{-}	33^{+}	;1	4	34n
Pg8	8111	Hajira	;1	;1^{+}	34	11^{+}	;1
	9321	Rodney 0	1^{-}	$1^{\pm}$	$3^{+}4$	12^{-}	;1
Pg9	5844-1	Sante Fe select	11^{+}	4	;1	4	34n
	9322	Rodney 0	12	4	;1^{+}	4	$3^{+}4$
Pg10	2824	Illinois Hulless	$3^{\pm}$N	23^{+}N	24N	23^{+}N	13^{-}N
	8457	X-1588	13N	12^{+}N	23N	12^{+}N	22^{+}n
Pg13	2647	*A. sterilis*	;1	34	;1	;1	;1
	9212	Rodney 0	;1^{-}	34	;1^{-}	;1	;1
Pg15	1830	*A. sterilis*	34	34	;1	34	34
	9351	Rodney 0	34	34	;1	34	23^{+}
Pg16	D203	*A. barbata*	1^{-}	;1^{-}	1^{-}	;1^{-}	34
	9352	Rodney 0	11^{-}	;1	11^{-}	;1	34

[a] ITs are based on a 0-to-4 scale where ITs of 0, ;, 1, and 2 are indicative of a resistant (low) response and ITs of 3 or 4 of a susceptible (high) response (3). Symbols + and – indicate slightly larger and smaller pustule sizes, respectively. North American (NA) races use the nomenclature of Martens et al. (14).

[b] CI is the Cereal Introduction number (United States Department of Agriculture–Agricultural Research Service, Aberdeen, ID).

Table 5. Key to races of *Puccinia graminis* f. sp. *avenae* using the letter code nomenclature, North American (NA) nomenclature, and avirulence/virulence formula system[a]

Code	Race	Eff/ineff *Pg* genes	Code	Race	Eff/ineff *Pg* genes	Code	Race	Eff/ineff *Pg* genes
BDB	NA38	1,2,3,4,8,13,15,16,a/9	KBD	NA11	1,8,9,13,16,a/2,3,4,15	RBD	NA19	3,8,9,13,16,a/1,2,4,15
BDD	NA2	1,2,3,4,8,13,16,a/9,15	KDD	NA12	1,8,13,16,a/2,3,4,9,15	RDD	NA20	3,8,13,16,a/1,2,4,9,15
BDJ	NA3	1,2,3,4,8,16,a/9,13,15	KDJ	NA32	1,8,16,a/2,3,4,9,13,15	RDF	NA58	3,8,13,a/1,2,4,9,15,16
BLD	NA1	1,2,3,4,8,9,13,16,a/15	KJD	NA13	1,13,16,a/2,3,4,8,9,15	RDJ	NA54	3,8,16,a/1,2,4,9,13,15
CDJ	NA4	1,2,3,8,16,a/4,9,13,15	LDD	NA65	2,3,4,8,13,16,a/1,9,15	RGB	NA21	3,9,13,15,16,a/1,2,4,8
CLD	NA70	1,2,3,8,9,13,16,a/4,15	LGB	NA14	2,3,4,9,13,15,16,a/1,8	RGD	NA77	3,9,13,16,a/1,2,4,8,15
DBB	NA39	1,2,4,8,9,13,15,16,a/3	MDD	NA71	2,3,8,13,16,a/1,4,9,15	RJB	NA51	3,13,15,16,a/1,2,4,8,9
DBD	NA5	1,2,4,8,9,13,16,a/3,15	MGB	NA44	2,3,9,13,15,16,a/1,4,8	RJD	NA72	3,13,16,a/1,2,4,8,9,15
DDD	NA6	1,2,4,8,13,16,a/3,9,15	NBB	NA15	2,4,8,9,13,15,16,a/1,3	RJJ	NA75	3,16,a/1,2,4,8,9,13,15
DDJ	NA7	1,2,4,8,16,a/3,9,13,15	NDB	NA45	2,4,8,13,15,16,a/1,3,9	SBD	NA22	4,8,9,13,16,a/1,2,3,15
DJD	NA53	1,2,4,13,16,a/3,8,9,15	NDD	NA35	2,4,8,13,16,a/1,3,9,15	SDD	NA61	4,8,13,16,a/1,2,3,9,15
FBD	NA56	1,2,8,9,13,16,a/3,4,15	NDJ	NA47	2,4,8,16,a/1,3,9,13,15	SGB	NA23	4,9,13,15,16,a/1,2,3,8
FDD	NA74	1,2,8,13,16,a/3,4,9,15	NDL	NA46	2,4,8,13,15,16/1,3,9,a	SGD	NA63	4,9,13,16,a/1,2,3,8,15
FDJ	NA8	1,2,8,16,a/3,4,9,13,15	NGB	NA16	2,4,9,13,15,16,a/1,3,8	TBD	NA24	8,9,13,16,a/1,2,3,4,15
GBD	NA59	1,3,4,8,9,13,16,a/2,15	NGD	NA18	2,4,9,13,16,a/1,3,8,15	TDB	NA52	8,13,15,16,a/1,2,3,4,9
GDD	NA64	1,3,4,8,13,16,a/2,9,15	NGL	NA17	2,4,9,13,15,16/1,3,8,a	TDD	NA25	8,13,16,a/1,2,3,4,9,15
GDJ	NA34	1,3,4,8,16,a/2,9,13,15	NJB	NA48	2,4,13,15,16,a/1,3,8,9	TDF	NA55	8,13,a/1,2,3,4,9,15,16
HBD	NA69	1,3,8,9,13,16,a/2,4,15	PBD	NA57	2,8,9,13,16,a/1,3,4,15	TDJ	NA26	8,16,a/1,2,3,4,9,13,15
HDB	NA40	1,3,8,13,15,16,a/2,4,9	PBG	NA66	2,8,9,15,16,a/1,3,4,13	TGB	NA27	9,13,15,16,a/1,2,3,4,8
HDD	NA9	1,3,8,13,16,a/2,4,9,15	PDB	NA49	2,8,13,15,16,a/1,3,4,9	TGD	NA29	9,13,16,a/1,2,3,4,8,15
HDJ	NA31	1,3,8,16,a/2,4,9,13,15	PDD	NA36	2,8,13,16,a/1,3,4,9,15	TGL	NA28	9,13,15,16/1,2,3,4,8,a
JBD	NA10	1,4,8,9,13,16,a/2,3,15	PDJ	NA37	2,8,16,a/1,3,4,9,13,15	TJB	NA68	13,15,16,a/1,2,3,4,8,9
JDB	NA41	1,4,8,13,15,16,a/2,3,9	QBB	NA73	3,4,8,9,13,15,16,a/1,2	TJD	NA30	13,16,a/1,2,3,4,8,9,15
JDD	NA33	1,4,8,13,16,a/2,3,9,15	QBD	NA60	3,4,8,9,13,16,a/1,2,15	TJG	NA76	15,16,a/1,2,3,4,8,9,13
JDJ	NA42	1,4,8,16,a/2,3,9,13,15	QDD	NA62	3,4,8,13,16,a/1,2,9,15	TJJ	NA67	16,a/1,2,3,4,8,9,13,15
KBB	NA43	1,8,9,13,15,16,a/2,3,4	QGB	NA50	3,4,9,13,15,16,a/1,2,8			

[a] Code = letter code, Race = NA race, and Eff/ineff = effective/ineffective. The letter code system infers that reaction to *Pg12* is identical to *Pg-a*, all NA races are avirulent to *Pg10*, and only races NA1 and NA70 are virulent to *Pg6*.

ACKNOWLEDGMENTS

We thank K. Dunsmore, C. Leclerc, T. Zegeye, and L. Wanschura for their technical assistance.

LITERATURE CITED

1. Adhikari, K. N., McIntosh, R. A., and Oates, J. D. 1999. Inheritance of the stem rust resistance phenotype *Pg-a* in oats. Euphytica 105:143-154.
2. Adhikari, K. N., McIntosh, R. A., and Oates, J. D. 2000. Distribution and temperature sensitivities of genes for stem rust resistance in Australian oat cultivars and selected germplasm. Aust. J. Agric. Res. 51:75-83.
3. Bailey, D. L. 1925. Physiologic specialization in *Puccinia graminis avenae* Erikss. and Henn. Minn. Agric. Exp. Stn. Bull. 35.
4. Chong, J., Leonard, K. J., and Salmeron, J. J. 2000. A North American system of nomenclature for *Puccinia coronata* f. sp. *avenae*. Plant Dis. 84:580-585.
5. Fetch, T. G., Jr. 2003. Physiologic specialization of *Puccinia graminis* on wheat, barley, and oat in Canada in 2000. Can. J. Plant Pathol. 25:174-181.
6. Fetch, T. G., Jr. 2006. Effect of temperature on expression of seedling resistance in oats to *Puccinia graminis* f. sp. *avenae*. Can. J. Plant Pathol. 28:558-565.
7. Green, G. J. 1965. Stem rust of oats in Canada in 1964. Can. Plant Dis. Surv. 45:19-22.
8. Harder, D. E. 1994. Virulence dynamics of *Puccinia graminis* f. sp. *avenae* in Canada, 1921–1993. Phytopathology 84:739-746.
9. Harder, D. E. 1999. Usefulness of gene *Pg10* as a source of stem rust resistance in oat breeding. Phytopathology 89:1214-1217.
10. Harder, D. E., Chong, J., Brown, P. D., and Martens, J. W. 1990. Inheritance of resistance to *Puccinia coronata avenae* and *P. graminis avenae* in an accession of *Avena sterilis* from Spain. Genome 33:198-202.
11. Levine, M. N., and Smith, D. C. 1937. Comparative reaction of oat varieties in the seedling and maturing stages to physiologic races of *Puccinia graminis avenae* and the distribution of these races in the United States. J. Agric. Res. 55:713-729.
12. Long, D. L., and Kolmer, J. A. 1989. A North American system of nomenclature for *Puccinia recondita* f. sp. *tritici*. Phytopathology 79:525-529.
13. Martens, J. W. 1985. Stem rust of oats. Pages 103-129 in: The Cereal Rusts: Volume II: Diseases, Distribution, Epidemiology, and Control. A. P. Roelfs and W. R. Bushnell, eds. Academic Press, New York.
14. Martens, J. W., Roelfs, A. P., McKenzie, R. I. H., Rothman, P. G., Stuthman, D. D., and Brown, P. D. 1979. System of nomenclature for pathotypes of *Puccinia graminis* f. sp. *avenae*. Phytopathology 69:293-294.
15. McKenzie, R. I. H., and Martens, J. W. 1968. Inheritance in the oat strain C.I. 3034 of adult plant resistance to race C10 of stem rust. Crop Sci. 60:625-627.
16. Newton, M., and Johnson, T. 1944. Physiologic specialization of oat stem rust in Canada. Can. J. Res. 22:201-216.
17. Roelfs, A. P., and Martens, J. W. 1988. An international system of nomenclature for *Puccinia graminis* f. sp. *tritici*. Phytopathology 78:526-533.
18. Sadanaga, K., and Simons, M. D. 1960. Transfer of crown rust resistance of diploid and tetraploid species to hexaploid oats. Agron. J. 52:285-288.
19. Simons, M. D., Martens, J. W., McKenzie, R. I. H., Nishiyama, I., Sadanaga, K., Sebesta, J., and Thomas, H. 1978. Oats: a standardized system of nomenclature for genes and chromosomes and catalog of genes governing characters. U. S. Dep. Agric. Handb. 509, Washington, DC.
20. Stakman, E. C., Levine, M. N., and Bailey, D. L. 1923. Biologic forms of *Puccinia graminis* on varieties of *Avena* spp. J. Agric. Res. 24:1013-1018.
21. Stewart, D. M., and Roberts, B. J. 1970. Identifying races of *Puccinia graminis* f. sp. *avenae*. A modified international system. U. S. Dep. Agric. Tech. Bull. 1416.