

System of Nomenclature for Races of *Puccinia graminis* f. sp. *avenae*

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ABSTRACT

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A formula system for describing *Puccinia graminis* f. sp. *avenae* avirulence/virulence combinations on *Avena sativa* based on nine single-gene backcross differential lines (including two new genes for resistance)

and one undefined genotype is proposed for international use. Thirty different avirulence/virulence combinations have been identified in *P. graminis* f. sp. *avenae* in North America with this group of differential lines.

Additional key words: *Avena barbata*, *Avena sterilis*, oat stem rust, oats.

Simple and precise description of the virulence of isolates of physiologically specialized pathogens has always been a problem. As data relating to a host-parasite system accumulate, and as new differentials are discovered and used, the descriptions become increasingly complex and more difficult to interpret, especially for scientists not working with the particular system.

Since the first four races of *Puccinia graminis* f. sp. *avenae* were described (11), the nomenclature of isolates has undergone several minor and one major revision (12) and has shifted to systems based on the hypothesis of host-parasite gene-for-gene interactions (5,8). The system proposed here, suggested for international use, is new only in that it presents a formally standardized system with some newly discovered differential hosts. The concept, with some variations, has been used previously for a number of cereal rusts by many workers (2,4,5,6,8,9). Advances in the knowledge of the genetics of resistance in oats have made the system possible.

THE PROPOSED SYSTEM

The differential lines for the proposed system are given in Table 1. Except for the Pg a line, they are backcross-derived lines in the Rodney O (C.I. No. 9317, R.L. NO. 805) oat background, and those up to Pg-13 have been described (10). Gene Pg-15 was obtained from *Avena sterilis* Canada Avena (CAV) No. 1830, collected 40 km east of Uskudar, Turkey (1). The Pg-16 line is a 44-chromosome disomic addition line with resistance from the tetraploid *A. barbata* line No. D203 (3) backcrossed four times to the oat cv. Rodney O. The differential line designated Pg a is a selection from C.I. 9139 with what appears to be Pg-12 and probably one or two unknown genes or modifiers from *A. sterilis*. Genetic studies on lines having Pg-15 and Pg-16 and a line with the Pg a complex are in progress.

A number of described genes for resistance (10) have been excluded from the differential set because they are (i) the same as included ones (Pg-5), (ii) in a diploid background (Pg-6, -7), (iii) too temperature sensitive (Pg-10), (iv) effective only in the adult plant stage (Pg-11), or (v) effective primarily in the seedling stage (Pg-12) or (vi) because not enough is known about their reaction to

North American races (Pg-14).

The effect of temperature on the expression of resistance for genes Pg-1, -2, -3, -4, -8, and -9 has been described (7). Resistance conferred by genes Pg-13 and Pg-15 is expressed at temperatures up to 20–25 C (*unpublished*). Resistance conferred by gene Pg-16 is expressed to all known races at temperatures up to 20–22 C, but the resistance is not fully expressed at temperatures above this level (*unpublished*). The line with the Pg a complex is highly resistant to most North American cultures of *P. graminis* f. sp. *avenae*, but a gradient of virulence that ranges from a mesothetic to a completely susceptible reaction has been discovered. This reaction appears to be somewhat temperature sensitive, although temperature breakdown has not been demonstrated (authors, *unpublished*).

The proposed method of nomenclature describes the virulence of any culture in terms of a simple formula (Table 2). The formula consists of numbers corresponding to those assigned the specific genes for resistance in the differential lines. Numbers designating the genes that condition resistance to the culture are written first, followed by a slash line, and then the numbers designating the resistance genes that are ineffective (6). Numbers on both sides of the slash line are separated by commas except when the reaction to only a combination of genes within a line is known (eg, if Pg a is subsequently shown to be Pg-12 plus an additional gene) or when genes in combination result in a reaction different from that expected of the sum of the components (eg, an isolate is virulent on the components of a line but not the combination). Then, numbers designating all the genes in the line are listed and connected by hyphens (eg, 12-b,13,16/1,2,3,4,8,9,15 and 8,9-12,16/1,2,3,4,8,9,13,15). The method has the advantage that no complicated keys are required, the formulas are self-explanatory, differential lines can be added or dropped at will, and new avirulence/virulence combinations are easily described by writing new formulas.

Infection types 0 to 2+ are considered to indicate a resistant host response; infection types 3 and 4 are considered to indicate a susceptible host response (12). The designation of the mesothetic reaction becomes a matter of judgment. If what is expressed is potentially effective resistance (in terms of disease control), then the reaction is considered avirulent; if not, it is considered virulent. Unknown genotypes may be included temporarily by designation with lowercase roman letters (eg, Pg a). For North America, new numbers will be assigned by the Minnesota laboratory. Of course, anyone may add local or new differential

TABLE 1. Differential lines comprising the basis for avirulence/virulence combination identification of *Puccinia graminis* f. sp. *avenae*

Resistance gene	C.I. no.	R.L. no.	Typical resistance reaction type at 20 C	Source of resistance
<i>Pg-1</i>	9318	899	2	cv. White Russian, USSR
<i>Pg-2</i>	9319	815	1	cv. Hajira, Algeria
<i>Pg-3</i>	9320	902	1,X ⁻	cv. Joannette, France
<i>Pg-4</i>	6661	2123	1	cv. Hajira, Algeria
<i>Pg-8</i>	9321	903	2	cv. Hajira, Algeria
<i>Pg-9</i>	9322	879	2	C.I. 6792, USA
<i>Pg-13</i>	9212	618	2 ⁻	<i>Avena sterilis</i> CAV 2647, Tunisia
<i>Pg-15</i>	9351	997	1 ⁺	<i>A. sterilis</i> CAV 1830, Turkey
<i>Pg-16</i>	9352	822	1 ⁺	<i>A. barbata</i> D203, Israel
<i>Pg a</i>	...	...	0:1 ⁼	C.I. 9139, USA

TABLE 2. Avirulence/virulence combinations of *Puccinia graminis* f. sp. *avenae* identified in North America

North American nos.	Avirulence/virulence formula (Pg genes)
NA 1	1,2,3,4,8,9,13,16,a/15
NA 2	1,2,3,4,8,13,16,a/9,15
NA 3	1,2,3,4,8,16,a/9,13,15
NA 4	1,2,3,8,16,a/4,9,13,15
NA 5	1,2,4,8,9,13,16,a/3,15
NA 6	1,2,4,8,13,16,a/3,9,15
NA 7	1,2,4,8,16,a/3,9,13,15
NA 8	1,2,8,16,a/3,4,9,13,15
NA 9	1,3,8,13,16,a/2,4,9,15
NA 10	1,4,8,9,13,16,a/2,3,15
NA 11	1,8,9,13,16,a/2,3,4,15
NA 12	1,8,13,16,a/2,3,4,9,15
NA 13	1,13,16,a/2,3,4,8,9,15
NA 14	2,3,4,9,13,15,16,a/1,8
NA 15	2,4,8,9,13,15,16,a/1,3
NA 16	2,4,9,13,15,16,a/1,3,8
NA 17	2,4,9,13,15,16/1,3,8,a
NA 18	2,4,9,13,16,a/1,3,8,15
NA 19	3,8,9,13,16,a/1,2,4,15
NA 20	3,8,13,16,a/1,2,4,9,15
NA 21	3,9,13,15,16,a/1,2,4,8
NA 22	4,8,9,13,16,a/1,2,3,15
NA 23	4,9,13,15,16,a/1,2,3,8
NA 24	8,9,13,16,a/1,2,3,4,15
NA 25	8,13,16,a/1,2,3,4,9,15
NA 26	8,16,a/1,2,3,4,9,13,15
NA 27	9,13,15,16,a/1,2,3,4,8
NA 28	9,13,15,16/1,2,3,4,8,a
NA 29	9,13,16,a/1,2,3,4,8,15
NA 30	13,16,a/1,2,3,4,8,9,15

lines. Representative avirulence/virulence combinations will be maintained at both laboratories. Workers outside North America wishing to use the system need not follow the NA designations; they

may simply write their own formulas. All tests should be conducted at temperatures not exceeding 20 C to avoid problems with the expression of resistance.

The virulence combinations that have been found on the new differential lines in North America to date are given in Table 2.

Small quantities of seed of the differential lines may be obtained from the Minnesota or the Winnipeg laboratory. Seed will be supplied under C.I. or R.L. numbers so that all sources can be identified.

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