Occurrence and Virulence of *Puccinia recondita* in Minnesota in 1982 and 1983

D. V. McVEY, Research Plant Pathologist, and K. HAMILTON, Research Technician, Cereal Rust Laboratory, USDA-ARS, St. Paul, MN 55108

ABSTRACT

McVey, D. V., and Hamilton, K. 1985. Occurrence and virulence of *Puccinia recondita* in Minnesota in 1982 and 1983. Plant Disease 69:404-405.

Twenty-five avirulent/virulent combinations (races) of leaf rust (*Puccinia recondita*) were identified on 12 near-isogenic *Lr* differential lines from 334 isolates in 1982 and on 19 races from 144 isolates in 1983 collected in a leaf rust survey conducted in Minnesota. Lines with genes *Lr*16 and *Lr*19 were resistant to all isolates, whereas lines with *Lr*9 and *Lr*24 were resistant to most isolates.

Leaf rust of wheat (*Triticum aestivum* L.), caused by *Puccinia recondita* Rob. ex Desm. f. sp. *tritici*, is a potentially dangerous disease. For many years, cultivar and germ plasm development has been accomplished by selecting resistant lines under conditions of field inoculation and natural infection without knowledge of virulence combinations present in the natural *P. recondita* population. Therefore, as a preliminary step in determining the resistances in a germ plasm development program, it is desirable to know the virulence variation in the natural pathogen population. Virulence surveys have been reported regularly from Canada (4,5), periodically from North Dakota (6–8), and more recently from across the United States (3). Results of surveys made in Minnesota during the past 2 yr are reported in this paper.

MATERIALS AND METHODS

The 1982 collections were obtained from cultivars in demonstration plots, disease screening nurseries, and certified production fields—primarily of the cultivars Marshall and Era—along a route westward from St. Paul to Morris, MN, and across the southern part of Minnesota. The 1983 collections, made from the same area as in 1982, were also obtained from a route down the Red River Valley as far as Stephens, MN. Each collection was used to inoculate 7-day-old wheat seedlings of Thatcher wheat (CI 10003) that had been treated with maleic hydrazide to enhance spore production. After 12–14 days, up to four leaves bearing or pruned to bear a single uredia were retained and incubated, permitting loose urediospores on leaves to germinate. Urediospores from single uredia were collected separately 2–4 days later from up to three uredia (each such collection becoming an isolate). The urediospores from single uredia were used to inoculate Thatcher seedlings, and the urediospores collected from this increase were used to inoculate seedlings of near-isogenic, leaf rust-resistant lines *Lr*1, *Lr*2a, *Lr*2c, *Lr*3, *Lr*3ka, *Lr*9, *Lr*10, *Lr*16, *Lr*19 (in a Thatcher background) and *Lr*24 (Agent, CI 13523) in both years. *Lr*14a and *Lr*14b were included only in 1982; *Lr*17 and *Lr*18 were included only in 1983.

Seeds were planted in the corners of 8-cm plastic pots containing vermiculite, with six pots placed in a tray, and fertilized with a water-soluble fertilizer (23-19-17, NPK) at a rate of 2.5 g per tray when the seedlings were 5 and 8 days old. At 7 days, seedlings were inoculated with a light mineral oil suspension of urediospores. The oil was allowed to evaporate from the leaves, and the inoculated plants were placed in a dew chamber at 18 C overnight. The next morning, the temperature in the chamber was allowed to rise gradually over a 4-hr period to 30 C so that the dew evaporated slowly. The seedlings were placed in a greenhouse. Fourteen days after inoculation, the plants were scored for infection type. Infection types 0, 1, 2, and X were considered low (resistant); infection types 3 and 4 were considered high (susceptible).

RESULTS AND DISCUSSION

A total of 334 and 144 isolates was obtained from single-uredial isolations in 1982 and 1983, respectively, yielding 25 and 19 avirulent/virulent combinations (races) on 12 lines used as differential hosts (Tables 1 and 2). The percentage of

Table 1. Effective/ineffective formulas, number of isolates, and percentage of each (of *Puccinia recondita*) on near-isogenic lines for resistance to leaf rust identified from Minnesota field collections in 1982[z]

Effective (avirulent)/ineffective (virulent)	Isolates	
	No.	Percent
1,9,16,19,24/2a,2c,3,3ka,10,14a,14b	115	34.4
2a,2c,9,16,19,24/1,3,3ka,10,14a,14b	62	18.6
9,16,19,24/1,2a,2c,3,3ka,10,14a,14b	39	11.7
1,2a,2c,9,16,19,24/3,3ka,10,14a,14b	26	7.8
1,2a,16,19,24/2c,3,3ka,9,10,14a,14b	20	6.0
2a,16,19,24/1,2c,3,3ka,9,10,14a,14b	10	2.7
2a,9,16,19,24/1,2c,3,3ka,10,14a,14b	7	2.1
9,10,16,19,24/1,2a,2c,3,3ka,14a,14b	6	1.8
2a,2c,16,19,24/1,3,3ka,9,10,14a,14b	6	1.8
1,2a,9,16,19,24/2c,3,3ka,10,14a,14b	6	1.8
16,19,24/1,2a,2c,3,3ka,9,10,14a,14b	5	1.5
1,2a,2c,9,10,16,19,24/3,3ka,14a,14b	5	1.5
2a,10,16,19,24/1,2c,3,3ka,9,14a,14b	4	1.2
1,16,19,24/2a,2c,3,3ka,9,10,14a,14b	4	1.2
2a,2c,9,16,19/1,3,3ka,10,14a,14b,24	4	1.2
1,2a,10,16,19,24/2c,3,3ka,9,14a,14b	3	0.9
1,2a,2c,16,19,24/3,3ka,9,10,14a,14b	3	0.9
2a,2c,3,9,16,19,24/1,3ka,10,14a,14b	2	0.6
10,16,19,24/1,2a,2c,3,3ka,9,14a,14b	1	0.3
2a,2c,9,10,16,19/1,3,3ka,14a,14b,24	1	0.3
2a,2c,9,10,16,19,24/1,3,3ka,14a,14b	1	0.3
1,2a,9,10,16,19,24/2c,3,3ka,14a,14b	1	0.3
1,3,9,16,19,24/2a,2c,3ka,10,14a,14b	1	0.3
1,2a,2c,9,10,16,19/3,3ka,14a,14b,24	1	0.0
1,2a,2c,3,3ka,9,10,16,19,24/14a,14b	1	0.3

[z] Total combinations = 25; total isolates = 334.

Cooperative investigation, USDA-ARS and Department of Plant Pathology, University of Minnesota, St. Paul. Paper No. 14,073, Scientific Journal Series, Minnesota Agricultural Experiment Station.

Accepted for publication 23 October 1984.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

Table 2. Effective/ineffective formulas, number of isolates, and percentage of each (of *Puccinia recondita*) on near-isogenic lines for resistance to leaf rust identified from Minnesota field collections in 1983[z]

Effective (avirulent)/ineffective (virulent)	Isolates	
	No.	Percent
2a,2c,9,16,17,18,19,24/1,3,3ka,10	41	28.5
1,9,16,17,18,19,24/2a,2c,3,3ka,10	41	28.5
9,16,17,18,19,24/1,2a,2c,3,3ka,10	13	9.0
2a,2c,9,16,18,19,24/1,3,3ka,10,17	13	9.0
2a,2c,9,16,19,24/1,3,3ka,10,17,18	9	6.3
9,16,18,19,24/1,2a,2c,3,3ka,10,17	6	4.2
1,2a,9,16,18,19,24/2c,3,3ka,10,17	5	3.5
1,2a,2c,9,16,17,18,19,24/3,3ka,10	4	2.8
2a,2c,9,16,17,19,24/1,3,3ka,10,18	2	1.4
2a,9,16,17,18,19,24/1,2c,3,3ka,10	1	0.7
2a,9,16,19,24/1,2c,3,3ka,10,17,18	1	0.7
1,2a,9,16,17,18,19,24/2c,3,3ka,10	1	0.7
1,2a,10,16,17,18,19,24/2c,3,3ka,9	1	0.7
2a,3,3ka,9,16,17,18,19,24/1,2c,10	1	0.7
9,16,19,24/1,2a,2c,3,3ka,10,17,18	1	0.7
1,2a,2c,9,16,19,24/3,3ka,10,17,18	1	0.7
1,2a,2c,9,10,16,17,19,24/3,3ka,18	1	0.7
1,2a,2c,3,3ka,9,16,17,18,19,24/10	1	0.7
2a,3,9,16,17,18,19/1,2c,3ka,10,24	1	0.7

[z] Total combinations = 19; total isolates = 144.

Table 3. Number and percentage of *Puccinia recondita* isolates virulent to seedlings of near-isogenic lines for resistance to leaf rust identified in Minnesota field collections in 1982 and 1983

Near-isogenic line or cultivar[x]	1982		1983	
	No. of isolates	Percent virulent	No. of isolates	Percent virulent
*Lr*1	148	44.3	92	63.9
*Lr*2a	171	51.2	61	42.3
*Lr*2c	221	66.1	72	50.0
*Lr*3	330	97.9	141	97.9
*Lr*3ka	333	99.7	142	98.6
*Lr*9	56	16.8	1	0.7
*Lr*10	310	92.8	142	98.6
*Lr*14a[y]	334	100.0	···	···
*Lr*14b[y]	334	100.0	···	···
*Lr*16	0	0.0	0	0.0
*Lr*17[z]	···	···	36	25.0
*Lr*18[z]	···	···	15	10.4
*Lr*19	0	0.0	0	0.0
*Lr*24 (Agent)	6	1.8	1	0.7

[x] Near-isogenic lines in Thatcher background, except *Lr*24.
[y] 1982 Only.
[z] 1983 Only.

isolates virulent to each of the near-isogenic lines to *P. recondita* is presented in Table 3. All isolates were virulent to *Lr*14a and *Lr*14b in 1982. These two lines were replaced by *Lr*17 and *Lr*18 in 1983. Almost all isolates were virulent to *Lr*3, *Lr*3ka, and *Lr*10 in both years, and therefore, they also were of no value in providing protection from *P. recondita*. Virulence to *Lr*1, *Lr*2a, and *Lr*2c was relatively high in both years. Individually, they were of little value for protection against *P. recondita*. *Lr*1 and *Lr*2a are probably the most common seedling genes for resistance to *P. recondita* in the spring wheats. Virulence to *Lr*17 and *Lr*18 occurred in 25 and 10% of the isolates, respectively, in 1983. Individually, they would have provided some protection. Few isolates were found with virulence to *Lr*9 and *Lr*24; however, virulence to *Lr*9 has been common in the southern and eastern United States (3), and virulence to *Lr*24 occurs in south central United States (3). The greater number of isolates virulent to *Lr*9 in 1982 was biased, because an effort was made to collect from wheat lines known to possess *Lr*9. No virulence was found to *Lr*16 or *Lr*19 either year. *Lr*16 provides an intermediate level of protection; however, its use as a single source of resistance should be questioned. *Lr*19 provides a very high level of resistance. Knott (1,2) reported breaking the adverse linkage between *Lr*19 and yellow pigment for flour color, allowing *Lr*19 now to be useful.

When the eight lines, *Lr*1, *Lr*2a, *Lr*2c, *Lr*3, *Lr*3ka, *Lr*9, *Lr*10, and *Lr*24, were compared between years, the same four most common avirulence/virulence combinations constituted about 72 and 92% of the combinations, respectively, in 1982 and 1983. The same four avirulence/virulence combinations were also frequently found in Manitoba (4) as well as Minnesota in 1982, when these same *Lr* genes were compared, with one exception. No isolates were found virulent to *Lr*3ka in Manitoba, whereas only one avirulent isolate was found in Minnesota. *Lr*3ka produces an intermediate infection type of 2 to 2+3. The Minnesota isolates were evaluated during the summer and early fall, whereas those in Canada were evaluated during the winter. The difference in test environment and/or classification of infection type probably explains the difference.

Table 4. Percent effectiveness of selected gene combinations conditioning resistance to *Puccinia recondita*

Lr gene combination	Minnesota		Manitoba[a]
	1982	1983	1982
*Lr*1 + *Lr*2a	85.2	86.2	96.9
*Lr*1 + *Lr*9	92.2	100.0	100.0
*Lr*1 + *Lr*17	···	79.2	91.3
*Lr*1 + *Lr*18	···	91.0	96.4
*Lr*1 + *Lr*24	98.6	99.3	98.2
*Lr*2a + *Lr*9	97.3	100.0	100.0
*Lr*2a + *Lr*17	···	95.2	100.0
*Lr*2a + *Lr*18	···	99.3	98.2
*Lr*2a + *Lr*24	100.0	100.0	100.0
*Lr*9 + *Lr*17	···	100.0	100.0
*Lr*9 + *Lr*18	···	100.0	97.3
*Lr*9 + *Lr*24	100.0	100.0	100.0
*Lr*17 + *Lr*18	···	91.6	100.0
*Lr*17 + *Lr*24	···	100.0	100.0
*Lr*18 + *Lr*24	···	100.0	100.0

[a] From Samborski (5).

The effectiveness provided by gene combinations, for which virulence was found for the genes individually, is shown in Table 4 for Minnesota and Manitoba surveys. Although 100% protection is indicated by several combinations of only two genes, further pyramiding (multiple gene combinations) would probably provide longer protection. Pyramiding of resistance genes requires multiple gene mutations for virulence in the pathogen to overcome the resistance in such a cultivar. This would require larger pathogen populations for pathogenic variants to occur than for single or double virulence gene mutations.

ACKNOWLEDGMENT

This work was supported in part and page costs provided by a grant from The Minnesota Wheat Research and Promotion Council.

LITERATURE CITED

1. Knott, D. R. 1980. Mutation of a gene for yellow pigment linked to *Lr*19 in wheat. Can. J. Genet. Cytol. 22:651-654.
2. Knott, D. R. 1984. The genetic nature of mutations of a gene for yellow pigment linked to *Lr*19 in 'Agatha' wheat. Can. J. Genet. Cytol. 26:392-393.
3. Long, D. L., Schafer, J. F., and Roelfs, A. P. 1985. Specific virulence of *Puccinia recondita* f. sp. *tritici* in the United States from 1978 through 1983. Plant Dis. 69:000-000.
4. Samborski, D. J. 1982. Occurrence and virulence of *Puccinia recondita* in Canada in 1981. Can. J. Plant Dis. 3:228-230.
5. Samborski, D. J. 1983. Occurrence and virulence of *Puccinia recondita* in Canada in 1982. Can. J. Plant Dis. 5:194-196.
6. Statler, G. D., and Nolte, P. 1977. Wheat leaf rust in North Dakota in 1975 and 1976. Plant Dis. Rep. 61:591-594.
7. Statler, G. D., and Nolte, P. 1979. Wheat leaf rust in North Dakota in 1977 and 1978. Plant Dis. Rep. 63:336-340.
8. Statler, G. D., Miller, J. D., and Leben, S. 1982. Wheat leaf rust in North Dakota during 1979–1981. Plant Dis. 66:1174-1176.