Virulence of *Puccinia recondita* f. sp. *tritici* in the United States in 1987

D. L. LONG, Plant Pathologist, J. F. SCHAFER, Collaborator, and A. P. ROELFS, Research Plant Pathologist, Cereal Rust Laboratory, USDA-ARS, Department of Plant Pathology, University of Minnesota, St. Paul 55108, and J. J. ROBERTS, Research Plant Pathologist, USDA-ARS, Georgia Agricultural Experiment Station, Experiment 30212

ABSTRACT

Long, D. L., Schafer, J. F., Roelfs, A. P., and Roberts, J. J. 1989. Virulence of *Puccinia recondita* f. sp. *tritici* in the United States in 1987. Plant Disease 73:294-297.

Isolates of *Puccinia recondita* f. sp. *tritici* were obtained from wheat leaf collections made by cooperators and from field rust surveys conducted by the authors in the Great Plains, Ohio Valley, and Gulf Coast states in 1987. Testing of 947 isolates for virulence to 14 single-gene differentially resistant test lines showed 44 virulence/avirulence phenotypes, categorized into nine Unified Numeration races. An increased frequency of virulence to *Lr*1, 24, and 26 over recent years was found, and combined virulence to *Lr*16 and 26 was observed for the first time. No virulence was found to 15 of 24 additional entries in a resistant test series. Regional race distribution patterns again suggested that the central United States was a single epidemiological unit.

Additional keywords: plant disease monitoring, rust epidemiology, wheat leaf rust

Wheat leaf rust, caused by *Puccinia recondita* Rob. ex Desm. f. sp. *tritici*, occurs annually throughout most wheat-growing areas of the United States. In 1987, trace to 4% losses were reported in 35 states that produce over 96% of the wheat crop in the United States. Leaf rust was not as severe in 1987 as in the previous 2 yr. Estimated statewide wheat yield losses ranged up to 4% in Kansas, with an average of 1.8% on winter wheat in the United States (D. L. Long, *unpublished*). The objective of this study was to characterize the virulence of the *P. recondita* population in the United States in 1987 on selected wheat test stocks.

MATERIALS AND METHODS

Leaf rust uredinial collections were made from wheat over a 28,000-km route that included the Great Plains, Ohio Valley, and Gulf Coast states and by cooperators thoughout the United States. The surveys followed predetermined routes through selected areas where small grain cereals are important. Stops were made at commercial fields 32 km apart or at the first field thereafter. Additional stops were made at nurseries and trap plots along the route. Rust collections were made in at least one rusted field or nursery per county observed during 1987. Collections were also made from *Aegilops cylindrica* Host (goatgrass) growing near wheat fields in the southern Great Plains. A collection consisted of a varying number of leaves bearing uredinia from a single plant or cultivar.

Urediniospores from each collection were used to inoculate 7-day-old seedlings of wheat (*Triticum aestivum* L. 'Thatcher', CI 10003) treated at emergence with maleic hydrazide (1 g/3 L of H_2O) to enhance spore production. Plants were sprayed with spores suspended in light-weight mineral oil, then placed in a dew chamber overnight at 18 C. The plants were then placed in a greenhouse in which temperatures varied between 18 and 28 C during the diurnal cycle. After 12–15 days, up to three leaves, each bearing a single uredinium or pruned to a single uredinium, were saved per collection. Six to 9 days later, urediniospores were collected separately from one or two such uredinia per collection and were directly inoculated onto a differential host series consisting of wheat single-gene isolines known to possess resistance genes *Lr*1, 2a, 2c, 3, 3ka, 9, 10, 11, 16, 17, 18, 24, 26, and 30 in a Thatcher genetic background (16). Observations were recorded 10–14 days later as a dichotomous high or low infection type, as in previous surveys (6–8). Some of the variation in infection types of *Lr*3ka, 17, and 18 may have been due to variation in the greenhouse environment.

Data were grouped by eight agroecological geographic areas (Fig. 1) on the basis of the source of the collections: area 1, mainly southern-adapted soft red winter wheats; areas 2 and 3, mostly northern-adapted soft red and white winter wheats, but apparently partially separated epidemiologically by geographic features; area 4, mixed wheat types, but primarily hard red winter; area 5, hard red winter wheat; area 6, mixed wheat types, but primarily hard red spring and durum; area 7, spring wheats planted in late fall; and area 8, mixed wheat types, but primarily soft white

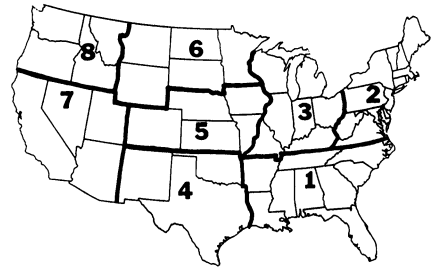

Fig. 1. Agroecological areas for *Puccinia recondita* f. sp. *tritici* in the United States: area 1, mainly southern-adapted soft red winter wheats; areas 2 and 3, mostly northern-adapted soft red and white winter wheats; area 4, a mixture of wheat types, but primarily hard red winter; area 5, hard red winter wheats; area 6, mixed wheat types, but primarily hard red spring and durum; area 7, spring wheats planted in late fall; and area 8, mixed wheat types, but primarily soft white winter types.

Accepted for publication 2 November 1988 (submitted for electronic processing).

winter. Results are presented in a form to provide historical continuity with a modified Unified Numeration (UN) race designation and are a continuation of previous surveys (6–8).

A second sample of spores from each collection was bulked with those from other collections made in the same state about the same time. A series of broadly

Table 1. Virulence formulas of *Puccinia recondita* f. sp. *tritici* isolates from collections made in the United States in 1987 as determined by the reactions of 14 wheat lines containing single genes for resistance and categorized by modified Unified Numeration (UN) races

UN race and virulence formula[a]	Isolates per area[b] (%)							United States total
	Area 1[c]	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	
UN 1	...	...	...	...	...	*[d]	*	*
UN 9								
1,2a,2c,17	3	...	...	4	4	...	...	2
1,2a,2c,11,17	*	...	...	...	1	...	...	*
UN 2								
3	*	...	...	...	...	...	...	*
3,10	*	...	...	2	...	...	13	1
3,11	12	...	7	2	...	*	...	3
3,26	...	...	...	...	...	...	13	*
3,10,11	6	3	...	...	...	...	...	2
3,10,26	...	...	...	...	...	...	38	1
UN 5								
1,3,10	16	11	15	10	23	15	19	15
1,2,10,11	6	2	...	...	...	*	...	2
1,3,10,16	2	...	...	11	12	5	...	6
1,3,10,24	6	1	15	14	9	7	...	8
1,3,10,26	...	...	...	...	...	1	...	*
1,3,10,24,26	2	3	4	5	6	5	6	4
UN 17								
2a,2c,3,10	6	2	...	22	8	8	6	10
2a,2c,3,10,18	...	2	...	...	...	...	...	*
2a,2c,3,10,24	*	...	...	...	*	1	...	*
2a,2c,3,10,24,26	...	...	...	...	...	*	...	*
UN 13								
1,2a,2c,3	1	...	...	...	...	...	...	*
1,2a,2c,3,10	11	15	22	26	32	32	...	24
1,2a,2c,3,10,11	2	3	...	...	...	1	...	1
1,2a,2c,3,10,16	...	...	...	...	*	1	...	*
1,2a,2c,3,10,17	*	...	...	...	...	8	...	2
1,2a,2c,3,10,24	1	...	...	3	4	2	...	2
1,2a,2c,3,10,26	...	...	...	*	...	...	...	*
1,2a,2c,3,9,11,18	5	...	...	...	...	2	...	1
1,2a,2c,3,10,16,26	...	...	...	...	...	*	...	*
1,2a,2c,3,10,17,18	*	...	...	...	*	4	...	1
1,2a,2c,3,10,24,26	...	...	...	...	...	2	...	*
UN 14								
1,2c,10	*	2	...	...	...	*	...	*
1,2c,10,11	8	...	...	...	...	...	...	2
1,2c,10,11,18	2	1	...	...	...	...	6	*
1,2c,10,17,18	...	2	...	...	...	...	...	*
UN 3								
2c,3,3ka,10,18,30	2	...	...	...	...	...	...	*
UN 6								
1,2c,3,10,11	1	3	...	...	...	1	...	1
1,2c,3,10,30	...	3	...	...	...	...	...	*
1,2c,3,10,11,17	...	7	...	...	...	1	...	1
1,2c,3,3ka,9,30	*	...	7	1	...	...	...	*
1,2c,3,3ka,10,30	...	...	...	...	...	1	...	*
1,2c,3,3ka,18,30	...	3	...	...	...	*	...	*
1,2c,3,3ka,11,18,30	...	21	4	*	1	...	...	3
1,2c,3,3ka,10,11, 18,30	*	10	15	...	...	...	...	2
1,2c,3,3ka,9,10, 18,30	4	4	11	...	...	*	...	2
				Number of collections				
	171	80	27	140	132	126	12	688
				Number of isolates				
	191	100	27	204	196	213	16	947

[a] The *Lr* single-gene differentials tested = 1, 2a, 2c, 3, 3ka, 9, 10, 11, 16, 17, 18, 24, 26, and 30. The virulence formula indicates differentials that are susceptible. The UN race designation is based on the reactions of *Lr*1, 2a, 2c, and 3 (6).

[b] Column total 100% (±4%).

[c] Areas are based on host types and geographic isolation (Fig. 1). No collections received from area 8.

[d] Less than 0.6%.

resistant wheat lines consisting of Thatcher isolines *Lr*19, 21, and 29 (11,16), and of Aepoglom, Anex (=Purdue 52158A1-1-1) (18), Anfron (=Purdue 52157A1-9-3-1-11) (18), Buck Manantial, CI 17906 (*Lr*9 and 24) (23), Cowbird 'S', Kavkaz, Lani (=Purdue 52160A2-10-1) (18), Len, Lex (=Purdue 52159A4-3-1-3) (18), PI 338438, PI 436414 (Chile), Redcoat (13), RL 6059 (*Lr*33 and 34) (17), Stoa, Coker 68-15/Skorospelka, Transec (*Lr*25), 448-1180 (West Germany), two AZ-male sterile selected lines (22), and susceptible check Thatcher was inoculated with 50 such bulked collections. Alondra, Chasqui, Columbus, Granka, Hahn 'S', and Siouxland were not included because virulence was detected in 1986 (8).

After the initial identifications of isolates were made using the differential host series of 14 lines, 54 isolates possessing representative virulence combinations were saved. These were used to inoculate a commonly grown cultivar series of Arkan (12), Auburn (14), Brule (20), Celtic, Coker 762, Coker 916, Coker 983, Collin (10), Florida 302, Frankenmuth (4), Hawk, Katepwa, Magnum, Marshall (2), Monroe (3), Newton (5), Norak, ProBrand 812, Siouxland (21), Success, TAM 107 (15), Thunderbird, Vic, and Wheaton (1).

RESULTS AND DISCUSSION

The 44 virulence formulas describing the 947 isolates obtained, based on the 14 differential host lines each possessing a known single gene for resistance, are summarized by source area in Table 1. Results are presented as percentages of isolates within areas. No rust collections were received from cooperators in area 8. Virulence formulas are arranged in Table 1 by modified UN race numbers, based on the reactions of *Lr*1, 2a, 2c, and 3, historical differential hosts (6).

More than 66% of the total isolates identified in 1987 were in the UN 5 and 13 race categories. The most commonly identified phenotype was UN 13 (24%), with a virulence formula of p1,2a,2c,3,10 (p = virulence), which was found throughout the Great Plains (areas 4, 5, and 6), and to a lesser extent in areas 1, 2, and 3 (Table 1). In 1986, the distribution of this phenotype was similar (8).

The second most common phenotype (15%) was UN 5, with a virulence formula of p1,3,10, which was the most commonly identified phenotype (19%) in 1986 (8). The wide distribution of the same phenotypes of UN 5 and 13 found throughout areas 4, 5, and 6 in 1987 again suggests that these areas are a continuous south-north epidemiological unit, as previously proposed (7,8). Most isolates representing these two UN races (66%) possess virulence to *Lr*10. Virulence overcoming *Lr*3 and 10 is also common in other phenotypes (95 and 91% of the total, respectively) (Table 2). This follows the pattern of the last 10 yr.

The third most frequent UN race group (10%) was UN 17, with only four different phenotypes. As in previous years (6–8), phenotype p2a,2c,3,10 was predominant, and the other three phenotypes constituted a minor portion of the UN 17 group (Table 1).

UN 6 was found predominantly in the eastern soft winter wheat region (areas 1, 2, and 3). Only a few UN 6 isolates were found in the Great Plains (areas 4, 5, and 6) (Table 1).

The UN 2 group was found scattered thoughout the United States with many diverse phenotypes. The p3,11 virulence combination was commonly found in the southern soft red winter wheat area, where some of the cultivars appear to have *Lr*11 (19).

UN 9 and UN 14 are recent uncommon races with *Lr*3 avirulence. Phenotypes of UN 9, with virulence formulas of p1,2a,2c,17 and p1,2a,2c,11,17, were identified from seven *A. cylindrica* collections made in Texas, Oklahoma, and Kansas. Although UN 9 was the only UN race obtained from *Aegilops*, it was only rarely identified from wheat collections made in the southern soft red winter area and southern Great Plains area. UN 14 was found in the eastern soft wheat region, but was conspicuously absent from the main wheat areas of the central region.

In 1987, there was an increase in prevalence of *Lr*24 virulence, found in 16% of the total population, compared with 10% in 1986 and 2% in 1985 (Table 2). This may represent a selective advantage to these isolates due to an increase in cultivars that have *Lr*24 as their leaf rust resistance. In 1986 and 1987, *Lr*24 virulence occurred in UN 5 and 17, but it also was identified for the first time in 1987 in the UN 13 group in two different virulence combinations.

*Lr*26 virulence was found in 6% of the total population (Table 2). This is an increase from 1986 when only 1% of the population was virulent to *Lr*26. The *Lr*26 resistance is now present in United States cultivars (i.e., CIMMYT-developed lines growing in the United States). Combined virulence to *Lr*24 and 26 was found in the three common race groups (UN 5, 13, 17). Siouxland has both *Lr*24 and 26 (21), and is grown from southern Texas to North Dakota. In 1986, this p24,26 combination was found only in one virulence phenotype, but in 1987 this combination was present in three different phenotypes (Table 1).

There was a significant decrease in *Lr*16 virulence for the first time in the past 3 yr (Table 2). In 1987, *Lr*16 virulence was identified from collections made from many different cultivars, whereas in 1985 most were from ProBrand 812 (7,9).

*Lr*9 virulence was found in UN 6 (p1,2c,3,3ka,9,30 and p1,2c,3,3ka,9,11,18) and UN 13 (p1,2a,2c,3,9,11,18). *Lr*9 virulence continues to decrease in the United States population. During the period 1978–1983, *Lr*9 virulence was present in 25% of the sampled population (Table 2), whereas in 1987 it was identified in 4% of the collections. This decrease appears to relate to a reduction in the prevalence of cultivars possessing *Lr*9 resistance in the eastern region.

Table 2. Percentage of isolates of *Puccinia recondita* f. sp. *tritici* virulent to the single-gene differential lines used in the 1987 survey

Area[a]	Isolates virulent to *Lr* genes (%)														Number of isolates
	1	2a	2c	3	3ka	9	10	11	16	17	18	24	26	30	
1	72	32	50	87	8	9	77	43	4	5	12	9	2	6	191
2	91	22	78	95	40	4	62	54	0	7	39	4	3	41	100
3	93	22	59	100	37	19	81	26	0	0	30	19	4	37	27
4	75	55	57	96	1	1	93	2	11	4	*[b]	23	6	1	204
5	92	49	51	95	1	0	95	2	13	5	2	19	6	1	196
6	90	62	67	99	2	2	97	5	7	12	7	18	9	2	213
7	31	6	13	94	0	0	88	6	0	0	6	6	56	0	16
USA 1987	83	46	58	95	7	4	91	17	7	6	10	16	6	8	947
USA 1986[c]	77	37	51	91	6	7	81	16	17	6	12	10	1	5	972
USA 1985[c]	54	52	68	98	11	9	83	9	11	9	19	2	...[d]	...	1,148
USA 1984[c]	62	32	51	94	10	6	80	21	...	9	18	2	...	11	836
USA 1978–1983[c]	34	25	53	95	26	25	73	...	0	11	10	4	...	...	1,928

[a] Area description in text and Figure 1.
[b] Less than 0.6%.
[c] Long et al (8).
[d] Not used in this survey.

No virulence was found on 15 of the resistant series entries: Aepoglom, Anex (18), Anfron (18), Buck Manantial, CI 17906 (23), Lani (18), Lex (18), RL 6059 (*Lr*33 and 34) (17), Stoa, 448-1180 (West Germany), Transec (*Lr*25), two AZ-male sterile germplasm selections (22), and Thatcher isolines *Lr*19 and 29 (11,16).

Each of the entries in the commonly grown cultivar series was susceptible to at least one of the isolates representing the most common virulence phenotypes found in 1987 in the United States.

ACKNOWLEDGMENTS

We wish to thank Shelly McFarland and Mark Hughes for their technical assistance.

LITERATURE CITED

1. Busch, R., McVey, D., Rauch, T., Baumer, J., and Elsayed, F. 1984. Registration of Wheaton wheat. Crop Sci. 24:622.
2. Busch, R., McVey, D., Youngs, V., Heiner, R., and Elsayed, F. 1983. Registration of Marshall wheat. Crop Sci. 23:187.
3. Cantrell, R. G., Dick, J. W., Miller, J. D., and Quick, J. S. 1986. Registration of 'Monroe' durum wheat. Crop Sci. 26:200-201.
4. Everson, E. H., Freed, R. D., Zwer, P. K., Morrison, L. W., Marchetti, B. L., Clayton, J. L., and Yamazaki, W. T. 1986. Registration of 'Frankenmuth' wheat. Crop Sci. 26:202.
5. Heyne, E. G., and Niblett, C. L. 1978. Registration of Newton wheat. Crop Sci. 18:696.
6. 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. 69:343-347.
7. Long, D. L., Schafer, J. F., Roelfs, A. P., and Roberts, J. J. 1986. Virulence and epidemiology of *Puccinia recondita* f. sp. *tritici* in the United States in 1985. Plant Dis. 70:1107-1110.
8. Long, D. L., Schafer, J. F., Roelfs, A. P., and Roberts, J. J. 1988. Virulence of *Puccinia recondita* f. sp. *tritici* in the United States in 1986. Plant Dis. 72:22-24.
9. Marshall, D. 1988. Characteristics of the 1984–1985 wheat leaf rust epidemic in central Texas. Plant Dis. 72:239-241.
10. Marshall, D., Gardenhire, J. H., Gilmore, E. C., McDaniel, M. E., and Erickson, C. A. 1986. Collin. A new semidwarf hard red winter wheat for the Texas Blacklands. Tex. Agric. Exp. Stn. Misc. Publ. 1615. 4 pp.
11. Martens, J. W., and Dyck, P. L. 1988. Occurrence and virulence of *Puccinia recondita* in Canada in 1986. Can. J. Plant Pathol. 10:268-272.
12. Martin, T. J., Bockus, W. W., Browder, L. E., Finney, K. F., Hatchett, J. H., and Wetzel, D. L. 1983. Registration of Arkan wheat. Crop Sci. 23:1221-1222.
13. Patterson, F. L., Schafer, J. F., and Gallun, R. L. 1978. Registration of Redcoat wheat. Crop Sci. 18:527.
14. Patterson, F. L., Shaner, G. E., Ohm, H. W., Finney, R. E., Gallun, R. L., Roberts, J. J., and Foster, J. E. 1982. Registration of Auburn wheat. Crop Sci. 22:161-162.
15. Porter, K. B., Worrall, W. D., Gardenhire, J. H., Gilmore, E. C., McDaniel, M. E., and Tuleen, N. A. 1987. Registration of 'TAM 107' wheat. Crop Sci. 27:818-819.
16. Samborski, D. J. 1984. Occurrence and virulence of *Puccinia recondita* in Canada in 1983. Can. J. Plant Pathol. 6:238-242.
17. Samborski, D. J., and Dyck, P. L. 1982. Enhancement of resistance to *Puccinia recondita* by interactions of resistance genes in wheat. Can. J. Plant Pathol. 4:152-156.
18. Schafer, J. F., Caldwell, R. M., Patterson, F. L., and Compton, L. E. 1963. Wheat leaf rust resistance combinations. Phytopathology 53:569-573.
19. Schafer, J. F., and Long, D. L. 1988. Relations of races and virulences of *Puccinia recondita* f. sp. *tritici* to wheat cultivars and areas. Plant Dis. 72:25-27.
20. Schmidt, J. W., Johnson, V. A., Mattern, P. J., Dreier, A. F., McVey, D. V., and Hatchett, J. H. 1983. Registration of Brule wheat. Crop Sci. 23:1223.
21. Schmidt, J. W., Johnson, V. A., Mattern, P. J., Dreier, A. F., McVey, D. V., and Hatchett, J. H. 1985. Registration of 'Siouxland' wheat. Crop Sci. 25:1130-1131.
22. Thompson, R. K. 1983. Registration of AZ-MSFRS-82RR rust resistant common wheat germplasm. Crop Sci. 23:605.
23. Young, H. C., Jr., and Smith, E. L. 1981. Registration of four germplasm lines of wheat. Crop Sci. 21:993.