Races and Virulence of *Puccinia recondita* f. sp. *tritici* in China in 1986

CHANG-CHENG HU, Institute of Plant Protection, Agricultural Academy of China, Ma-Lin-Wa, Beijing, The People's Republic of China, and A. P. ROELFS, Research Plant Pathologist, Cereal Rust Laboratory, USDA-ARS, University of Minnesota, St. Paul 55108

ABSTRACT

Hu, C.-C., and Roelfs, A. P. 1989. Races and virulence of *Puccinia recondita* f. sp. *tritici* in China in 1986. Plant Disease 73: 499-501.

During 1986, 113 isolates of *Puccinia recondita* f. sp. *tritici* were studied; 16 races were identified by the reactions of eight Chinese differentials. The most commonly identified race was CL-4 (CL = China leaf rust), constituting 29% of the isolates. Other races, in order of frequency, were CL-38, CL-34, CL-7, CL-2, CL-44, CL-3, CL-19, CL-29, CL-12, and CL-17. Five additional virulence patterns were found but not named. Sixteen wheat lines with single genes for leaf rust resistance were inoculated with 87 isolates. Virulence to genes *Lr*2c, *Lr*14a, *Lr*14b, *Lr*21, *Lr*17, and *Lr*3 was nearly universal, at 95, 92, 91, 91, 87, and 84%, respectively. Unified numeration race 13 (virulent to *Lr*1, *Lr*2a, *Lr*2c, and *Lr*3) was the most common race in China.

Wheat leaf rust, caused by *Puccinia recondita* Rob. ex Desm. f. sp. *tritici*, is an important disease occurring annually in China. Epidemics in 1969, 1973, and 1975 resulted in severe losses in the northern part of the wheat region (3).

Continual monitoring of variation in the virulence of the population is needed to breed disease-resistant wheats (6). The objective of this study was to determine the occurrence of physiologic races of *P. r.* f. sp. *tritici* in China in 1986 and to analyze the virulences and virulence combinations of races of this pathogen.

MATERIALS AND METHODS

Leaf rust samples were collected from nine provinces: Xin-jiang, Gan-su, He-nan, Gui-zhou, Liao-ning, Shan-xi, Si-chuan, Shaan-xi, and He-bei (Fig. 1 and Table 1). Seven-day-old seedlings of susceptible cultivars (Ming-Sian 169 and Ming-Sian 5389) were inoculated with uredial collections by rubbing or spatula inoculation techniques (2) for spore increase. After incubation, the plants were covered with a glass cylinder (9 cm in diameter and 20 cm long) to reduce contamination between cultures. Spores were collected after pustules were fully developed. An isolate was obtained from the viable spores from each collection, where possible. Isolates were evaluated on 24 differential cultivars and lines.

The eight Chinese differentials selected at the Tong-xian Rust Conference in 1977 were Lovrin 10, 6068, IRN 66-331, Redman, Dong-Feng-Hong 3, Feng-Chen 3, Bai-You-Bao, and Tai-Shan 4. Additionally, the 16 isogenic lines in a Thatcher background, with leaf rust resistance genes *Lr*1, *Lr*2a, *Lr*2b, *Lr*2c, *Lr*3, *Lr*3ka, *Lr*9, *Lr*10, *Lr*14a, *Lr*14b,

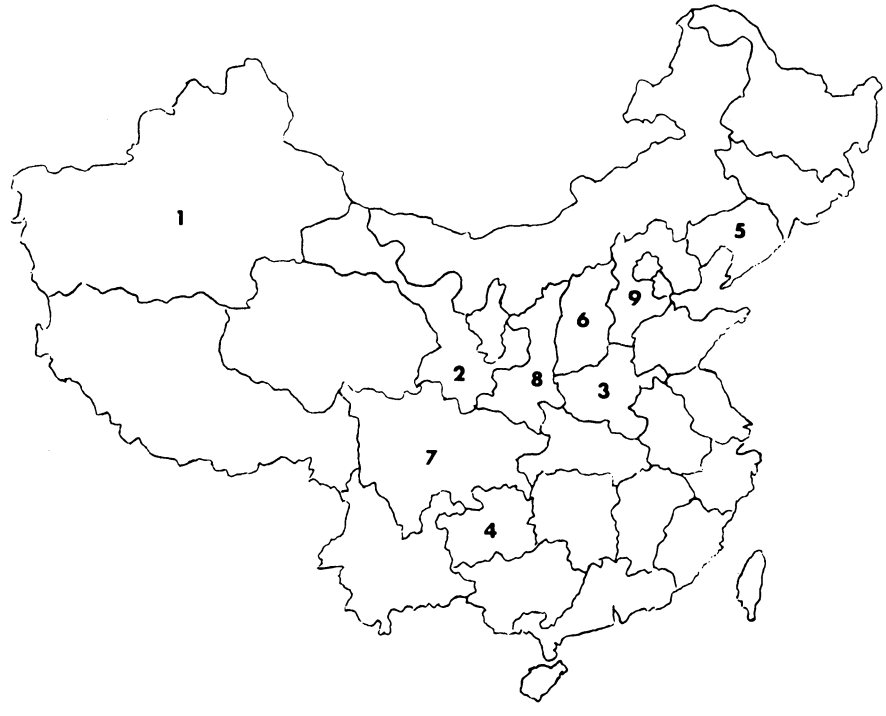

Fig. 1. Provinces in which collections were made, with older transliterations in parentheses: 1 = Xin-jiang (Xinjian Uygur Zizhigu); 2 = Gan-su (Gansu); 3 = He-nan (Henan); 4 = Gui-zhou (Kweichow); 5 = Liao-ning (Liaoning); 6 = Shan-xi (Shanxi); 7 = Si-chuan (Szechwan); 8 = Shaan-xi (Shaansi); and 9 = He-bei (Hopei).

Paper No. 16,128, Scientific Journal Series, Minnesota Agricultural Experiment Station.

Accepted for publication 19 January 1989 (submitted for electronic processing).

Table 1. Sources of the collections of *Puccinia recondita* f. sp. *tritici* received and the number of isolates established in China in 1986

Province[a]	Number of collections[b]	Number of isolates[c]
Xin-jiang	51	38
Gan-su	29	29
He-nan	15	13
Gui-zhou	10	9
Liao-ning	4	4
Shan-xi	2	2
Si-chuan	2	2
Shaan-xi	1	1
He-bei	15	15
Total	129	113

[a] See Figure 1.
[b] Each collection is a series of rust-infected leaves from a field or cultivar.
[c] Each isolate is a culture established in the greenhouse from a collection.

*Lr*15, *Lr*16, *Lr*17, *Lr*18, *Lr*19, and *Lr*21, were used as supplemental differentials for the identification of virulence genes of *P. r.* f. sp. *tritici* in China. These Thatcher lines are used worldwide for the classification of virulence phenotypes of *P. recondita*.

The differential hosts were planted in a 30- × 20- × 10-cm plastic tray. Seven days after planting, when the first leaf was fully extended, the plants were inoculated by rubbing the spore suspension on the first leaf. The plants were put into a metal cylinder for incubation for about 24 hr at 18 C. They were then moved to a greenhouse at 20 C. Infection types were recorded after 14 days.

RESULTS AND DISCUSSION

On the basis of the reactions of the eight unified Chinese differentials, the 113 isolates were classified into 16 races (Table 2). Since the China leaf rust (CL) races CL-1, CL-2, and CL-3 were designated at the Tong-xian Rust Conference in 1977, a total of 44 CL races have been described on the basis of results obtained throughout China.

CL-4 is virulent on all eight Chinese differentials. It made up 29% of the isolates in 1986. Historically, CL-4 has occurred mainly in Shan-dong Province. CL-19, CL-34, and CL-12, which also are virulent to *Lr*26, were grouped in the Lovrin 10 race cluster with CL-4. These races are currently a major threat to commercial cultivars that have *Lr*26, derived from the translocation of the 1R chromosome from rye to wheat.

CL-38 is virulent on the Chinese differentials Dong-Feng-Hong 3 and Feng-Chen 3. It makes up 20% of the isolates. This was the most common race during the 1970s and was then designated CL-1. Obviously, this race remains an important part of the Chinese leaf rust population.

CL-34 is virulent on the Chinese differentials Dong-Feng-Hong 3, Feng-Chen 3, and Lovrin 10. It was widespread, severe, and the dominant race of the cultures virulent on Lovrin 10 in the Huang-Huai-Hai area of northern China.

CL-2 is virulent on the Chinese differentials Dong-Feng-Hong 3, Feng-Chen 3, Bai-You-Bao, and Tai-Shan 4. Historically, CL-2 has occurred at a low frequency.

CL-3 is virulent on all Chinese differentials except Lovrin 10. It made up only 4.4% of the isolates in 1986, probably because of the increase in cultivars derived from Lovrin 10. CL-3 was the dominant race in 1983, when it made up 40% of the isolates identified. Most commercial cultivars with *Lr*26 are resistant to this race.

Other races identified in 1986 at low frequencies were CL-7, CL-19, CL-29, CL-12, CL-17, and CL-44. Five new virulence-avirulence patterns appeared at low frequencies in 1986 for which no race designations have yet been assigned (Table 2).

Basile's unified numeration (UN) race designations are based on the reactions of Malakof (*Lr*1), Webster (*Lr*2a), Loros (*Lr*2c), and Democrat (*Lr*3), historical differential host cultivars (1). Samborski (7), using the Thatcher isogenic lines having *Lr*1, *Lr*2a, *Lr*2c, and *Lr*3, distinguished 12 races in North America. These races generally corresponded to 12 of Basile's UN races. The reaction of four isogenic lines to 12 UN races and the number and percentage of isolates of these 12 races identified in China in 1986 and in the United States (4) and Canada (5) in 1986 are shown in Table 3.

The virulence gene frequency of *P. r.* f. sp. *tritici* in China was similar to that

Table 2. Physiologic races of *Puccinia recondita* f. sp. *tritici* identified by means of the unified Chinese differentials in China in 1986

Chinese leaf rust race	Formula[a]	Number of isolates	Percentage of isolates
CL-4	/1,2,3,4,5,6,7,8	33	29.3
CL-38	1,2,3,4,7,8/5,6	22	19.5
CL-34	2,3,4,7,8/1,5,6	12	10.6
CL-7	1,2/3,4,5,6,7,8	7	6.2
CL-2	1,2,3,4/5,6,7,8	6	5.3
CL-44	1,2,3,4,5,6,7,8/	6	5.3
CL-3	1/2,3,4,5,6,7,8	5	4.4
CL-19	2,3,4/1,5,6,7,8	3	2.6
CL-29	1,2,3,4,8/5,6,7	3	2.6
CL-12	2,3/1,4,5,6,7,8	1	0.9
CL-17	1,2,4/3,5,6,7,8	1	0.9
New	2,7,8/1,3,4,5,6	6	5.3
New	6/1,2,3,4,5,7,8	5	4.4
New	6,7/1,2,3,4,5,8	1	0.9
New	3,4,6/1,2,5,7,8	1	0.9
New	4,7,8/1,2,3,5,6	1	0.9
Total		113	100

[a] Effective/ineffective resistance in the following hosts: 1 = Lovrin 10; 2 = 6068; 3 = IRN 66-331; 4 = Redman; 5 = Dong-Feng-Hong 3; 6 = Feng-Chen 3; 7 = Bai-You-Bao; 8 = Tai-Shan 4.

Table 3. Unified numeration (UN) races of *Puccinia recondita* f. sp. *tritici* identified in China, the United States, and Canada in 1986

UN race[a]	Avirulence/ virulence formula[b]	Percentage of isolates		
		China	United States[c]	Canada[d]
1	1,2a,2c,3/	2	*[e]	0
2	1,2a,2c/3	1	5	2
10	1,2a,3/2c	8	*	0
3	1,2a/2c,3	17	*	1
12	1,3/2a,2c	1	0	0
17	1/2a,2c,3	6	17	10
11	2a,2c,3/1	0	*	2
5	2a,2c/1,3	1	43	33
14	2a,3/1,2c	0	7	7
6	2a/1,2c,3	13	7	4
9	3/1,2a,2c	5	*	3
13	/1,2a,2c,3	46	20	38
Number of isolates		87	972	231

[a] UN races after Basile (1).
[b] Avirulence/virulence to leaf rust resistance genes *Lr*1, *Lr*2a, *Lr*2c, and *Lr*3.
[c] Data from Long et al (4).
[d] Data from Martens and Dyck (5).
[e] Present but less than 0.6%.

Table 4. Virulence frequency of *Puccinia recondita* f. sp. *tritici* in China, Canada, and the United States in 1986

Lr gene	Frequency of virulence (%)		
	China	Canada[a]	United States[b]
1	64	85	77
2a	58	51	37
2b	70	51	—[c]
2c	95	63	51
3	84	93	91
3ka	36	6	6
9	37	0	7
10	63	96	81
14a	92	95	High
14b	91	98	High
15	74	—	—
16	95	2	17
17	87	10	6
18	67	27	12
19	0	0	0
21	91	0	—

[a] Data from Martens and Dyck (5).
[b] Data from Long et al (4).
[c] Not tested.

in North America in many cases (Table 4). The frequency of virulence to *Lr*3 was 84, 93, and 91% in China, Canada, and the United States, respectively. The virulence frequencies for *Lr*1, *Lr*14a, and *Lr*14b were high in China and North America. No virulence to *Lr*19 was observed in either area. The rare reports of virulence to *Lr*19 in the literature have not been verified.

There were some differences between virulence gene frequencies in North America and those in China. The virulence frequency for *Lr*2c was 95% in China but was 63 and 51% in Canada and United States, respectively. The virulence frequency for *Lr*16, *Lr*17, and *Lr*18 was high in China but low in Canada and the United States. The virulence frequency for *Lr*9 was 7, 0, and 37% in the United States, Canada, and China, respectively. The virulence frequency for seedlings with *Lr*21 was 91% in China, but no virulence was found in Canada.

The frequency of physiologic races of *P. r.* f. sp. *tritici* identified in China was different from that of races identified in North America (Table 3). In China, UN race 13 (virulent to *Lr*1, *Lr*2a, *Lr*2c, and *Lr*3) was dominant, with a frequency of 46%, and UN race 3 (virulent to *Lr*2c and *Lr*3) had a frequency of 17%. The dominant races in the United States were UN races 5, 13, and 17, with frequencies of 43, 20, and 17%, respectively. In the United States, UN race 3 was detected but currently makes up less than 1% of the isolates. The Canadian population was very similar. Although the Canadian wheat cultivars are similar to those in the northern United States, cultivars in the southern United States are quite different, which along with differences in environment may account for some of the differences between the U.S. and Canadian rust populations.

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