Virulence of *Puccinia recondita* f. sp. *tritici* in the United States During 1988–1990

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ABSTRACT

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Isolates of *Puccinia recondita* f. sp. *tritici* were obtained from wheat leaf collections made by cooperators throughout the United States and from cereal rust field surveys of the Great Plains, Ohio Valley, and Gulf Coast states in 1988, 1989, and 1990. Forty-one virulence/avirulence phenotypes were found among 618 isolates in 1988, 45 among 983 isolates in 1989, and 53 among 906 isolates in 1990 on 14 host lines with single designated genes for leaf rust resistance. The frequencies of virulence to lines with *Lr*11 and *Lr*26 during 1988–1990 were greater than in previous years. Isolates were tested on 14 additional entries selected for potentially useful resistance to common races of *P. r. tritici*. No virulence was found to 12 of these 14 entries during 1988–1990. Regional race distribution patterns again suggested the central United States is a single epidemiological unit distinct from the eastern United States.

Additional keywords: wheat leaf rust

Wheat leaf rust, caused by *Puccinia recondita* Roberge ex Desmaz f. sp. *tritici* (Eriks. & E. Henn.) D. M. Henderson, occurs annually throughout most wheat-growing areas of the United States. In 1988, 1989, and 1990 losses ranged from 0 to 5% in the 35 states that produce more than 94% of the wheat crop. Losses to leaf rust in winter wheat (*Triticum aestivum* L.) were estimated at 1.1% in 1988, 0.9% in 1989, and 2.2% in 1990 in the United States (D. L. Long, *unpublished*).

Virulence surveys of *P. r. tritici* have been conducted at the Cereal Rust Laboratory since 1978 (5). In addition, ongoing surveys have been conducted in Canada since 1931 (3), in Texas since 1984 (9), and in Mexico since 1988 (15). The Canadian survey data have been used to characterize virulence and race dynamics and phenotypic diversity within and among wheat-growing areas of Canada (1–3).

The objective of this study was to characterize the virulence of the *P. recondita* population in the United States in 1988, 1989, and 1990 on North American differentials (4) and other selected lines of wheat and to compare these results with those of previous surveys.

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MATERIALS AND METHODS

Uredinial collections of *P. r. tritici* were made from wheat in surveys of the Great Plains, Ohio Valley, and Gulf Coast states and by cooperators throughout the United States. The surveys followed predetermined routes (approximately 28,000 km) 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. Collections also were made from *Aegilops cylindrica* Host (goatgrass) growing near or in wheat fields in the southern Great Plains. A collection consisted of one to several leaves bearing uredinia from a single plant or cultivar.

Urediniospores from each collection were used to inoculate 7-day-old seedlings of wheat cv. Thatcher (CI 10003) treated at emergence with maleic hydrazide (1 g per 3 L of H_2O) to enhance spore production. Plants were sprayed with spores suspended in lightweight mineral oil and then set in a dew chamber overnight at 18 C. The plants then were placed in a greenhouse where temperatures varied between 18 and 28 C during the diurnal cycle. After 12–15 days, three leaves were saved per collection, each bearing a single uredinium or trimmed to a single uredinium. Six to 9 days later,

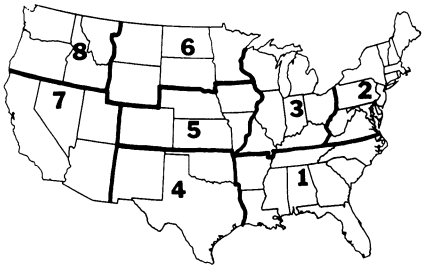

Fig. 1. Agroecological areas for *Puccinia recondita* f. sp. *tritici* in the United States. Area 1 = mainly southern-adapted soft red winter wheats; areas 2 and 3 = mostly northern-adapted soft red and white winter wheats; area 4 = a mixture of wheat types but primarily hard red winter; area 5 = hard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

Table 1. Races of *Puccinia recondita* f. sp. *tritici* (Prt) collected from fields (F) and nurseries (N) in agroecological areas 1, 2, and 3 of the United States in 1988, 1989, and 1990

	Percentage of isolates from indicated source																
	Area 1[b]						Area 2[b]						Area 3[b]				
	1988		1989		1990		1988		1989		1990		1988	1989		1990	
Prt code[a]	F	N	F	N	F	N	F	N	F	N	F	N	N	F	N	F	N
BBB-10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BBG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
BLG	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CBB-10	0	0	4	1	3	0	0	0	6	0	0	0	0	0	0	0	0
CBG	0	5	12	5	11	2	5	2	0	0	5	0	0	0	3	4	3
CBG-10	0	1	0	4	0	2	0	0	3	5	0	0	0	4	0	4	3
CBG-10,18	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
CLL-18	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
DBB-18	0	0	0	0	0	0	11	5	0	0	0	0	0	0	0	0	0
DBG-18	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
FBB-10,18	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
FBM	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
FBM-18	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	8	12
FBM-10,18	0	4	0	1	0	2	0	0	0	3	9	7	0	4	1	0	3
FBR-10,18	0	0	8	1	2	3	0	0	0	0	0	7	0	0	0	0	0
FLM-18	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0	0	0
JCB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
KBB-10	0	4	0	2	2	0	0	2	3	0	0	7	0	4	2	0	3
KBG-10	0	0	0	2	3	4	0	0	6	0	0	0	0	4	6	8	0
LBB-10,18	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0
LBG	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
LCB-10,18	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
LLG-18	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
MBB	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0
MBB-10	0	26	4	5	2	1	0	2	0	0	0	0	9	6	0	13	7
MBD-10	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
MBG	0	2	0	3	0	6	0	0	3	3	0	3	0	8	5	29	12
MBG-10	0	7	20	21	46	43	0	0	6	3	23	38	18	4	13	17	18
MBG-10,18	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3
MBJ-10	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
MBR-10	0	0	0	0	0	1	0	0	6	0	0	0	0	0	0	0	0
MCB-10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCG-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
MDB-10	0	9	0	3	0	3	0	0	0	0	0	0	0	0	7	0	0
MFB-10	25	4	12	12	0	0	0	0	0	3	0	10	0	8	8	0	6
MGB-10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
NBB-10	0	0	0	0	0	0	0	7	0	10	0	3	0	0	0	0	0
NBB-10,18	0	0	0	0	0	0	0	9	0	5	0	0	0	0	0	0	0
NBG-10,18	0	1	0	0	0	0	0	9	0	10	0	0	0	0	0	0	0
PBB-10	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
PBD	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
PBG-10	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBM-18	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0
PBM-10,18	0	1	0	0	0	3	16	7	0	0	0	0	0	0	0	4	0
PBR-18	25	0	0	0	0	0	42	23	21	5	0	0	0	0	0	0	0
PBR-10,18	0	0	0	1	0	1	5	16	12	15	27	0	0	0	2	0	0
PLM-18	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
PLM-10	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0
PLM-10,18	0	4	0	2	0	0	0	0	15	13	9	0	0	27	6	0	3
PLR-10,18	0	0	0	3	0	0	0	0	12	0	0	0	0	10	0	0	4
SCD	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TBB-10	0	19	32	22	2	1	0	0	9	15	0	0	55	4	40	0	6
TBD-10	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
TBG-10	50	3	0	4	3	8	0	0	0	0	18	7	0	8	3	4	9
TBG-10,18	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
TBJ	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
TCB-18	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0
TCB-10	0	2	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
TDB-10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TFB-10	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0
TGB-10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TLG-18	0	0	8	4	23	7	0	0	0	0	0	0	0	2	0	4	0
No. of isolates	4	140	25	377	65	254	19	43	34	40	22	29	11	49	86	24	67

[a] North American Prt races based on 12 North American differential lines (4) plus lines with *Lr*10 and *Lr*18.
[b] Agroecological areas are shown in Figure 1.

Table 2. Races of *Puccinia recondita* f. sp. *tritici* (Prt) collected from fields (F) and nurseries (N) in agroecological areas 4, 5, and 6 of the United States in 1988, 1989, and 1990

	Percentage of isolates from indicated source																	
	Area 4[b]						Area 5[b]						Area 6[b]					
	1988		1989		1990		1988		1989		1990		1988		1989		1990	
Prt code[a]	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N
BBB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
BBB-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
BBG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
CBB-10	0	0	0	0	1	1	0	0	0	3	1	0	0	0	0	0	0	0
CBG-10	1	0	0	1	0	0	0	0	0	0	0	0	0	0	5	1	0	0
CBT	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCB-10	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
DBB	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4
DBB-18	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0
FBM-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
JCB	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
JCD	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
KBB-10	5	6	10	10	0	1	6	7	3	8	0	1	0	3	2	1	0	0
KBG-10	0	0	2	1	7	3	0	0	7	5	7	4	0	0	2	9	0	3
KDB-10	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
KFB-10	0	0	0	0	1	1	0	0	0	0	0	3	0	0	0	0	0	1
LBB-10,18	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
MBB-10	20	16	3	11	4	4	26	12	14	18	0	1	5	9	7	5	0	0
MBD-10	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0
MBG	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
MBG-10	1	1	0	1	19	17	0	0	0	3	9	11	0	1	2	2	0	9
MBJ-10	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MBK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
MCB-10	0	0	0	0	0	0	0	3	3	5	0	0	0	0	0	1	0	0
MCG-10	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
MDB-10	8	15	10	10	8	10	6	12	3	5	7	1	0	12	5	8	29	1
MFB-10	3	3	10	19	24	22	15	33	17	13	17	15	10	15	11	16	14	19
MGB-10	1	1	0	0	0	3	3	0	0	0	3	0	0	0	0	0	0	0
PBP-10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
PBR-18	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0
PLM-10,18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0
SBD	0	4	9	0	9	0	0	0	0	0	2	0	0	0	0	0	0	0
SCD	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TBB-10	46	41	48	42	11	10	41	30	48	37	13	4	70	51	36	30	14	6
TBD-10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	0
TBD10,18	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	4
TBG-10	11	4	0	0	14	24	0	0	3	0	34	34	0	0	20	21	29	23
TBG-10,18	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	14	16
TCB-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
TCB-10	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TCG-10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	4
TDB-10	3	0	0	0	0	2	0	0	0	0	1	9	0	0	0	0	0	0
TDD-10,18	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TFB-10	0	3	0	0	1	0	3	0	0	0	1	0	0	0	0	0	0	1
TGB-10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
TLG-18	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. of isolates	74	68	58	72	74	115	34	76	29	38	94	79	20	68	44	101	7	69

[a] North American Prt races based on 12 North American differential lines (4) plus lines with *Lr*10 and *Lr*18.
[b] Agroecological areas are shown in Figure 1.

urediniospores were collected separately from one or two such uredinia per collection. If necessary, the single uredinial isolates were increased through one uredinial generation on Thatcher before inoculating the differential lines. Otherwise, they were directly inoculated onto the differential host series consisting of wheat single-gene isolines known to possess resistance genes *Lr*1, 2a, 2c, 3, 3ka, 9, 11, 16, 17, 24, 26, and 30 in a Thatcher genetic background (11). Isolines possessing *Lr*10 and 18 were added to the *P. r. tritici* differential series. Observations were recorded 10–14 days later as either high or low infection type as in previous surveys (5–8). Some of the variation in infection types of *Lr*3ka, 11, 17, and 18 may have been attributable to variation in the greenhouse environment. Data are grouped by eight agroecological geographic areas (Fig. 1).

A second sample of urediniospores from each rust collection was bulked with those from other collections made in the same state at about the same time. Bulked collections were tested on a series of wheat lines resistant to common leaf rust isolates. This series consisted of Thatcher isolines *Lr*19, 21, and 29 (2,11); Aepoglom; AZ-FH 50-4-1-1-1; AZ-FH 51-2-2-1 (16); Buck Manantial; CI 17906 (*Lr*9 and 24) (17); Lex; RL 6059 (*Lr*33 and 34) (12); Stoa; Success; Siouxland/PRO Brand 812; Transec (*Lr*25); and Thatcher, a susceptible check. This series

was inoculated with 30 such bulked collections in 1988, 45 collections in 1989, and 42 collections in 1990.

RESULTS AND DISCUSSION

Over the 3 yr of this study, a total of 2,512 urediniospore isolates were characterized. Based on the 14 differential host lines, each possessing a known single gene for resistance, 79 virulence formulae were identified (Tables 1–3). Virulence formulae are arranged in the tables by *P. r. tritici* code (4), which are based on the reactions on *Lr*1, 2a, 2c, 3, 3ka, 9, 10, 11, 16, 17, 18, 24, 26, and 30. Results are presented as percentages of isolates within areas separated into collections made from nurseries and fields. More than two-thirds of the isolates identified in 1988 (75%), 1989 (71%), and 1990 (80%) had the M-- (virulent on *Lr*1 and 3) or T-- (virulent on *Lr*1, 2a, 2c, and 3) phenotypes. The most frequently identified race in 1988 and 1989 was TBB-10 (29 and 27%). As in 1986 and 1987 (7,8), race TBB-10 was found throughout the Great Plains (areas 4–6) and to a lesser extent in areas 1–3. The MBG-10 (25% of the isolates) and TBG-10 (17% of the isolates) races were the two most commonly found races in 1990. They were widely scattered throughout the Great Plains and the eastern United States. Although these races are virulent on lines with *Lr*1 and *Lr*3, which are among the earliest identified leaf rust genes, they lack virulence to lines with some of the genes widely used in recent years. The four predominant M-- phenotypes in the 3-yr period were MBB-10 (17% in 1988, 6% in 1989, and 3% in 1990), MBG-10 (3% in 1988, 11% in 1989, and 25% in 1990), MDB-10 (8% in 1988, 5% in 1989, and 4% in 1990), and MFB-10 (9% in 1988, 12% in 1989, and 9% in 1990). The wide distribution of these phenotypes of M and T throughout areas 4–6 in 1988, 1989, and 1990 again suggests that these areas are a continuous south-north epidemiological unit as previously proposed (6–8). A few less common T-- and M-- phenotypes are avirulent on *Lr*10.

In previous years (5–7), the K-- coded races were some of the most frequently identified races in the total U.S. population. However, the frequency of this race group has decreased from the high of 39% in 1985 (6) to 5% in 1990 (Tables 1–3) of the total population.

Most of the C--, F--, N--, and P-- races were found in the eastern soft winter wheat region (areas 1–3) (Table 1). The exception was race CCB-10, which was the most commonly identified race from California (area 7) in these 3 yr. A few C-- and P-- races were found in the Great Plains (areas 4–6) between 1988 and 1990 (Table 2). The races B--, D--, J--, L--, and S-- individually comprise less than 0.5% of the population identified. Except for the S races, they were collected mainly from nurseries scattered around the country. The S-- races were identified from *A. cylindrica* collections made in the southern Great Plains in 1989 and 1990 (Table 2).

The incidence of virulence on lines with *Lr*11 increased significantly from 16% in 1987 (8) and 1988 to 62% in 1990 (Table 4). Virulence to lines with *Lr*11 was identified in 22 different virulence combinations in 1990 compared with nine combinations in 1988. This may reflect a selective advantage of this virulence attributable to an increase in the hectarage of cultivars with *Lr*11 (13). Fla 302, which has *Lr*11 (D. L. Long, *unpublished*), comprised about 20% of the southern soft red winter wheat hectarage in 1989.

The frequency of virulence to *Lr*24 has remained stable in recent years at 16% frequency in 1987 (8), 18% in 1988, and 17% in 1989 and 1990. *Lr*26 virulence increased in frequency from 6% in 1987 (8) to 15% in 1988, 13% in 1989, and 14% in 1990 (Table 4). Cultivars with *Lr*24 are widely grown in the southern Great Plains (10), and those with *Lr*26 are found from southern Texas to North Dakota and in California. Combined virulence to *Lr*24 and 26 was found in races MF- and TF-. The cultivar Siouxland has *Lr*24 and 26 (14) and is grown from central Texas to South Dakota; 80% of the isolates identified from Siouxland collections had this *Lr*24 and 26 combination.

Virulence to *Lr*9 increased from 1% in 1988 to 9% in 1989 and then decreased to 5% in 1990. Hectarage planted to Coker 9766 (*Lr*2a and 9 resistance) increased in areas 1 and 2 (D. L. Long, *unpublished*) where Coker 9766 was rusted in 1989 and 1990.

Virulence for *Lr*16 has significantly decreased from 17% in 1986 to 2% in 1990. In Texas, virulence to *Lr*16 occurred in 52% of isolates tested in 1986 but decreased to 18% in 1987 (10). The same was true in Canada, where virulence to *Lr*16 occurred in 6% of the

Table 3. Races of *Puccinia recondita* f. sp. *tritici* (Prt) collected from fields (F) and nurseries (N) in agroecological areas 7 and 8 of the United States in 1988, 1989, and 1990

	Percentages of isolates from indicated source								
	Area 7[b]					Area 8[b]			
	1988		1989	1990		1988		1989	1990
Prt code[a]	F	N	N	F	N	F	N	N	N
CBB-10	0	4	13	0	0	0	0	0	0
CCB	0	0	0	0	13	0	0	0	0
CCB-10	83	45	67	0	31	0	0	0	0
KBB-10	0	4	0	0	0	0	14	0	0
LBB-10,18	0	0	0	0	0	0	0	14	0
MBB	0	0	0	0	13	0	0	0	0
MBB-10	0	36	13	0	38	0	0	14	50
MBG-10	0	6	0	0	0	0	0	0	0
MCB-10	0	2	0	0	0	0	0	0	0
MCD-10	0	0	0	100	0	0	0	0	0
MFB-10	17	2	0	0	0	0	0	0	0
NBB	0	0	0	0	0	0	0	0	50
NBB-10	0	0	0	0	0	100	0	0	0
NBG-10,18	0	0	0	0	0	0	71	0	0
PBB-10	0	0	7	0	0	0	0	29	0
PBD	0	0	0	0	0	0	14	0	0
PDB-10	0	0	0	0	0	0	0	43	0
TBG-10	0	0	0	0	6	0	0	0	0
No. of isolates	6	47	15	2	16	1	7	7	2

[a] North American Prt races based on 12 North American differential lines (4) plus lines with *Lr*10 and *Lr*18.
[b] Agroecological areas are shown in Figure 1.

Table 4. Percentage of isolates of *Puccinia recondita* f. sp. *tritici* virulent to the single-gene differential lines used in the 1988–1990 surveys

Year	Area	Source	No. of isolates	Percentage of isolates virulent on *Lr* gene													
				1	2a	2c	3	3ka	9	10	11	16	17	18	24	26	30
1988	1	Field	4	100	50	75	100	25	0	75	75	0	0	25	25	25	25
1988	1	Nursery	140	86	29	45	99	9	4	94	24	1	0	10	14	6	9
1988	2	Field	19	84	0	95	89	84	0	21	53	0	0	95	0	0	84
1988	2	Nursery	43	81	5	95	70	51	2	63	51	0	2	77	0	0	51
1988	3	Nursery	11	100	55	73	100	18	18	100	18	0	0	0	0	0	18
1988	4	Field	74	51	23	23	58	0	0	58	14	1	0	0	14	3	0
1988	4	Nursery	68	93	63	63	94	0	0	96	6	1	4	0	22	9	0
1988	5	Field	34	94	50	50	100	0	0	100	0	3	0	0	24	18	0
1988	5	Nursery	76	93	38	38	100	0	0	100	0	1	3	0	45	36	0
1988	6	Field	20	95	80	80	100	0	0	100	0	0	10	10	10	15	0
1988	6	Nursery	68	96	57	63	100	6	0	96	6	0	3	4	28	15	6
1988	7	Field	6	17	0	0	100	0	0	100	0	0	0	0	17	100	0
1988	7	Nursery	47	47	4	4	100	0	0	100	6	0	0	0	2	49	0
1988	8	Field	1	100	0	100	0	0	0	100	0	0	0	0	0	0	0
1988	8	Nursery	7	86	14	100	29	0	0	86	71	0	14	71	0	0	0
1989	1	Field	25	76	40	48	100	8	8	80	48	0	0	16	12	12	8
1989	1	Nursery	377	84	35	44	99	9	10	87	49	1	3	12	15	13	9
1989	2	Field	34	82	18	76	100	65	26	76	68	0	0	59	0	0	65
1989	2	Nursery	40	90	18	80	70	35	13	90	43	0	8	55	3	3	35
1989	3	Field	49	78	22	67	100	47	45	84	41	0	0	49	8	8	45
1989	3	Nursery	86	84	52	63	99	12	7	88	33	0	0	12	15	9	10
1989	4	Field	58	86	72	72	90	2	0	88	5	0	16	2	22	12	2
1989	4	Nursery	72	88	57	57	100	0	4	96	8	0	0	4	29	19	0
1989	5	Field	29	90	62	62	100	0	0	100	10	0	0	0	21	21	0
1989	5	Nursery	38	84	50	50	100	0	0	100	8	0	3	0	18	18	0
1989	6	Field	44	89	66	70	100	5	2	95	30	0	2	7	16	14	5
1989	6	Nursery	101	89	63	67	100	4	3	99	35	0	2	4	24	18	4
1989	7	Nursery	15	20	0	7	100	0	0	100	0	0	0	0	0	67	0
1989	8	Nursery	7	100	0	71	86	0	0	100	0	0	0	14	43	0	0
1990	1	Field	65	80	35	37	98	2	25	62	89	0	0	29	0	3	2
1990	1	Nursery	254	86	28	37	97	10	9	80	85	0	2	26	4	3	10
1990	2	Field	22	86	23	68	95	45	9	91	77	0	0	45	0	5	45
1990	2	Nursery	29	79	17	34	86	14	0	93	55	0	0	24	14	24	14
1990	3	Field	24	71	17	29	96	13	4	50	75	0	0	17	0	0	13
1990	3	Nursery	67	76	19	42	100	22	7	73	58	0	0	25	7	12	22
1990	4	Field	74	91	43	43	91	0	0	91	26	0	23	0	35	27	0
1990	4	Nursery	115	95	41	41	100	0	0	98	47	3	0	0	34	24	0
1990	5	Field	94	89	61	62	95	0	0	96	51	3	2	3	27	19	0
1990	5	Nursery	79	82	63	66	89	0	0	90	54	0	3	15	28	23	0
1990	6	Field	7	100	57	57	100	0	0	100	43	0	0	14	43	14	0
1990	6	Nursery	69	86	59	64	90	0	0	91	58	0	6	20	23	26	1
1990	7	Field	2	100	0	0	100	0	0	100	0	0	100	0	0	100	0
1990	7	Nursery	16	56	6	6	100	0	0	75	6	0	0	0	0	44	0
1990	8	Nursery	2	100	0	50	50	0	0	50	0	0	0	0	0	0	0

isolates tested in 1987 but decreased to zero by 1989 (2). In 1986, 80% of the *Lr*16 virulent isolates were identified from the cultivar PRO Brand 812, which has *Lr*16 resistance (13) but is no longer grown to any extent.

During the 3-yr period, no virulence was found on the following 12 resistant series entries: Thatcher isolines *Lr*19, 21 and 29; Aepoglom; AZ-FH 50-4-1-1-1; AZ-FH 51-2-2-1; Buck Manantial; CI 17906 (*Lr*9 and 24); Lex; RL 6059 (*Lr*33 and 34); Stoa; and Transec (*Lr*25).

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