Races of *Puccinia graminis* f. sp. *tritici* in the United States and Mexico in 1981

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ABSTRACT

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Wheat stem rust was light in 1981. Rust was found overwintering in three locations in the southern United States. Disease spread was retarded by dry weather and advanced crop maturity in the northern winter wheat areas. Resistant cultivars prevented disease development in the spring and durum wheat area. Race 151-QFB comprised 39% of 596 isolates obtained from 230 rust collections; 15-TNM, 36%; 17-HDL, 7%; 11-RCR, 5%; 17-HNL, 3%; 151-QSH, 2%; 15-TDM, 15-TLM, 151-QCB, 113-RKQ, 113-RTQ, 29-HJC, and 56-MBC, 1% or less of the total isolates identified. No virulence was found in bulked uredospore collections for seedlings with *Sr* genes 13, 22, 24, 25, 26, 27, 29, 30, 31, 32, 33, Gt, Tt-2, and Wld-1.

Wheat stem rust caused by *Puccinia graminis* Pers. f. sp. *tritici* is a major disease of wheat, *Triticum* spp., in the United States and Mexico. The disease is currently controlled in North America by the use of resistant cultivars. Specific host genes for resistance (designated *Sr* genes) provide the basis for much of this control. Changes, however, for virulence on cultivars possessing these host genes for resistance may occur in the pathogen population, causing a previously resistant cultivar to become susceptible. In order to maintain and improve the resistance in commercially grown cultivars, it is necessary to detect changes in the pathogen population as early as possible and provide adequate resistance in new cultivars. The process of breeding a wheat cultivar may require 8–12 yr or more; therefore, continual and current monitoring of the pathogen population is necessary so that resistance is effective at cultivar release. In the case of wheat stem rust, such studies have been conducted annually in the United States since 1918. Since 1930, there have been only four major regional epidemics (1935, 1937, 1953, and 1954), with none in the past 27 yr. This is due in part to the early recognition of new combinations of virulence and to the successful effort to breed resistant cultivars before the pathogen causes an epidemic. Results of the 1981 survey are presented here.

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MATERIALS AND METHODS

A collection consisted of a varying number of stems or leaves bearing *P. graminis* f. sp. *tritici* uredia from a field, nursery, individual plant, or cultivar. Upon receipt of uredial collections, two spore samples were collected. One sample was used to inoculate 7-day-old seedlings of wheat, *Triticum aestivum* L. em Thell 'McNair 701' (CI 15288), 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 uredium were saved and reincubated to permit loose uredospores to germinate. Uredospores were collected separately 3–4 days later from up to three uredia (each such collection an isolate); each uredium provided enough spores to inoculate a differential host series. Wheat lines with the single gene for *Sr*5, 6, 7b, 8, 9a, 9b, 9d, 9e, 10, 11, 13, 15, 16, 17, Tt-1, and Tmp were evaluated for their response to each rust isolate (4).

The second portion of spores, bulked with those from other collections made in the same area at about the same time, was used to inoculate the "universally" resistant series—lines with the host genes *Sr*22, 24, 25, 26, 27, 29, 30, 31, 32, 33, Gt, Tt-2, and Wld-1 and the cultivars Era, Cando, Olaf, Leeds, and Ward. These lines and cultivars have been selected over a period of years as resistant to stem rust (4).

A lightweight mineral oil served as a spore carrier. Inoculated plants were placed in a dew chamber overnight at 18 C, followed by 3 hr of fluorescent light (10,000 lux) as the temperature gradually rose to 30 C. Plants were then placed in an 18–28 C greenhouse. Infection types were observed after 10–14 days. Races were described by the Cereal Rust Laboratory system, which uses host differential single-gene lines (Table 1).

The data were arranged into nine ecological areas (Fig. 1), based on the source location of collections. Area 1S has mainly fall-sown spring wheats; area 1N, mixed wheat types; area 2, mostly soft red winter wheat; area 3, southern hard red winter wheat; area 4, mostly soft red winter wheat and scattered barberries; area 5, mixed wheat types; area 6, hard red spring and durum wheat; area 7, northern hard red winter wheat; and area

Table 1. A key defining the Cereal Rust Laboratory races of *Puccinia graminis* f. sp. *tritici*

Code[y]	Response of host with *Sr* genes[z]			
Set 1:[y]	5	9 d	9 e	7 b
Set 2:	11	6	8	9 a
Set 3:	Tt-1	9 b	13	10
B	R	R	R	R
C	R	R	R	S
D	R	R	S	R
F	R	R	S	S
G	R	S	R	R
H	R	S	R	S
J	R	S	S	R
K	R	S	S	S
L	S	R	R	R
M	S	R	R	S
N	S	R	S	R
P	S	R	S	S
Q	S	S	R	R
R	S	S	R	S
S	S	S	S	R
T	S	S	S	S

[y]Combination of host responses from set 1 determines the first letter of code, set 2 the second, and set 3 the third.

[z]R = host not susceptible; S = host susceptible.

8, mostly soft winter wheats and spring wheats.

RESULTS AND DISCUSSION

Wheat stem rust was scattered throughout the United States in 1981. Overwintering stem rust was found in only three nurseries (in southern Texas, southern Louisiana, and southern Alabama). No rust was reported by cooperators in Mexico. Traces of stem rust were found in commercial winter wheat fields, but the disease spread was retarded by dry weather and advanced crop maturity. Stem rust was widespread and severe in trap plots of susceptible spring wheats throughout Minnesota and North Dakota; however, no stem rust developed on the commonly grown cultivars, which remained resistant to stem rust.

Data from the 1981 race survey (Table 2) are presented for eight ecological areas and the U.S. total. Data from collections made from commercial fields and naturally occurring hosts were separated from those made in nurseries and plots. No data were included from collections made in or near nurseries known to be inoculated.

The most prevalent race was 151-QFB (39% of all isolates). A member of the race 15 group has been the most common race since 1965. From 1948 to 1965, the most frequently identified races were 15 and 56. Part of the increase in frequency of 151-QFB is due to the large number of isolates in 1981 (206) from the southeastern

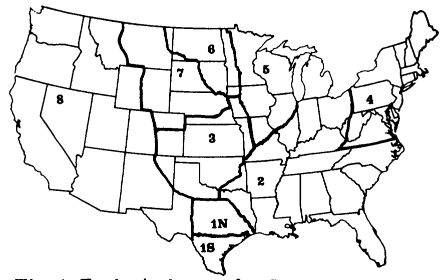

Fig. 1. Ecological areas for *Puccinia graminis* f. sp. *tritici* in the United States. Area 1S, mainly fall sown spring wheat; 1N, mixed wheat types; 2, soft red winter wheat; 3, southern hard red winter wheats; 4, mostly soft red winter wheat and barberries; 5, mixed wheat types and widely dispersed fields; 6, hard red spring and durum wheats; 7, northern hard red winter wheat; and 8, mostly soft winter wheats and spring wheats.

Table 2. Summary of the identified races of *Puccinia graminis* f. sp. *tritici* by area and source of collection in 1981

		Number of		Percent of isolates of each race[b]													
				15			151			113		11	17		29	56	
Area[a]	Source	Collection	Isolates	TDM	TLM	TNM	QCB	QFB	QSH	RKQ	RTQ	RCR	HDL	HNL	HJC	MBC	Others[c]
United States	Field	42	110	···	···	16	2	46	1	2	···	6	12	3	···	6	6
	Nursery	188	486	*[d]	*	41	1	37	2	1	1	4	6	3	*	···	3
	Total	230	596	*	*	36	1	39	2	1	1	5	7	3	*	1	4
1S	Field	1	1	···	···	···	···	100	···	···	···	···	···	···	···	···	···
	Nursery	8	8	···	···	···	···	38	···	···	···	···	···	50	13	···	···
	Total	9	9	···	···	···	···	44	···	···	···	···	···	44	11	···	···
1N	Field	3	9	···	···	···	···	100	···	···	···	···	···	···	···	···	···
	Nursery	13	35	···	···	14	···	77	···	···	···	···	9	···	···	···	···
	Total	16	44	···	···	11	···	82	···	···	···	···	7	···	···	···	···
2	Field	9	26	···	···	···	8	35	4	···	···	15	38	···	···	···	···
	Nursery	68	180	···	···	11	2	60	*	2	2	11	9	4	···	···	···
	Total	77	206	···	···	9	2	56	1	2	2	12	13	3	···	···	···
3	Nursery	20	49	···	···	63	···	14	12	···	···	···	8	2	···	···	···
4	Field	5	10	···	···	···	···	50	···	20	···	···	···	···	···	30	···
5	Field	17	44	···	···	41	···	36	···	···	···	7	7	7	···	2	···
	Nursery	18	52	4	···	67	···	19	···	···	···	···	···	10	···	···	···
	Total	35	96	2	···	55	···	27	···	···	···	3	3	8	···	1	···
6	Field	4	11	···	···	···	···	100	···	···	···	···	···	···	···	···	···
	Nursery	56	147	···	1	73	···	17	3	···	···	1	4	···	···	···	*[e]
	Total	60	158	···	*	68	···	23	3	···	···	1	4	···	···	···	*
8	Field	3	9	···	···	···	···	···	···	···	···	···	···	···	···	33	67
	Nursery	5	15	···	···	···	···	···	···	···	···	···	···	···	···	···	100
	Total	8	24	···	···	···	···	···	···	···	···	···	···	···	···	13	87

[a] Area 1S (south Texas), 1N (central Texas), 2 (eastern United States), 3 (southern Great Plains), 4 (northeastern states), 5 (Wisconsin, Iowa, and eastern Minnesota), 6 (Dakotas and western Minnesota), and 8 (western United States).
[b] Cereal Rust Laboratory races (see Table 1).
[c] From Washington: BBC, 13 isolates; MDC 3; CBC 3; RCC and GBC 1.
[d] * Less than 0.6%.
[e] An orange mutant race KBC was also recovered.

Table 3. Incidence of virulence in *Puccinia graminis* f. sp. *tritici* isolates to the resistance of single gene differential isolines used in the 1981 survey

	Percentage of isolates virulent on *Sr* gene[b]														
Area[a]	5	6	7b	8	9a	9b	9d	9e	10	11	15	16	17	Tt-1	Tmp
1S	44	11	56	100	44	0	100	0	11	44	100	100	56	44	0
1N	93	0	18	100	82	7	100	11	11	11	89	100	82	18	11
2	84	5	41	86	4	17	100	9	22	16	91	100	77	41	9
3	90	12	73	100	14	12	100	63	76	76	37	100	71	73	63
4	100	20	50	70	70	20	70	0	30	0	100	100	80	20	0
5	89	0	73	96	30	3	99	57	61	64	43	100	54	72	58
6	96	2	73	98	26	3	100	68	72	70	32	100	70	73	68
8	29	0	42	13	42	0	8	0	100	0	96	92	96	0	0
United States 1981	87	4	56	90	46	9	96	37	48	42	63	100	72	54	37
United States[c] 1980	92	8	64	84	39	9	92	48	64	44	49	100	56	61	53
United States[d] 1979	93	20	71	88	31	20	97	48	60	56	51	100	45	65	52

[a] Area 1S (south Texas), 1N (central Texas), 2 (eastern United States), 3 (southern Great Plains), 4 (northeastern United States), 5 (Wisconsin, Iowa, and eastern Minnesota), 6 (Dakotas and western Minnesota), 8 (western United States).
[b] All isolates were avirulent on *Sr*13.
[c] Roelfs et al (1).
[d] Roelfs et al (3).

United States, where QFB and the similar QCB have frequently been isolated in recent years. The scarcity of the race 15 group in 1980 (3) may have caused it to be eliminated in some parts of the country. The first isolates identified from collections made in nurseries in the southernmost counties of Texas, Alabama, and Louisiana were race 151-QFB, suggesting that this race overwintered in the southernmost wheat-growing areas of the United States. Races 151-QFB and -QCB are virulent on *Sr*15, *Sr*16, and *Sr*17 but their avirulence on *Sr*6, 10, 11, Tt-1, and Tmp prevent them from being a major threat to the commercial production of wheat in North America.

Race 15-TNM, historically an important race, was first found in 1981 in collections from northern Texas and was the predominant race in the northern Great Plains. This race is virulent on *Sr*16 and Tmp and avirulent on *Sr*15. In 1981, 56% of the cultures of 15-TNM were virulent on *Sr*17. In 1979 and 1980, only 11% were virulent on *Sr*17. This increase in *Sr*17 virulence causes concern because some of the spring bread wheats contain *Sr*17 in addition to other sources of resistance; however, TNM currently lacks the necessary combinations of virulence for the commercial cultivars. Race 151-QSH, virulent on *Sr*6, 11, and 17, comprised only 2% of the isolates, which may indicate a lack of aggressiveness over the wide range of environmental conditions present.

Races 15-TDM, 15-TLM, 17-HDL, 17-HNL, 29-HJC, 56-MBC, 113-RKQ, 113-RTQ, 11-RCR, and 151-QCB continue to be a minor portion of the pathogen population. The 21 isolates from Washington were comprised of BBC, 13 isolates; MDC and CBC, three isolates each; and one isolate each of GBC and RCC. This type of variation is typical of a sexually derived pathogen population (2).

No virulence was detected for seedling wheats containing any of the genes *Sr*13, 22, 24, 25, 26, 27, 29, 30, 31, 32, 33, Gt, Tt-2, or Wld-1. The important spring wheat cultivars Era and Olaf and durum wheat cultivars Cando, Leeds, and Ward were also resistant as seedlings. The incidence of virulence for the differential host resistance genes tested is shown in Table 3. Compared with 1979 and 1980, the increase in 1981 *Sr*15 and 17 virulence is mainly the result of an increase in QFB race frequency.

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