Virulence of *Puccinia recondita* in the Pacific Northwest

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ABSTRACT

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Virulence for resistance genes *Lr1, Lr2a, Lr2b, Lr2d, Lr3a, Lr3bg, Lr10, Lr15, Lr16, Lr17,* and *Lr18* was found among collections of *Puccinia recondita* f. sp. *tritici* (the causal agent of wheat leaf rust) from Washington and adjacent Idaho and Oregon. No virulence for genes *Lr3b, Lr3ka, Lr9, Lr11, Lr19, Lr24, LrEG,* or *LrT* was detected. The races of *P. recondita* were most clearly differentiated on isolines having *Lr1* and *Lr2a*. Western *P. recondita* race 1 (WPR-1) was avirulent on both isolines, WPR-2 was avirulent on *Lr2a* and virulent on *Lr1*, WPR-3 was avirulent on *Lr1* and virulent on *Lr2a*, and WPR-4 was virulent on both isolines. Race WPR-2 is widely distributed throughout the Pacific Northwest east of the Cascade Mountains and is currently the most important race. More than 99% of the wheat acreage and all newly released cultivars in the Pacific Northwest are susceptible to race WPR-2.

Leaf rust of wheat (*Triticum aestivum*), caused by *Puccinia recondita* Rob. ex Desm. f. sp. *tritici* Eriks., has become increasingly more important in Washington within the last 15 yr. Little is known about the virulence of *P. recondita* in the Pacific Northwest. Johnston et al (3) reported that race UN 11, which was avirulent for resistance genes *Lr1* and *Lr2a*, was prevalent in Washington from 1936 to 1960. Browder and Eversmeyer (2), using 1972 data, reported that no collections of *P. recondita* from the Western United States (California, Washington, Oregon, Nevada, Utah, and Arizona) had virulence for gene *Lr2a* but six of seven collections had virulence for gene *Lr1*. However, none of these collections were from the Pacific Northwest. The purpose of our study was to identify the virulence genes present in the Pacific Northwest pathogen population and to evaluate local cultivars for specific resistance genes.

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MATERIALS AND METHODS

Uredospores of *P. recondita* were collected from commercial fields and experimental plots of wheat in north-central Oregon, northern Idaho, and Washington in 1976 and 1977 and used to inoculate seedlings of a susceptible cultivar (usually the same cultivar from which the collection was made). The inoculated plants were placed in a dew chamber at 10–12 C for 12–16 hr. After the dew period, the inoculated plants were moved to a greenhouse bench and placed inside booths designed to keep the collections isolated from one another. Greenhouse temperatures were programmed to change gradually from 10 C at 0200 hr to 25 C at 1400 hr. Natural light was supplemented with 2,000–2,400 lux from Sylvania Gro-Lux fluorescent lights operating on a 16-hr photoperiod. The spores that developed on these seedlings were then used to inoculate seedlings of isolines with single genes for leaf rust resistance (5) to determine the virulence of each collection.

Virulence of the collections was measured by rating the infection types that developed on the primary leaf (first seedling leaf) of the isoline seedlings. Infection types were rated according to the size of the sporulating area, using the 0–9 scale (0 = no sporulation to 9 = largest sporulating area) developed by Browder (1). Mixed infection types were designated with the symbols of McNeal et al (4).

Races were differentiated according to their virulence on the isolines. Once identified, new races were considered as type cultures and given a Western *Puccinia recondita* (WPR) number in the order in which they were identified. When possible, depending on the virulence of the race and the susceptibility of the cultivar, inoculum of each race was

increased on seedlings of selective wheat cultivars. Spores of each race were collected on separate days with a vacuum spore collector and air-dried before storage. Spores were stored in snap-cap vials at 5 C for short periods (1 mo or less) and in sealed vials under liquid nitrogen for longer periods. Spores stored under liquid nitrogen were heat-shocked for 5 min at 45 C before use as inoculum. The races were used to evaluate the resistance of local cultivars in the seedling stage.

RESULTS

Virulence for resistance genes *Lr1, Lr2a, Lr2b, Lr2d, Lr3a, Lr3bg, Lr10, Lr15, Lr16, Lr17,* and *Lr18* was found among the collections of *P. recondita* (Table 1). No collections were virulent on genes *Lr3b, Lr3ka, Lr9, Lr11, Lr19, Lr24, LrEG,* or *LrT.*

Four races of *P. recondita* were identified and were most clearly differentiated on isolines *Lr1* and *Lr2a* (Table 1). Race WPR-1 is similar to a race first identified in the Pacific Northwest in 1926 (3); it was virulent on *Lr16* and avirulent on *Lr1, Lr2a, Lr3a, Lr3bg,* and *Lr15.* Races WPR-2, 3, and 4 were virulent on *Lr3a, Lr3bg,* and *Lr15* but avirulent on *Lr16.* Race WPR-2 was virulent on *Lr1* and *Lr17* but avirulent on *Lr2a.* This race was first isolated from late-maturing Norco wheat in 1976 from experimental plots near Pullman, WA. Race WPR-3 was collected near Mt. Vernon, WA, in early 1977. It was virulent on *Lr2a* but avirulent on *Lr1* and *Lr18.* This is the first report of virulence on *Lr2a* in the Pacific Northwest (L. E. Browder, *personal communication*). Race WPR-4 was isolated in very low proportions from a greenhouse culture of race WPR-2 in 1978. It was virulent on *Lr1, Lr2a, Lr17,* and the cultivar Chancellor (CI 12333), which was resistant to the other three races.

Dirkwin, Hyslop, McDermid, Norco, and Walladay appear to have resistance gene *Lr1* (Table 2), which provides protection against races WPR-1 and WPR-3 but not against races WPR-2 and WPR-4. These cultivars were considered resistant before the increase of race WPR-2. Daws and Luke were a mixture of lines with different leaf rust resistance; most plants were resistant to races WPR-1 and WPR-3 but all were susceptible to races WPR-2 and WPR-4. No local cultivars appeared to have gene *Lr2a* or a combination of genes *Lr1* and *Lr2a.* Therefore, races WPR-3 and WPR-4 attacked the same local cultivars as races WPR-1 and WPR-2, respectively.

Borah, Fieldwin, Wampum, Wandell, and Yamhill lacked the high resistance expressed by most *Lr* genes but were moderately resistant to all four WPR races, as evidenced by their range of infection types. Wared was the only local cultivar that was highly resistant to the

Table 1. Infection types produced by four Pacific Northwest races of *Puccinia recondita* on 19 wheat isolines with different genes for leaf rust resistance

Isoline	Accession number	Infection type[a] Race WPR-1	Race WPR-2	Race WPR-3	Race WPR-4
Lr2b	R.L. 6019	8	8	8	8
Lr2d	R.L. 6001	8	8	8	8
Lr10	R.L. 6004	8	8	8	8
Lr1	R.L. 6003	0	8	0	8
Lr2a	R.L. 6016	0	0	8	8
Lr3a	R.L. 6002	0	8	8	8
Lr3bg	R.L. 6042	0	8	8	8
Lr15	R.L. 6052	0	8	8	8
Lr16	R.L. 6005	8	0	0	1 = 3
Lr17	R.L. 6008	0	8	0	6
Lr18	R.L. 6009	8	8	3	8
Lr3b	...	0 = 3	0 = 2	0 = 2	0
Lr3ka	R.L. 6007	0 = 3	1 = 3	0 = 3	0 = 1
Lr9	R.L. 6010	0	0 = 1	0	0
Lr11	R.L. 6053	0 = 5	0 = 5	0 = 3	0 = 3
Lr19	R.L. 6040	0	0	0	0
Lr24	...	0	0	0	0
LrEG	R.L. 6048	1 = 3	0 = 3	0 = 2	1 = 2
LrT	R.L. 6049	3	3	0 = 2	0 = 1

[a] Infection type indicates size of sporulating area from 0 = no sporulation to 9 = largest sporulating area. Equal sign (=) denotes range of infection types on same leaf. Infection type preceding symbol is predominant type. Infection types with sporulating areas estimated at 0–3, 4–6, and 7–9 are classified as low (resistant/avirulent), intermediate, and high (susceptible/virulent), respectively.

Table 2. Infection types produced by four Pacific Northwest races of *Puccinia recondita* on the predominant wheat cultivars in the Pacific Northwest

Cultivar	CI number[b]	Type[c]	Infection type[a] Race WPR-1	Race WPR-2	Race WPR-3	Race WPR-4
Daws	17419	SWW	0, 8	8	0, 8	8
Dirkwin	17745	SWS	0	8	0	8
Hyslop	14564	SWW	0	8	0	8
Luke	14586	SWW	0, 8	8	0, 8	8
McDermid	14565	SWW	0	8	0	8
Norco	14482	SWF	0	8	0	8
Walladay	17759	SWF	0	8	0	8
Wared	15926	HRS	0 = 3	0	0	0
Borah	17267	HRS	0 = 8	8 = 0	5 = 0	8 = 0
Fielder	17268	SWS	0 + 8	8	8 = 0	8 = 0
Fieldwin	17425	SWS	0 + 8	8 = 0	6 = 0	8 = 0
Wampum	17691	HRS	0 = 6	8 = 0	8 = 0	0 = 6
Wandell	15070	DUR	6 = 0	0 = 3	0 = 8	5 = 0
Yamhill	14563	SWW	8 = 5	8 = 5	8 = 5	0 = 3
Barbee	17417	SWW	8	8	8	8
Faro	17590	SWW	8	8	8	8
Federation	4734	SWS	8	8	8	8
Gaines	13448	SWW	8	8	8	8
Lemhi	11415	SWS	8	8	8	8
Marfed	11919	SWS	8	8	8	8
Moro	13740	SWW	8	8	8	8
Nugaines	13968	SWW	8	8	8	8
Omar	13072	SWW	8	8	8	8
Raha	14485	SWW	8	8	8	8
Raeder	17418	SWW	8	8	8	8
Rew	17294	SWW	8	8	8	8
Sprague	15376	SWW	8	8	8	8
Springfield	14589	SWS	8	8	8	8
Stephens	17569	SWW	8	8	8	8
Twin	14588	SWS	8	8	8	8
Urquie	17413	SWF	8	8	8	8
Wanser	13844	HRS	8	8	8	8

[a] Infection type indicates size of sporulating area from 0 = no sporulation to 9 = largest sporulating area. Comma (,) denotes mixture of plants with different infection types; plus sign (+) denotes two distinct infection types on same leaf; equal sign (=) denotes range of infection types on same leaf. Infection type preceding symbol is predominant type. Infection types with sporulating areas estimated at 0–3, 4–6, and 7–9 are classified as low (resistant/avirulent), intermediate, and high (susceptible/virulent), respectively.

[b] USDA Cereal Investigation number.

[c] DUR = durum, HRS = hard red spring, SWF = soft white facultative, SWS = soft white spring, SWW = soft white winter.

four WPR races. The remaining cultivars listed in Table 2 were susceptible to all four WPR races and are very susceptible in the field.

DISCUSSION

Race WPR-1 is found throughout the wheat-growing regions of the Pacific Northwest, whereas race WPR-2 has been found only east of the Cascade Mountains. We believe that race WPR-1 was the predominant race before cultivars with gene *Lr1* were widely grown and that the increased production of these cultivars provided selection pressure for an increase of race WPR-2. Washington Selection 101 (CI 13438) is a common parent for cultivars in the Pacific Northwest and appears to be the source of the *Lr1* gene in Daws, Hyslop, Luke, McDermid, Norco, and Walladay.

Race WPR-2 is presently widely distributed throughout the Pacific Northwest east of the Cascade Mountains and is now the most important race of *P. recondita* in the region. Greenhouse tests showed that it can attack all but one of the commercial cultivars in the Pacific Northwest, including all newly released cultivars (Daws, Dirkwin, Faro, Raeder, Stephens, and Walladay). This race was first identified late in 1976. It was prevalent in 1977 but was not destructive because the weather was too dry for leaf rust to develop to high intensities. In 1978, however, rust caused by WPR-2 developed to epidemic levels and significantly damaged wheat cultivars in eastern Washington and Oregon and in northern Idaho.

Race WPR-3 was found only in western Washington. It attacked the same Pacific Northwest cultivars as race WPR-1 because none of these cultivars has gene *Lr2a*. Race WPR-4 has not yet been collected directly from the field but probably occurs at a low percentage in the pathogen population.

The races identified in this study probably do not reflect the total genetic variability of *P. recondita* in the Pacific Northwest but do reflect the predominant virulence of the pathogen. The shift from race WPR-1 to race WPR-2 as cultivars with gene *Lr1* became more widely grown points out the effect of specific resistance genes in regulating the pathogen population.

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