# Virulence of *Puccinia recondita* and Cultivar Relationships in Texas from 1985 to 1987

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**ABSTRACT**

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Texas was divided into eight agroecological areas of adaptation for wheat leaf rust. Those areas were the High Plains, Rolling Plains, Blacklands, Gulf Coast, east, southwest, south-central, and south Texas. Isolates of *Puccinia recondita* were collected in each area over a 2-yr period. The isolates were characterized into 39 virulence/avirulence phenotypes, which were grouped into 10 Unified Numeration (UN) races. The most prevalent race was UN 5, which made up 43% of the 1,065 isolates collected. During 1985–1986, 52% of the isolates sampled were virulent to *Lr*16, whereas only 18% were virulent to *Lr*16 during 1986–1987. The decline in the percentage of isolates virulent to *Lr*16 paralleled a decrease in plantings of the cultivar Probrand 812. Races carrying virulence to *Lr*24 became widespread throughout Texas during 1986–1987, following an increase in acreage of cultivars carrying the *Lr*24 gene. Races carrying virulence to *Lr*3, 11, 18 and *Lr*3, 9, 3ka in race UN 2, and *Lr*1, 2a, 2c, 10, 17 in race UN 9 were isolated for the first time from Texas. No correlation was found between the number of virulence genes and the frequency of races.

During 1984–1985, leaf rust was epidemic on wheat in Texas and reduced grain yields by 40% or more on susceptible cultivars (12). The loss in forage production also was large, but went unaccounted. Because of the endemic nature of leaf rust in Texas, breeding long-lasting rust resistance into wheats with high grain and forage potential is a major objective of the Texas Agricultural Experiment Station wheat improvement program. However, in order to better understand which resistance gene combinations to incorporate into breeding material, it is advantageous to know the frequency of virulence genes in the pathogen population. This is particularly true for leaf rust of wheat, caused by *Puccinia recondita* Rob. ex Desm., because of wide variability in the fungal population (7,15).

Long et al (7–10) grouped Texas, Oklahoma, and New Mexico into one agroecological area of adaptation for *P. recondita*, based on geographic, environmental, and wheat classification similarities. In Texas, especially in the central and southern portions of the state, leaf rust typically infects in the fall and overwinters in colonized leaves (3,4). Throughout the winter months, plants can often be found that have no evidence of leaf rust on the newer leaves, but have sporulating leaf rust pustules on the older leaves (Marshall, *unpublished observation*). When such plants are removed from the field and brought into the warm conditions of the greenhouse, the newer leaves typically exhibit rust pustules within 4–7 days. In an effort to better understand changes that may occur during overwintering, Marshall (11) found that cooler temperatures (such as those during overwintering in Texas) can indirectly influence virulence frequency in races of *P. recondita*.

The objective of this study was to characterize the virulence of the *P. recondita* population in Texas by geographical areas, and to relate this to certain wheat cultivars in order to better discern agroecological areas of adaptation.

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## MATERIALS AND METHODS

Texas was divided into eight areas of adaptation based on type of wheat, sowing time, and geographic and environmental parameters (Fig. 1). The wheat cultivars sown over most of the areas were hard red winter. However, soft red winter wheat cultivars were sown predominantly in east Texas and the Gulf Coast. Wheat sowing typically begins in the more northern and western areas of the state in early September and ends in the southern parts of the state in early December.

Urediniospore collections were made throughout the state at various times during the year while making surveys of the wheat crop. The surveys followed a planned, serpentine-type route, stopping at commercial fields every 20 miles. All production areas were not surveyed the same number of times. As a result, the total number of collections from each area was variable. All collections were transported back to the laboratory in Dallas, where the urediniospores were used to inoculate seedlings of cultivar Thatcher (CI 10003) that had been treated with chlormequat chloride to ensure a more compact plant. After 12 days, urediniospores from a single uredinium were collected and inoculated onto a set of Thatcher near-isogenic lines and placed in a dew chamber for a 14-hr dark period at 18 C. The set of Thatcher near-isogenic lines used were *Lr*1, 2a, 2c, 3, 3ka, 9, 10, 11, 16, 17, 18, 24, 26, and 30 (15). The inoculated plants were placed on greenhouse benches at 23–26 C after the dew chamber treatment. Infection types were recorded 10–12 days following inoculation and were classified as types ; (fleck), 0, 1, and 2, indicating avirulent reactions, and types 3 and 4 indicating virulent reactions (6).

## RESULTS AND DISCUSSION

There were 1,065 urediniospore collections characterized over the two growing seasons (Table 1). The percentages collected from each area were Blacklands, 39%; Gulf Coast, 14%; Rolling Plains, 13%; south-central Texas, 13%; southwest Texas, 8%; High Plains, 6%; south Texas, 4%; and east Texas, 3%.

The isolates were characterized into 39 virulence combinations and grouped into 10 UN races (1,5). The UN 5 phenotype made up 43% of the total number of isolates collected over both years. During 1985–1986, the most common UN 5 virulence formula was p1,3,10,16. This virulence combination made up 52% of

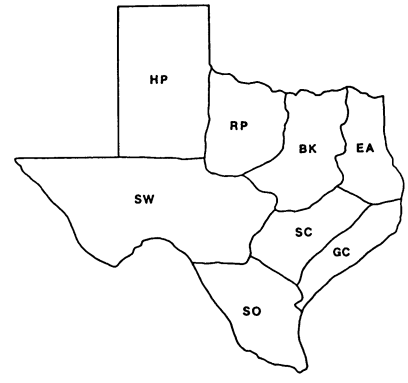


**Fig. 1.** Agroecological areas of adaptation for *Puccinia recondita* in Texas: HP = High Plains, RP = Rolling Plains, BK = Blacklands, EA = east Texas, SW = southwest Texas, SC = south-central Texas, GC = Gulf Coast, and SO = south Texas.

the UN 5 phenotype in that year, but only 18% during 1986–1987. Long et al (9) reported the rapid buildup in isolates carrying *Lr*1 and *Lr*16 virulence in the southern Great Plains, and Texas in particular. This virulence increased following widespread plantings of the cultivar Probrand 812, which occupied 63% of the central Texas acreage during 1984–1985 (12). Schafer and Long (16) suggested that the virulence combination p1,3,10,16 was possibly initially selected

**Table 1.** Virulence combinations of *Puccinia recondita* on wheat in Texas during the 1985–1986 and 1986–1987 growing seasons

| UN race[a] and virulence formula | No. of isolates per production area and year[b] | | | | | | | | | | | | | | | | Total over years |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HP | | RP | | BK | | SC | | SW | | EA | | GC | | SO | | |
| | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | |
| **UN 2** | | | | | | | | | | | | | | | | | |
| 3,10 | 0 | 0 | 0 | 3 | 3 | 1 | 1 | 3 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 15 |
| 3,11 | 1 | 0 | 1 | 5 | 10 | 19 | 2 | 5 | 1 | 1 | 0 | 1 | 4 | 0 | 0 | 0 | 50 |
| 3,24 | 0 | 1 | 0 | 8 | 0 | 24 | 0 | 6 | 1 | 4 | 0 | 1 | 1 | 2 | 1 | 3 | 52 |
| 3,10,11 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 9 |
| 3,10,24 | 0 | 2 | 0 | 3 | 1 | 7 | 2 | 3 | 1 | 5 | 0 | 0 | 3 | 2 | 0 | 0 | 29 |
| 3,10,26 | 0 | 1 | 0 | 4 | 0 | 9 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 19 |
| 3,11,18 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 3,9,3ka | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 5 |
| UN 2 total | 1 | 4 | 1 | 24 | 15 | 67 | 6 | 21 | 3 | 12 | 0 | 4 | 10 | 8 | 1 | 5 | 182 |
| **UN 3** | | | | | | | | | | | | | | | | | |
| 2c,3,3ka,18 | 0 | 0 | 1 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 7 |
| **UN 5** | | | | | | | | | | | | | | | | | |
| 1,3,10 | 2 | 1 | 3 | 10 | 15 | 25 | 10 | 11 | 4 | 5 | 2 | 0 | 4 | 0 | 1 | 1 | 94 |
| 1,3,10,11 | 0 | 0 | 0 | 2 | 0 | 6 | 0 | 4 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 14 |
| 1,3,10,16 | 10 | 1 | 18 | 3 | 47 | 22 | 9 | 5 | 2 | 2 | 7 | 1 | 33 | 6 | 3 | 0 | 169 |
| 1,3,10,17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 3 |
| 1,3,10,24 | 4 | 1 | 1 | 3 | 14 | 24 | 1 | 11 | 0 | 1 | 0 | 1 | 20 | 25 | 0 | 2 | 108 |
| 1,3,10,26 | 0 | 1 | 0 | 1 | 0 | 3 | 0 | 1 | 1 | 2 | 0 | 0 | 2 | 5 | 0 | 1 | 17 |
| 1,3,10,11,16 | 0 | 0 | 0 | 0 | 8 | 5 | 10 | 3 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 30 |
| 1,3,10,16,18 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 7 |
| 1,3,10,17,18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 7 |
| 1,3,10,24,26 | 0 | 1 | 0 | 3 | 0 | 8 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 14 |
| UN 5 total | 16 | 5 | 22 | 22 | 86 | 94 | 30 | 37 | 9 | 13 | 10 | 3 | 66 | 36 | 7 | 7 | 463 |
| **UN 6** | | | | | | | | | | | | | | | | | |
| 1,2c,3,3ka,10,17 | 2 | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 1,2c,3,3ka,18,30 | 4 | 1 | 4 | 2 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 1,2c,3,3ka,9,18,30 | 1 | 0 | 1 | 1 | 2 | 1 | 1 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| UN 6 total | 7 | 1 | 5 | 3 | 6 | 1 | 1 | 0 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 33 |
| **UN 9** | | | | | | | | | | | | | | | | | |
| 1,2a,2c,17 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 9 |
| 1,2a,2c,10,17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 | 2 | 0 | 0 | 8 |
| UN 9 total | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 0 | 1 | 6 | 1 | 2 | 2 | 0 | 1 | 17 |
| **UN 10** | | | | | | | | | | | | | | | | | |
| 2c,10,17 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 7 |
| **UN 11** | | | | | | | | | | | | | | | | | |
| 1,10,17,18 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 9 |
| **UN 13** | | | | | | | | | | | | | | | | | |
| 1,2a,2c,3 | 1 | 0 | 1 | 0 | 4 | 1 | 0 | 1 | 3 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 15 |
| 1,2a,2c,3,10 | 5 | 1 | 4 | 2 | 7 | 2 | 3 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 33 |
| 1,2a,2c,3,11 | 0 | 0 | 0 | 2 | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 10 |
| 1,2a,2c,3,18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 4 |
| 1,2a,2c,3,10,18 | 0 | 0 | 3 | 1 | 15 | 7 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 3 | 35 |
| 1,2a,2c,3,10,24 | 0 | 1 | 0 | 2 | 1 | 4 | 3 | 7 | 2 | 3 | 0 | 0 | 0 | 1 | 1 | 1 | 26 |
| 1,2a,2c,3,10,11,18 | 0 | 2 | 0 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 12 |
| 1,2a,2c,3,10,11,30 | 1 | 0 | 2 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 14 |
| UN 13 total | 7 | 4 | 10 | 10 | 32 | 19 | 11 | 14 | 9 | 8 | 2 | 4 | 4 | 4 | 4 | 7 | 149 |
| **UN 14** | | | | | | | | | | | | | | | | | |
| 1,2c,18 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 6 |
| 1,2c,10,11 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 1,2c,11,18 | 0 | 0 | 0 | 0 | 6 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 13 |
| UN 14 total | 0 | 0 | 0 | 1 | 6 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 3 | 1 | 23 |
| **UN 17** | | | | | | | | | | | | | | | | | |
| 2a,2c,3,10 | 9 | 5 | 15 | 17 | 44 | 22 | 0 | 5 | 8 | 10 | 0 | 1 | 2 | 5 | 4 | 2 | 149 |
| 2a,2c,3,10,24 | 0 | 0 | 0 | 5 | 1 | 6 | 0 | 3 | 1 | 2 | 0 | 1 | 2 | 3 | 1 | 1 | 26 |
| UN 17 total | 9 | 5 | 15 | 22 | 45 | 28 | 0 | 8 | 9 | 12 | 0 | 2 | 4 | 8 | 5 | 3 | 175 |

[a] Unified Numeration race.

[b] Wheat production areas, where HP = High Plains, RP = Rolling Plains, BK = Blacklands, SC = south-central Texas, SW = southwest Texas, EA = east Texas, GC = Gulf Coast, and SO = south Texas.

**Table 2.** Isolates of *Puccinia recondita* virulent to the cv. Thatcher near-isogenic lines in Texas from 1985 to 1987

| Area[a] | Isolates virulent to *Lr* genes (%) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2a | 2c | 3 | 3ka | 9 | 10 | 11 | 16 | 17 | 18 | 24 | 26 | 30 |
| HP | 61 | 43 | 57 | 97 | 13 | 2 | 75 | 6 | 18 | 6 | 13 | 16 | 5 | 11 |
| RP | 53 | 41 | 50 | 98 | 6 | 1 | 76 | 11 | 15 | 1 | 11 | 18 | 6 | 7 |
| BK | 62 | 31 | 36 | 96 | 3 | 0.7 | 80 | 18 | 20 | 2 | 12 | 22 | 5 | 1 |
| SC | 74 | 25 | 29 | 95 | 0.7 | 0.7 | 80 | 26 | 21 | 2 | 9 | 27 | 3 | 0.7 |
| SW | 56 | 45 | 57 | 96 | 10 | 6 | 76 | 9 | 6 | 7 | 15 | 23 | 6 | 15 |
| EA | 80 | 43 | 46 | 71 | 6 | 0 | 80 | 26 | 26 | 28 | 17 | 23 | 0 | 8 |
| GC | 79 | 16 | 18 | 95 | 0.7 | 0 | 88 | 5 | 30 | 4 | 7 | 40 | 5 | 0 |
| SO | 66 | 42 | 53 | 87 | 4 | 0 | 74 | 6 | 6 | 15 | 34 | 23 | 4 | 0 |
| Mean | 66 | 36 | 43 | 92 | 5 | 1 | 79 | 13 | 18 | 8 | 15 | 24 | 4 | 5 |

[a] Wheat production areas, where HP = High Plains, RP = Rolling Plains, BK = Blacklands, SC = south-central Texas, SW = southwest Texas, EA = east Texas, GC = Gulf Coast, and SO = south Texas.

and increased on Probrand 812 in Texas. The data from Table 1 indicate that this virulence was particularly prevalent in the Texas Blackland and Gulf Coast areas. The decrease in frequency of this virulence from the 1986 to the 1987 growing season was paralleled by a decrease in the widespread plantings of Probrand 812 (the planted acreage of Probrand 812 decreased to about 28% during 1985–1986 and to 16% during 1986–1987 in central Texas, *unpublished data*). These results, combined with a similar buildup of races carrying virulence to *Lr*16 following widespread plantings of cultivar Selkirk in western Canada between 1961 and 1966 (14), indicate a high level of cultivar-directed selection for this virulence gene. Table 2 shows that virulence to *Lr*16 was present in only 6% of the isolates collected from the southwest and south Texas areas, but in 15–30% of the isolates from all other Texas areas. This suggests that the virulence possibly increased initially in central Texas or the Gulf Coast. Virulence to *Lr*16 was only found in a UN 5 phenotype over both years of this study, but virulence to *Lr*16 has been isolated by others in a UN 13 phenotype (9,10).

Virulence to *Lr*24 was found in moderately low levels in several areas during 1985–1986 in races UN 2, UN 5, UN 13, and UN 17. During 1986–1987, this virulence increased to 49% of the UN 2 phenotype, 38% of UN 5, 27% of UN 13, and 24% of UN 17. The virulence p3,24 was not detected in the Blacklands and Rolling Plains during 1985–1986, but was prevalent in those areas the following year. The virulence p1,3,10,24 made up a large proportion of the Gulf Coast isolates in both years. Long et al (9,10) reported virulence to *Lr*24 in only 1% of the isolates collected in the southern Great Plains in 1985, but in 14% in 1986. Table 2 indicates that virulence to *Lr*24 had become widespread throughout Texas by 1987. The cultivar Siouxland (17), and other cultivars that carry the *Lr*24 gene (13), have increased in acreage in Texas since 1984–1985. Virulence to *Lr*24 may have a selective advantage on compatible wheat cultivars in overwintering areas, as with the cultivar Agent in Texas and Oklahoma in the early 1970s (15). Marshall (11) has suggested that incubation temperatures below 20 C may influence the fitness and subsequent frequency of phenotypes virulent toward *Lr*24. Browder and Eversmeyer (2) have reported temperature × infection type interactions with virulence to *Lr*1, *Lr*16, and *Lr*17.

Other than race UN 5, the most prevalent races were UN 2, 17%; UN 17, 16%; and UN 13, 14%. These four races have made up the majority of races detected in the Great Plains since 1978 (7). Several races and virulences were found in the present study (Table 1) that had not been previously detected in the southern Great Plains. Among these were p3,11,18 and 3,9,3ka in a UN 2 phenotype, and p1,2a,2c,10,17 in a UN 9 phenotype.

Race UN 6 has been predominantly found in the western and eastern regions of the United States (7). The present study indicated that race UN 6 made up about 3% of the total isolates over the 2 years (Table 1). All of the UN 6 isolates had complex virulences of from six to seven genes.

Although only about one-third of the described *Lr* genes were tested, it was found over the 2 years of this study that *P. recondita* phenotypes with two virulence genes made up 11% of the population; three genes, 16%; four genes, 48%; five genes, 13%; six genes, 8%; and seven genes, 4% (Table 1). Thus, the frequency of race occurrence was not correlated with either simple or complex virulences.

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