Virulence Polymorphism of *Puccinia recondita* f. sp. *tritici* and Effectiveness of *Lr* Genes for Leaf Rust Resistance of Wheat in Ukraine

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ABSTRACT

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In 2002 and 2003, 1,300 isolates of *Puccinia recondita* f. sp. *tritici* were obtained from six commercial cultivars of wheat at three locations in the eastern forest-steppe region of Ukraine. All isolates were tested for virulence on an international set of eight differential cultivars. Seventeen known wheat leaf rust races and several new, unnamed races were identified. The most common races in each year were races 61, 149, and 192. In 2003, up to 20 isolates each of the seven most common leaf rust races plus 8 to 10 isolates of unnamed races were tested for virulence to 35 near-isogenic wheat lines with different single *Lr* genes for leaf rust resistance. Isolates were polymorphic for virulence on *Lr1*, *Lr2a*, *Lr2b*, *Lr2c*, *Lr9*, *Lr19*, *Lr23*, *Lr26*, and the combination *Lr27* + *Lr31*. No isolates were found virulent on *Lr24*, *Lr25*, or *Lr28*, and few isolates were virulent on *Lr9*. Few isolates of known races but most isolates of the new, unnamed races were virulent on *Lr19*. The 35 *Lr* gene lines also were exposed to mixed-race inoculum in field plots to tests effectiveness of their resistance. Lines with *Lr24*, *Lr25*, and *Lr28* suffered no leaf rust damage in the field, and lines with *Lr9*, *Lr18*, *Lr35*, *Lr36*, and the combination *Lr27* + *Lr31* showed less than 10% severity.

Additional keywords: race-specific resistance

Leaf rust of wheat caused by *Puccinia recondita* Roberge et Desmaz. f. sp. *tritici* Eriks. is one of the most important diseases of wheat in Ukraine. The use of race-specific resistance in breeding wheat cultivars with effective leaf rust resistance relies on extensive knowledge of virulence polymorphism in the pathogen populations. The necessary knowledge includes understanding how readily the frequencies of individual virulence alleles change in response to selection pressures from the use of known resistance genes as well as in response to other factors, such as gene flow and genetic drift, that may contribute to changes in virulence frequencies. Such knowledge can be gained from virulence surveys and field tests of effectiveness of individual resistance genes against leaf rust in different regions of Ukraine. It also is important to understand the value of various genetic donors as potential sources of new resistance genes that may be effective against the Ukraine populations of *P. recondita* f. sp. *tritici* (4).

Regular surveys of virulence polymor-

phism in *P. recondita* f. sp. *tritici* have been carried out in Ukraine since 1960 (1,7,8,13,15,19,20,22). Race identification in these surveys was based on the international register of pathogenic races (3), in which races are distinguished by eight standard differential cultivars (Malakof, Webster, Carina, Brevit, Loros, Mediterranean, Hussar, and Democrat), which include the known leaf rust resistance genes *Lr1*, *Lr2a*, *Lr2b*, *Lr2c*, *Lr3*, *Lr11*, and *LrB*. During 1967 to 1969, 40 pathogenic races were identified, with the largest number, 34 races, found in 1969 (5). Races 77, 149, 130, and 21 were predominant, with 56 to 77% of the isolates identified as race 77, which is virulent to all eight differential cultivars. From 1971 to 1978, 16 races were found in Ukraine, with 13 found in 1971 and only 4 to 7 races found in the other years. From 1974 to 1978, the pathogen population was made up almost entirely of race 77. Race 12 (avirulent on Malakof and Webster) also was found in each year, and races 142, 61, and 57 were found less consistently. From 1979 to 1984, 48 races were identified (8,10), 16 of which were new and not registered in the last international race catalog of Johnston and Browder (3). From 1985 to 1987, 39 races were identified (7), of which 9 races were not registered in the international race catalog, 8 differed from those found from 1979 to 1984 in Ukraine, and 5 were new in Ukraine. As in earlier years, the

predominant race was race 77 (18). Other races found in the south of Ukraine included races 114, 149, 162, 167, 184, 186, 192, and 206. In 1988 to 1996, 59 races (including 9 not in the international race catalog) were found in the south of Ukraine, and race 77 again was predominant (1).

Over the last 15 years, the effectiveness of many known leaf rust resistance genes (*Lr* genes) has been tested on single-gene lines in field plot tests at various locations in central and western (7,9), southern (1,18), and eastern regions of Ukraine (14,15). Results showed that effectiveness of some *Lr* genes against regional populations of *P. recondita* f. sp. *tritici* in field tests varied among regions. On the other hand, some *Lr* genes showed a general tendency to lose effectiveness over time in all regions, whereas others generally increased in effectiveness over time. The objectives of this study were to (i) determine the frequencies of wheat leaf rust races in the eastern forest-steppe region of Ukraine in 2002 and 2003 and (ii) determine the virulence of representative isolates from the most common races to near-isogenic lines of wheat with 36 different *Lr* genes for resistance.

MATERIALS AND METHODS

Isolates of *P. recondita* f. sp. *tritici* were collected from three locations in Kharkov state in the eastern forest-steppe region of Ukraine in 2002 and 2003. In 2002, 100 isolates were obtained from each of four wheat cultivars, Odessa 267, Donetsk 46, Ukrainian Odessa, and Kharkov 96 in three locations. In addition, 100 isolates were obtained from the new cv. Kuyalnik in one of the locations in 2002. In 2003, 100 isolates were obtained from each of four wheat cultivars, Odessa 267, Donetsk 46, Ukrainian Odessa, and Kharkov 105 in the same three locations as in 2002, and 100 isolates were obtained from the new cv. Podolianka in one location. Thus, there were 13 collections of 100 isolates each in each year. Donetsk 46 has been grown commercially in Ukraine for many years and is practically regarded as susceptible to all leaf rust races. Leaf rust resistance genotypes of the other cultivars are not known.

Leaves with leaf rust uredinia were collected according to standard procedures (17) at 50 sites, one leaf per site, in each of the four cultivars at each location and in

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one new cultivar at one location in each year. The collections were taken at equidistant sites during the time of maximum rust development (milk-dough stage). Each rusted leaf was placed in a filter paper package and the package was labeled. Packages of rusted leaves were held at 4°C in a refrigerator until urediniospores were collected for inoculation in the greenhouse. Urediniospores were collected by placing a piece of the rusted leaf sample in a flask of water plus a detergent Tween 80 (1 or 2 drops/liter), and the flask was shaken to produce a suspension of urediniospores. The urediniospore suspension was sprayed onto fresh detached leaf pieces of the susceptible wheat cv. Eritrospermum 15 in a petri dish on water agar plus benzimidazole at 0.004 µg/ml to establish isolates from single uredinia (12). Eritrospermum 15 has no known *Lr* genes for leaf rust resistance. The petri dishes were covered with moistened filter paper to maintain 100% relative humidity (RH) for 1 day. After 1 day, the filter paper was removed and the closed petri dishes were incubated at 24°C under artificial light at 10⁵ lux. When chlorotic spots indicating leaf rust infection became visible, leaf pieces bearing single leaf rust infections were transferred to fresh petri dishes. At 10 days after inoculation, uredinia with abundant sporulation were present on the single uredinium leaf pieces. A soft brush was used to remove urediniospores of the single uredinial isolates and spread them over detached leaves of Eritrospermum 15 wheat on water agar and benzimidazole in a petri dish for a generation of urediniospore increase of each isolate prior to inoculation of the differential cultivars for race identification. Two single uredinial

isolates were established from each individual rusted leaf that was collected from the field. Thus, the 50 rusted leaves collected per cultivar at each location yielded 100 single uredinial isolates for race determination, or a total of 1,300 isolates over all cultivars and locations per year.

The single uredinial isolates were tested for virulence on the eight standard differential cultivars of Johnston and Browder (3,8): Malakof, Carina, Brevit, Webster, Loros, Mediterranean, Hussar, and Democrat (Tables 1 and 2). Detached leaves of each differential cultivar were incubated under artificial light on water agar with benzimidazole as described for establishment of single uredinial isolates. In previous tests, it was determined that infection types on detached leaf pieces under these conditions were comparable with those on intact seedlings in the greenhouse (8). Leaves of each differential cultivar were placed in a separate petri dish. The detached leaves were inoculated by spraying them with a suspension of urediniospores of a single uredinial isolate in water with Tween 80 and incubated for 1 day with the petri dishes covered with moist filter paper as described above. The work site and equipment were sterilized with 96% ethanol between inoculations with different isolates to prevent cross contamination. After 1 day, the moist filter paper was removed from the petri dishes and replaced with glass covers. After 10 days under artificial light at 24°C, the leaf rust reaction types on each differential cultivar were determined according to Mains and Jackson's (11) scale, with infection types 0, 1, and 2 considered resistant and infection types 3 and 4 considered susceptible.

Selected isolates of seven races as well as isolates of unnamed races collected in 2003 were tested for virulence on 35 near-isogenic wheat lines. With the exception of one line with both *Lr27* and *Lr31*, each line had a different single *Lr* gene for leaf rust resistance (Table 3). The isolates tested included 20 each from races 57, 61, 77, 149, and 192, and 8 to 10 isolates each of races 12, 52, and the unnamed races (Table 2). The 35 near-isogenic wheat lines were tested both as seedlings in the greenhouse and as adult plants in field plots. In the greenhouse, the lines were grown in soil in boxes and were inoculated 10 days after planting, when the second leaves were beginning to form. Seedlings were sprayed with a suspension of urediniospores in water with Tween 80, and the inoculated plants were incubated for 1 day at 100% RH before being returned to the greenhouse. Infection types were scored according to Mains and Jackson's (11) scale.

In field tests, the near-isogenic lines were planted in 1-m rows in blocks surrounded with spreader rows of a susceptible wheat cultivar. At 17 to 20 days prior to heading, the plots were inoculated by spraying them with a suspension of urediniospores (75 to 100 mg of spores/liter) in water with Tween 80. The inoculum consisted of a mixture of races 12, 52, 57, 61, 77, 149, 192, and unidentified races collected from fields at three locations in Kharkov state in Ukraine, as described above. The spore suspension was applied at a rate of 60 ml/m² (4 to 5 mg of urediniospores/m²). To maintain leaf wetness, the soil under the inoculated rows was watered heavily and the rows were covered with polyethylene sheets for 8 to 10 h after

Table 1. Race composition of collections of *Puccinia recondita* f. sp. *tritici* from commercial cultivars of winter wheat in Ukraine in 2002

Race	Avirulence/virulence ^b	Isolates from indicated cultivar (%) ^a					Total
		Odessa	Ukraine	Donetsk	Kharkov 96	Kuranik	
1	Ma,Ci,Bv,Wst,Ls,Mi,Hs,Do/	0	0	3	0	2	0.8
6	Ci,Wst/Ma,Bv.,Ls,Mi,Hs,Do	0	0	1	0	0	0.2
12	Ma,Wst/Ci,Bv.,Ls,Mi,Hs,Do	1	2	2	3	3	2.1
52	Ci,Bv,Wst,Ls/Ma,Mi,Hs,Do	2	3	3	2	2	2.5
57	Ma/Ci,Bv,Wst,Ls,Mi,Hs,Do	5	7	4	6	8	5.7
61	Ma,Ci,Wst/Bv,Ls,Mi,Hs,Do	25	27	21	27	22	24.8
77	/Ma,Ci,Bv,Wst,Ls,Mi,Hs,Do	9	12	11	10	12	10.6
117	Mi/Ma,Ci,Bv,Wst,Ls,Hs,Do	2	2	3	1	2	2.0
130	Ci,Bv/Ma,Wst,Ls,Mi,Hs,Do	0	1	2	2	1	1.2
141	Ma,Ci,Bv,Wst/Ls,Mi,Hs,Do	0	0	1	0	0	0.2
144	Wst/Ma,Ci,Bv,Ls,Mi,Hs,Do	2	3	3	0	6	2.3
147	Ci,Mi,Do/Ma,Bv,Wst,Ls,Hs	0	1	1	0	0	0.5
149	Ci/ Ma,Bv,Wst,Ls,Mi,Hs,Do	26	20	24	26	22	23.8
162	Ma/Ci,Bv,Wst,Ls,Mi,(Hs),Do	4	3	5	4	2	3.8
179	Ma,Ci,Bv,Wst,Ls,Mi/Hs,Do	1	1	2	3	0	1.6
184	Ma,Ci,Bv,Wst,Ls,Mi,Hs/Do	0	2	2	0	0	0.9
192	Ls/Ma,Ci,Bv,Wst,Mi,Hs,Do	20	17	12	14	14	15.6
Unidentified ^c	...	3	2	2	2	4	2.4
No. of isolates ^d	...	300	300	300	300	100	1,300

^a Complete names of cultivars are: Odessa 267, Donetsk 46, Ukrainian Odessa, Kharkov 96, and Kuyalnik.

^b Differential cultivars are Malakof, Carina, Brevit, Webster, Loros, Mediterranean, Hussar, and Democrat (4). Parentheses indicate an intermediate reaction for race 162 on Hussar.

^c New races not listed in Johnston and Browder's (4) international register of wheat leaf rust races.

^d Number of isolates tested.

inoculation. Infection type and severity of infection were determined at 15 days after inoculation. Infection type was scored according to Mains and Jackson's scale (11). Rust severity was scored as the percentage of leaf area affected based on Strakhov's scale (19). Strakhov's scale was adapted from that of Peterson et al. (16), with gradations of 0, 5, 15, 45, 65, and 100% infection relative to the proportion of leaf area covered by pustules at the maximum (37% of total leaf area covered by uredinia) level of leaf rust infection.

RESULTS

Seventeen known races of *P. recondita* f. sp. *tritici* were identified from collections from Ukraine in both 2002 (Table 1) and 2003 (Table 2). In addition, 2.4% of the isolates collected in 2002 and 1.7% of those from 2003 were determined to be of races not included in Johnston and Browder's (3) international register of races. Races 61 and 149, the two most common races, occurred at frequencies greater than 20% in both years. Race 192, the third most common race, occurred at 15.6% in 2002 and 11.5% in 2003. All 17 of the known races were found among isolates collected from the leaf-rust-susceptible cv. Donetsk 46 in both 2002 and 2003 (Tables 1 and 2). At least a few isolates of races 12, 52, 57, 61, 77, 117, 149, and 192 were collected from each of the seven cultivars from which collections of *P. recondita* f. sp. *tritici* were made in 2002 and 2003.

The frequencies of the 17 races of *P. recondita* f. sp. *tritici* collected over all cultivars were nearly the same in 2003 and 2002 (Tables 1 and 2). The frequency of race 12 increased from 2.1 to 6.1% and the

frequency of race 57 increased from 5.7 to 12.9% from 2002 to 2003. Bartos et al. (2) noted a similar change in frequency of race 57 in Slovakia. The frequency of race 77 decreased from 10.6 to 7.8% and the frequency of race 192 decreased from 15.6 to 11.5% from 2002 to 2003. For the other 13 known races, the frequency in 2003 differed from that in 2002 by only 1.6% or less.

Tests for virulence of isolates of races 12, 52, 57, 61, 77, 149, 192, and the isolates of unnamed races on seedlings of near-isogenic *Lr* gene lines of wheat in the greenhouse indicated that the population of *P. recondita* f. sp. *tritici* in the eastern part of the forest-steppe region of Ukraine is highly virulent to most of the *Lr* genes (Table 3). However, wheat lines with *Lr24*, *Lr25*, and *Lr28* were resistant to all of the isolates, and lines with *Lr9* were resistant to nearly all of the isolates. The *Lr19* line was susceptible to one isolate of race 77 and to a few isolates of the unnamed races but was resistant to all other isolates tested. *Lr26* was effective against all of the isolates of race 61, which was the most common race found in 2003, but *Lr26* was not effective against the other races. This is consistent with the observed increase in the frequency of virulence to *Lr26* in Ukraine since 1990 (13).

The lines with *Lr11* and *Lr18* appeared to be susceptible to all the isolates as seedlings in the greenhouse, but both showed considerable resistance as adult plants in field tests. The leaf rust reaction types of *Lr11* and *Lr18* are difficult to characterize, because their intermediate level of resistance is temperature sensitive and difficult to recognize in normal greenhouse tests. Thus, it is possible that many of our iso-

lates of *P. recondita* f. sp. *tritici* may lack virulence to *Lr11* or *Lr18* but mistakenly were rated as virulent in the greenhouse tests.

Races 61 and 192, which were found at 24.0 and 11.5% frequency, respectively, in 2003, appeared to be nearly homogeneous. All isolates of these two races showed similar reactions on all the *Lr* gene lines except for the line with *Lr27* + *Lr31*, which was susceptible to 41.2% of the race 61 isolates and 56.2% of the race 192 isolates. The unnamed races resembled race 192 on most of the *Lr* gene lines, except that most of the isolates of unnamed races were virulent on the *Lr19* line, and one isolate was virulent on the *Lr9* line. There was considerable heterogeneity among the isolates of *P. recondita* f. sp. *tritici* for virulence or avirulence to *Lr1*, *Lr2a*, *Lr2c*, and *Lr27* + *Lr31*, and some heterogeneity for virulence or avirulence to *Lr2b* and *Lr26*.

Little or no leaf rust developed on the lines with *Lr9*, *Lr24*, *Lr25*, and *Lr28* in field tests, which confirmed their resistance to all or nearly all isolates of *P. recondita* f. sp. *tritici* as seedlings in greenhouse tests. Although the *Lr19* line was highly resistant to most isolates as seedlings in the greenhouse test, it developed 52.3% leaf rust damage in the field. That may indicate that virulent isolates, particularly among the unnamed races, were more common in the field inoculum than they were in the general leaf rust population sampled for race testing. Four of the *Lr* genes, *Lr12*, *Lr22*, *Lr34*, and *Lr35*, have been characterized as conferring adult plant resistance that is not expressed or poorly expressed in the seedling stage. The *Lr35* line showed a high level of resistance

Table 2. Race composition of collections of *Puccinia recondita* f. sp. *tritici* from commercial cultivars of winter wheat in Ukraine in 2003

Race	Avirulence/virulence ^b	Isolates from indicated cultivar (%) ^a					Total
		Odessa	Ukraine	Donetsk	Kharkov 96	Podolianska	
1	Ma,Ci,Bv,Wst,Ls,Mi,Hs,Do/	1	0	2	2	1	1.2
6	Ci,Wst/Ma,Bv.,Ls,Mi,Hs,Do	0	2	3	0	0	1.2
12	Ma,Wst/Ci,Bv.,Ls,Mi,Hs,Do	4	6	6	8	7	6.1
52	Ci,Bv,Wst,Ls/Ma,Mi,Hs,Do	2	3	4	2	3	2.8
57	Ma/Ci,Bv,Wst,Ls,Mi,Hs,Do	10	12	14	16	12	12.9
61	Ma,Ci,Wst/Bv,Ls,Mi,Hs,Do	23	21	25	26	27	24.0
77	/Ma,Ci,Bv,Wst,Ls,Mi,Hs,Do	8	8	6	9	8	7.8
117	Mi/Ma,Ci,Bv,Wst,Ls,Hs,Do	3	4	2	4	2	3.2
130	Ci,Bv/Ma,Wst,Ls,Mi,Hs,Do	1	0	1	0	0	0.5
141	Ma,Ci,Bv,Wst/Ls,Mi,Hs,Do	0	0	1	0	0	0.3
144	Wst/Ma,Ci,Bv,Ls,Mi,Hs,Do	3	2	2	0	0	1.6
147	Ci,Mi,Do/Ma,Bv,Wst,Ls,Hs	0	1	2	0	0	0.7
149	Ci/Ma,Bv,Wst,Ls,Mi,Hs,Do	27	22	20	20	19	22.0
162	Ma/Ci,Bv,Wst,Ls,Mi,(Hs),Do	0	4	2	2	4	2.2
179	Ma,Ci,Bv,Wst,Ls,Mi/Hs,Do	1	0	1	0	2	0.6
184	Ma,Ci,Bv,Wst,Ls,Mi,Hs/Do	0	2	1	1	0	0.9
192	Ls/Ma,Ci,Bv,Wst,Mi,Hs,Do	16	12	6	11	14	11.5
Unidentified ^c	...	1	1	2	3	1	1.7
No. of isolates ^d	...	300	300	300	300	100	1,300

^a Complete names of cultivars are Odessa 267, Donetsk 46, Ukrainian Odessa, Kharkov 96, and Podolianska.

^b Differential cultivars are Malakof, Carina, Brevit, Webster, Loros, Mediterranean, Hussar, and Democrat (4). Parentheses indicate an intermediate reaction for race 162 on Hussar.

^c New races not listed in Johnston and Browder's (4) international register of wheat leaf rust races.

^d Number of isolates tested.

in the field test, and the *Lr22* line appeared to express some resistance. No resistance was apparent in the field tests with the *Lr12* line or the *Lr34* line. The adult plant resistance of *Lr12* is known to be race specific, but the lack of resistance expressed by the *Lr34* line is surprising, because no race specificity has been reported for *Lr34*.

Several other *Lr* gene lines had reduced leaf rust damage in field plot tests that could not be explained by their seedling reactions. The lines with *Lr11* and *Lr18* already have been mentioned in connection with the difficulty of recognizing their resistance in seedling tests when temperature is not strictly controlled. Lines with *Lr17*, *Lr29*, *Lr32*, and *Lr36* had 31.5, 22.5, 45.7, and 9.2% leaf rust, respectively, in field plot tests even though they were susceptible to all of the isolates tested in seedling tests in the greenhouse. It may be that some of the races in the inoculum used in the field plot inoculations were less virulent to the set of near-isogenic wheat lines than the isolates collected for race identification.

DISCUSSION

In this study, the most notable change in race frequencies compared with earlier studies was the decline in the frequency of race 77. Race 77 was once the predominant race in Ukraine, but it occurred at 10.6% frequency in 2002 and 7.8% in 2003. A sharp decline in frequency of race 77 has been observed in recent years. Babajants et al. (1) reported the frequency of race 77 at 46.8% in 1995 and 34.6% in 1996. Lesovoj (4) reported that the frequency of race 77 had fallen to as low as 4.65% in some regions of Ukraine. Slusarenko (18) considered the decline of race 77 to be due to the removal of cultivars such as Aurora and Caucasus, which have the 1B-1R rye chromosome translocation. Previously, nearly 100% of isolates from Aurora and Caucasus were found to be race 77.

In general, the frequencies of races were similar in collections from the seven different wheat cvs. Odessa, Ukraine, Donetsk, Kharkov 96, Kuranik, and Podolianka in this study. This indicates that these cultivars all lack several of the resis-

tance genes that are included in the standard differential cultivars of Johnson and Browder (3). For example, race 61, the most commonly found race, is avirulent on Malakof (*Lr1*), Webster (*Lr2a*), and Carina (*Lr2b*, *LrB*). Another common race, 192, is avirulent on Loros (*Lr2c*), and the relatively rare race 117, which was collected from all seven cultivars, is avirulent on Mediterranean (*Lr3*).

Resistance genes *Lr9* and *Lr19* were reported to be effective against all leaf rust races in Ukraine as early as the 1970s (11). By 1980 to 1990, *Lr9*, *Lr19*, and *Lr23* were considered highly effective against leaf rust in all regions of Ukraine (7,15); however, by 1992, *Lr23* began to lose effectiveness as races virulent to *Lr23* began to increase in frequency (15). On the other hand, *Lr26* began to gain effectiveness (14). In 1988 to 1989, all leaf rust isolates tested in Ukraine were virulent to *Lr26* (14); however, by 1994, 48% of the leaf rust isolates tested in Ukraine were avirulent to *Lr26*; by 1998, 61% of the isolates were avirulent; and in 1999, 80% of the isolates tested in Ukraine were avirulent to

Table 3. Virulence of *Puccinia recondita* f. sp. *tritici* isolates of different races found in 2003 to seedlings of near-isogenic wheat lines with different single *Lr* genes for resistance and severity of leaf rust on near-isogenic lines as adult plants in field plots^a

Line	Isolates of indicated race that were virulent (%) ^b							Unid. ^c	Field severity (%)
	12	52	57	61	77	149	192		
<i>Lr1</i>	0	69.5	0	0	100	65.5	100	100	100
<i>Lr2a</i>	0	80.0	100	0	79.2	72.2	100	100	80.2
<i>Lr2b</i>	0	100	100	0	100	100	100	100	100
<i>Lr2c</i>	0	75.2	100	0	65.5	81.4	100	100	100
<i>Lr3</i>	100	100	100	100	100	100	100	100	100
<i>Lr3ka</i>	100	100	100	100	100	100	100	100	100
<i>Lr3bg</i>	100	100	100	100	100	100	100	100	100
<i>Lr9</i>	0	0	0	0	0	0	0	5.6	1.5
<i>Lr10</i>	100	100	100	100	100	100	100	100	100
<i>Lr11</i>	100	100	100	100	100	100	100	100	34.6
<i>Lr12</i>	100	100	100	100	100	100	100	100	100
<i>Lr14a</i>	100	100	100	100	100	100	100	100	79.2
<i>Lr14b</i>	100	100	100	100	100	100	100	100	81.3
<i>Lr15</i>	100	100	100	100	100	100	100	100	100
<i>Lr16</i>	100	100	100	100	100	100	100	100	100
<i>Lr17</i>	100	100	100	100	100	100	100	100	31.5
<i>Lr18</i>	100	100	100	100	100	100	100	100	5.7
<i>Lr19</i>	0	0	0	0	12.5	0	0	75.2	52.3
<i>Lr20</i>	100	100	100	100	100	100	100	100	100
<i>Lr21</i>	100	100	100	100	100	100	100	100	60.2
<i>Lr22a</i>	100	100	100	100	100	100	100	100	70.2
<i>Lr23</i>	100	50.2	0	100	65.2	100	100	100	56.7
<i>Lr24</i>	0	0	0	0	0	0	0	0	0
<i>Lr25</i>	0	0	0	0	0	0	0	0	0
<i>Lr26</i>	100	100	100	0	52.7	100	100	100	40.2
<i>Lr27+Lr31</i>	45.2	56.1	38.0	41.2	56.9	61.4	56.2	81.4	6.7
<i>Lr28</i>	0	0	0	0	0	0	0	0	0
<i>Lr29</i>	100	100	100	100	100	100	100	100	22.5
<i>Lr30</i>	100	100	100	100	100	100	100	100	100
<i>Lr32</i>	100	100	100	100	100	100	100	100	45.7
<i>Lr33</i>	100	100	100	100	100	100	100	100	100
<i>Lr34</i>	100	100	100	100	100	100	100	100	100
<i>Lr35</i>	100	100	100	100	100	100	100	100	5.6
<i>Lr36</i>	100	100	100	100	100	100	100	100	9.2
<i>Lr37</i>	100	100	100	100	100	100	100	100	100

^a Races were identified according to Johnston and Browder's (4) international register of wheat leaf rust races. Field plots were inoculated 17 to 20 days before heading with a mixture of races typical of the natural population *P. recondita* f. sp. *tritici* in the eastern steppe region of Ukraine.

^b Seedlings of the near-isogenic lines were tested in the greenhouse against 20 isolates each of races 57, 61, 77, 149, and 192 and 8 to 10 isolates of the other races.

^c Unidentified; new races not listed in Johnston and Browder's (4) international register of wheat leaf rust races.

Lr26 (14). It appears that during the years 1988 to 1999, virulence to *Lr26* did not occur among the leaf rust races that were selected by the resistance of new wheat cultivars grown in Ukraine from 1988 to 1999. This trend now has been reversed. In 2003, we found that all isolates except those of race 61 and 47% of those of race 77 were virulent to *L26* (Table 3). Still, *Lr26* provided some protection against leaf rust in the field test. The *Lr26* line had only 40% leaf rust severity compared with 52% leaf rust severity on the *Lr19* line.

Previous reports of virulence frequencies in leaf rust in southern Ukraine, with the exception of virulence to *Lr24* and *Lr26*, are generally similar to our results from studies of isolates from the eastern forest-steppe region. Babajants et al. (1) reported that, in 1997 to 1999, the frequencies of virulence in southern Ukraine to *Lr9*, *Lr19*, *Lr24*, and *Lr26* were 1, 2, 29, and 29%, respectively. In the eastern forest-steppe region, *Lr24* was more effective, with no virulent isolates found and no leaf rust damage on the *Lr24* line in field tests. On the other hand, *Lr26* may be somewhat less effective in the eastern forest-steppe region than in southern Ukraine. We do not have information on past effectiveness of *Lr25* and *Lr28* against leaf rust in Ukraine, but our results in 2003 show that these genes, in addition to *Lr9* and possibly *Lr19*, should provide valuable protection against leaf rust in Ukraine, especially if used in multiple resistance gene combinations. Other genes that might be useful include *Lr35*, which conditions adult plant resistance; and *Lr18*, *Lr36*, and the combination of *Lr27* + *Lr31*, which appeared susceptible in seedling tests in the greenhouse but performed well in field tests. Mean leaf rust severities on lines with *Lr35*, *Lr18*, *Lr36*, and the combination of *Lr27* + *Lr31* in field plot tests in 2003 were 5.6, 5.7, 9.2, and 6.7%, respectively.

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NOTES

Some information about important references used in this manuscript:

4. This scientific journal is found in all Ukrainian agricultural universities' libraries.
 9. This book is the scientific works collection, which is found in the library of the Plant Protection Institute of Kiev.
 19. This is the old methodology, found in the library of the Plant Protection Institute of Kiev and Kharkov national agrarian university.
- Journal names were changed in the Literature Cited section from English to Ukrainian as follows: "Plant Protection Journal" to "Zakhist Roslin," "Mycology and Phytopathology" to "Mikologiya i fitopatologiya," "Newsletter of Agrarian and Science" to "Visnik Agrarnoy Nauki," and "Phytopathology Methods and Entomologic Researches in Plant Selection" to "Phytopatologicheskikh i entomologicheskikh issledovaniy v selektsii rastenii" so that readers will be able to find them in all Ukrainian agricultural university libraries.

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