

## VIRULENCE OF *PUCCINIA RECONDITA* F. SP. *TRITICI* ON WINTER WHEAT IN UKRAINE IN 2007

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**Abstract:** Thatcher and 36 near-isogenic Thatcher lines with different Lr genes for resistance to *Puccinia recondita* f. sp. *tritici* were planted in field plots at one location each in the eastern and central parts of the forest-steppe region of Ukraine where they were exposed to natural epiphytotic of leaf rust. Disease severity on the lines indicated that Lr9, Lr19, Lr24, Lr25, and Lr28 had highly effective resistance in both locations. Lines with Lr27+Lr31, Lr35, and Lr36 were resistant in the eastern location and highly resistant in central location. Bulk collections of *P. recondita* from fields of nine Ukrainian winter wheat cultivars in the eastern location were inoculated onto seedlings of each of the 36 Thatcher near-isogenic lines. Lines with Lr9, Lr19, Lr24, Lr25, and Lr28 remained free or nearly free of uredinia. A total of 133 single-uredinial isolates obtained from 19 susceptible Thatcher near-isogenic lines in field plots in the central part of the forest-steppe region were identified to race using the eight standard leaf rust differential varieties of Johnson and Browder. The most common races were races 6 (27.8%), 77 (18.0%), 149 (13.5%), and X-4 (9.8%). The three most common races were not found on the Lr26 line and may lack virulence to it.

**Key words:** *Puccinia triticina*, winter wheat, race-specific resistance

### INTRODUCTION

Wheat leaf rust, caused by the fungus *Puccinia recondita* Rob. ex Desm. f. sp. *tritici* Erikss. [= *P. triticina* (Anikster *et al.* 1997)] is a common pathogen of wheat (*Triticum aestivum* L.) and causes significant yield losses in many wheat-growing areas throughout the world. Fungicide applications are costly and not always advisable ecologically. Consequently, use of leaf rust resistant wheat varieties is widely recommended to reduce yield losses (Anikster *et al.* 1997; Bartos *et al.* 2001a). Research on genetics of resistance in wheat and virulence of the pathogen are needed for using most efficiently available race-specific resistance genes and to avoid epiphytotic caused by new highly virulent races of the leaf rust pathogen. Such research is especially important when there is evidence that the resistance genes in wheat varieties that are widely grown over large areas in one or many geographical regions have begun to lose their effectiveness. Selection of new leaf rust resistance in wheat will be more intensive and purposeful if wheat breeders are provided with the information on useful resistance donor lines, effectiveness of their resistance genes in a particular region, and diversity and virulence of local leaf rust population (Aleksieva *et al.* 1990; Bartos *et al.* 2001b; Kolmer 2002; Kolmer 1997; Long *et al.* 2002; Singh 1991). Regular surveys of virulence of *P. recondita* f. sp. *tritici* in major regions of wheat cultivation are of fundamental importance for forecasting pathogen virulence changes in efforts to

preserve effectiveness of resistance genes and limit disease losses. Hence, we have analyzed the frequencies of races and virulence of *P. recondita* f. sp. *tritici* populations in Ukraine. The objectives of this study were to characterize the virulence of *P. recondita* populations in the central and eastern part of Ukrainian forest-steppe in 2007 and to compare these results with those of previous surveys.

### MATERIALS AND METHODS

#### Effectiveness of leaf rust resistance genes in Ukraine

In field tests, the near-isogenic lines of Thatcher with single genes for leaf rust resistance were planted in test plots at two locations. The first location was in eastern part of the forest-steppe area of Ukraine (Kharkiv region), and the second was in the central part of the forest-steppe area (Kiev region). Plots consisted of 1 m rows of Thatcher plus 36 near-isogenic lines in blocks surrounded with spacing rows of a susceptible wheat variety. At the Kiev location Thatcher was not included in the test with the 36 near-isogenic lines. The 36 Thatcher near-isogenic lines included lines with Lr1, Lr2a, Lr2b, Lr2c, Lr3, Lr3ka, Lr3bg, Lr9, Lr10, Lr11, Lr12, Lr13, Lr14a, Lr14b, Lr15, Lr16, Lr17, Lr18, Lr19, Lr20, Lr21, Lr22a, Lr23, Lr24, Lr25, Lr26, Lr27+31, Lr28, Lr29, Lr30, Lr32, Lr33, Lr34, Lr35, Lr36, and Lr37. Natural epiphytotic of leaf rust developed in the plots at both locations in 2007, and the leaf rust reaction type and severity on each line were evalu-

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ated at several equidistant places within each plot during the time of maximum rust development (milk-dough stage). Leaf rust severity was estimated visually using the integrated scale for rust evaluation as a measure of the effectiveness of individual leaf rust resistance genes against a naturally occurring population of *P. recondita* f. sp. *tritici* at each test location. The integrated rust scale was developed by a group of cereal rust scientists in Ukraine for assessing resistance to leaf rusts in wheat, rye, barley, and oat (Goel and Saini 2001). A comparison between the integrated scale and the international unified leaf rust scale (Johnston and Browder 1964) is shown in table 1.

Table 1. Comparison of integrated scale and international unified scale for level of resistance in wheat to *P. recondita* f. sp. *tritici*

Description of reactions	Integrated scale	International unified scale*
Very highly resistant no uredinia or other macroscopic signs of infection	9	VR
Highly resistant no uredinia, but hypersensitive necrotic or chlorotic flecks of varying size	8	R
Resistant small or intermediate sized uredinia surrounded by necrosis or chlorosis, with uredinia occupying up to 10% of leaf area	7	R
Resistant small or intermediate size uredinia surrounded by necrosis or chlorosis, with uredinia occupying up to 15% of leaf area	6	MR
Moderately susceptible intermediate size uredinia with little necrosis or chlorosis, and with uredinia occupying up to 25% of leaf area	5	LM, M, SM
Susceptible intermediate to large uredinia, with uredinia occupying up to 40% of leaf area	4	LS
Susceptible intermediate to large uredinia, with uredinia occupying up to 90% of leaf area	3	S
Highly susceptible large uredinia occupying up to 90% of leaf area	2	H
Very highly susceptible large uredinia occupying up to 100% of leaf area	1	VHS

\*H – high; L – light; M – moderate; R – resistant; S – susceptible; V – very

#### Virulence of *P. recondita* f. sp. *tritici* from Ukrainian wheat cultivars

Leaves infected with *P. recondita* were collected from nine regional and perspective Ukrainian winter wheat cultivars, Kryzhynka, Smuglyanka, Prichernomorka, Astat, Perlina Lisostepu, Dolgushinskaya, Kharkovskaya 105, Donetskaya 48 and Ukrainka Odeskaya in the eastern part of the forest-steppe region of Ukraine in 2007. Rusted leaves were collected at 10 equidistant sites within plots of each of the nine cultivars according to standard procedures (Shopina 1967) during the time of maximum rust development (milk-dough stage). In the laboratory,

a piece of each rusted leaf sample was placed in a flask with water plus a detergent Tween-80 (1 or 2 drops per l), and the flask was shaken to produce a suspension of urediniospores. The urediniospore suspension from each leaf was used to inoculate a set of seedlings of the 36 near-isogenic Thatcher lines. The seedlings were grown in soil in boxes in the greenhouse and inoculated at 10 days after planting when their second leaves were beginning to form. After being sprayed with urediniospore suspensions, the seedlings were incubated for one day at 100% RH before being returned to the greenhouse. 15 days after inoculation, rust severity on each of the 36 near-isogenic lines was estimated as the percentage of leaf area affected based on Strakhov's scale (Starakhov 1951), which was adapted from the scale of Peterson (Peterson *et al.* 1948) with gradations of 0, 5, 15, 45, 65, and 100% infection relative to the area of the leaf covered by pustules at the maximum level of leaf rust infection.

#### Virulence of *P. recondita* f. sp. *tritici* collected from near-isogenic lines of Thatcher wheat

Leaves infected with leaf rust were collected from Thatcher wheat and the 36 near-isogenic Thatcher lines in field plots in the central part of the forest-steppe region of Ukraine in 2007 at 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 with water plus a detergent Tween-80, and the flask was shaken to produce a suspension of urediniospores. The urediniospore suspension was sprayed onto detached leaf pieces of the susceptible wheat variety Eritrospermum 15 in a Petri dish on water agar plus benzimidazole at 0.004 µg/ml to obtain isolates from single uredinia (Mikhailova and Kvitko 1970). The Petri dishes were covered with moistened filter paper to maintain 100% 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 10<sup>5</sup> 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, when uredinia with abundant sporulation were present on the single uredinium leaf pieces, urediniospores of the single uredinial isolates were transferred with a soft brush and spread over detached leaves of Eritrospermum 15 wheat on water agar with benzimidazole in a Petri dish to increase the urediniospores of the isolate prior to inoculation of the differential varieties for race identification. Two single uredinial isolates were established from each individual rusted leaf that was collected from the field. The single uredinial isolates were tested for virulence on the eight standard differential varieties (Johnston and Browder 1964; Kolmer 2002). Detached leaves of each differential variety were incubated under artificial light on water agar with benzimidazole as described for establishment of single uredinial isolates. Leaves of each differential variety were placed in a separate Petri dishes. The detached leaves were inoculated by spraying with a sus-

pension of urediniospores of a single uredinial isolate in water with Tween 80 and incubated one day in Petri dishes covered with moist filter paper as described above. After one 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 variety were determined according to Mains and Jackson's scale (Mains and Jackson 1926).

## RESULTS

### Determination of wheat resistance genes effectiveness

During the natural epiphytotic of leaf rust in the eastern and central part of Ukrainian forest-steppe the most efficient resistance genes in the field plots of the near-iso-

genic Thatcher lines in both regions were Lr9, Lr19, Lr24, Lr25, Lr27+31, Lr28, Lr35 and Lr36 (Table 2). Resistance genes Lr3bg, Lr12, Lr13, Lr18, Lr21, Lr22a, Lr23, Lr26, Lr29, Lr30, Lr32, and Lr33 also provided effective resistance in the central part of the Ukrainian forest-steppe region, although the level of resistance provided by Lr3bg, Lr12, Lr13, Lr26, Lr30, Lr32, and Lr33 was somewhat lower than that provided by Lr18, Lr21, Lr22a, and Lr29. The epiphytotic in the central part of the forest-steppe region was less severe than the epiphytotic in the eastern part as indicated by the resistance rating of 3 for Thatcher and the Lr37 line in the central part compared to the lower rating of 1 for 23 of the near-isogenic lines in the eastern part of the forest-steppe region (Table 2).

Table 2. The results of assessment of resistance level of Thatcher near-isogenic lines against the local population of *P. recondita* f. sp. *tritici* in the forest-steppe region of Ukraine in 2007

Line	Resistance rating				Line	Resistance rating			
	eastern part of forest-steppe		central part of forest-steppe			eastern part of forest-steppe		central part of forest-steppe	
Lr1	1 <sup>†</sup>	S <sup>‡</sup>	4 <sup>†</sup>	MS <sup>‡</sup>	Lr20	1 <sup>†</sup>	VS <sup>‡</sup>	5 <sup>†</sup>	M <sup>‡</sup>
Lr2a	1	VS	4–5	MS-M	Lr21	4	MS	8–7*	R
Lr2b	1	VS	5	M	Lr22a	1	VS	8*	R
Lr2c	1	VS	4	MS	Lr23	1	VS	9*	VR
Lr3	1	VS	4	MS	Lr24	9*	VR	9*	VR
Lr3ka	1	VS	4	MS	Lr25	9*	VR	9*	VR
Lr3bg	1	VS	6*	MR	Lr26	5	M	6–7*	MR-R
Lr9	9*	VR	9*	VR	Lr27+31	7*	R	8*	R
Lr10	1	VS	4	MS	Lr28	9*	VR	9*	VR
Lr11	1	VS	5	M	Lr29	5	M	8–9*	R-VR
Lr12	1	VS	7–6*	R-MR	Lr30	1	VS	6*	MR
Lr13	1	VS	6–7*	MR-R	Lr32	3	S	6–7*	MR-R
Lr14a	1	VS	5	M	Lr33	1	VS	6*	MR
Lr14b	1	VS	5	M	Lr34	1	VS	3	S
Lr15	1	VS	5	M	Lr35	7*	R	8–9*	R-VR
Lr16	1	VS	5–4	M-MS	Lr36	7*	R	8*	R
Lr17	1	VS	5	M	Lr37	1	VS	3	S
Lr18	4	MS	8*	R	Thatcher	–	–	3	S
Lr19	9*	VR	9*	VR	–	–	–	–	–

\* types of resistance are: 9 – very resistant (VR); 8, 7 – resistant (R) and 6 – moderately resistant (MR)

† by the integrated scale (Goel and Saini 2001)

‡ by international scales (Goel and Saini 2001; Johnston and Browder 1964)

### Virulence of *P. recondita* f. sp. *tritici* from Ukrainian wheat cultivars

Collections of *P. recondita* urediniospores from leaves of regional and perspective cultivars of winter wheat in the eastern part of Ukrainian forest-steppe in 2007 produced high levels of infection on seedlings of most of the near-isogenic Thatcher lines (Table 3), but little or no infection developed on lines with Lr9, Lr19, Lr24, Lr25, and Lr28. Seedlings of lines with Lr1, Lr2a, Lr2b, Lr2c, Lr26 and Lr27+Lr31 developed somewhat less infection on average than the most susceptible lines (Table 3). In 1988–1989 all leaf rust isolates tested in Ukraine were virulent to Lr26 (Long *et al.* 2002), but by 1994, 48% and by 2003, 40.2% of the isolates were virulent to Lr26 (Elyasi-Gomari and Pantelev 2006).

Although the differences in levels of virulence expressed by collection from the nine different source cultivars were not dramatic, the mean severity over all near-isogenic lines did differ between source cultivars. Urediniospores from the cultivars Kryzhynka and Smuglyanka, which had been rated highly resistant in previous field evaluation, were more virulent on average than urediniospores from other cultivars, particularly those from the highly susceptible Kharkovskaya 105, Donetskaya 48, and Ukrainka Odeskaya (Table 3). This was true for the lines with most effective resistance (Lr9, Lr19, Lr24, Lr25, and Lr28) and the lines with moderately effective resistance (Lr1, Lr2a, Lr2b, Lr2c, Lr26 and Lr27 + Lr31) as well as for the most susceptible near-isogenic lines.

Table 3. Leaf rust severity on seedlings of near-isogenic Thatcher lines inoculated with urediniospores of *P. recondita* collected from nine winter wheat cultivars\* in the eastern part of forest-steppe of Ukraine in 2007

Line	Leaf rust severity induced on seedlings of near-isogenic Thatcher wheat lines by urediniospore collections from indicated winter wheat cultivars									field mean severity [%]
	Kharkovskaya 105	Ukrainka Odeskaya	Donetskaya 48	Kryzhynka	Smuglyanka	Prichernomorka	Astet	Dolgushinskaya	Perlina Lisostepu	
Lr1	62	70	69	80	85	72	75	72	76	73.4
Lr2a	70	74	72	79	77	75	71	78	75	74.6
Lr2b	75	78	80	84	89	80	81	81	80	80.9
Lr2c	78	80	79	90	92	88	87	83	82	84.3
Lr3	100	100	100	100	100	100	100	100	100	100.0
Lr3ka	100	100	100	100	100	100	100	100	100	100.0
Lr3bg	100	100	100	100	100	100	100	100	100	100.0
Lr9	0	0	0	2	4	1	0	0	0	0.8
Lr10	90	92	89	90	92	87	85	83	85	88.1
Lr11	78	81	85	100	100	100	91	89	92	90.7
Lr12	80	82	78	100	100	100	90	95	97	91.3
Lr14a	90	87	89	90	93	85	84	86	89	88.1
Lr14b	86	85	85	91	94	88	82	85	90	87.3
Lr15	82	79	78	100	100	90	89	100	100	90.9
Lr16	80	82	83	100	100	89	91	100	100	91.7
Lr17	79	81	80	100	100	92	89	92	96	89.9
Lr18	90	92	89	100	100	91	90	97	98	94.1
Lr19	0	0	0	4	3	2	1	0	0	1.1
Lr20	100	100	100	100	100	100	100	98	99	99.7
Lr21	100	100	100	100	100	100	100	92	90	98.0
Lr22a	90	97	95	100	100	100	100	97	99	97.6
Lr23	85	82	80	90	96	89	89	87	100	88.7
Lr24	0	0	0	0	0	0	0	0	0	0.0
Lr25	0	0	0	3	4	2	1	0	0	1.1
Lr26	51	61	60	72	81	69	71	65	62	65.8
Lr27+Lr31	43	48	37	59	62	59	52	49	47	50.7
Lr28	0	0	0	0	0	0	0	0	0	0.0
Lr29	90	93	90	100	100	92	89	100	100	94.9
Lr30	90	87	79	89	91	90	87	78	82	85.9
Lr 32	85	84	83	100	100	89	90	100	100	92.3
Lr 33	87	82	85	100	100	90	89	87	97	90.8
Lr 34	90	91	92	100	100	88	87	99	100	94.1
Lr 35	79	77	75	90	90	90	92	98	100	87.9
Lr 36	81	80	90	100	100	89	95	95	98	92.0
Lr37	84	90	87	100	100	91	89	100	100	93.4
Mean	71.3	72.4	71.7	80.4	81.5	76.5	75.3	76.7	78.1	

\* cultivars Kharkovskaya 105, Donetskaya 48 and Ukrainka Odeskaya were previously rated highly susceptible to leaf rust in field observations in Ukraine, Varieties Dolgushinskaya and Perlina Lisostepu were rated moderately susceptible. Variety Astet was rated resistant, and varieties Kryzhynka, Prichernomorka, and Smuglyanka were rated highly resistant

### Races of *P. recondita* f. sp. *tritici* identified in the central part of the forest-steppe region

Seven single-uredinial isolates were obtained from leaves collected from each of 19 Thatcher near-isogenic lines growing in plots in the central part of the forest-steppe region of Ukraine (Table 4). No attempt was made to obtain isolates from the six very resistant lines, and no isolates could be obtained from rusted leaves obtained from the near-isogenic lines with Lr3ka, Lr11, and Lr17, because the urediniospores were not viable. Using the standard wheat leaf rust differential varieties of Johnson and Browder (Johnson and Browder 1964), we identified 15 different races among the 133 isolates (Table 4). Three of the races were previously unidentified races found in Ukraine but not included in the international register of wheat leaf rust races (Johnson and Browder 1964). The four most common races were race 6 (27.8%), race 77 (18.0%), race 149 (13.5%), and race X-4 (9.8%). Six of the 15 races identified were represented by only a single isolate each.

From three to five different leaf rust races were obtained from each of the Thatcher near-isogenic lines (Table 5). As expected, the most common races were found on many of the Thatcher near-isogenic lines. Isolates of races 6, 77, 149, and X4 were obtained from 15, 14, 10, and 7 different lines, respectively. For each of source near-isogenic line, the frequencies of all the races identified among the seven isolates from that line are presented also in Table 5.

Table 5. Wheat leaf rust races obtained from naturally infected near-isogenic Thatcher<sup>†</sup> lines in the central part of Ukrainian forest-steppe region in 2007

Line	Races obtained	Combined freq. [%] <sup>‡</sup>	Line	Races obtained	Combined freq. [%] <sup>‡</sup>
Thatcher	6, 77, 149, X-4	69.1	Lr14b	6, 77, 92, 144, 149, X-4	76.6
Lr1	77, 144, 149, 172	35.3	Lr15	6, 61, 149	48.5
Lr2a	77, 123, 192	30.0	Lr16	6, 77, 92, 192	56.3
Lr2b	6, 77, 149, 192, X-4, X-37	75.9	Lr20	6, 77, 123, 149	65.3
Lr2c	6, 77, 144, 149	62.3	Lr26	92, 123, 161, 192, X-4	27.1
Lr3	6, 61, 77, 92, 149	64.6	Lr30	6, 77, 149, 163, X-4	68.9
Lr10	6, 61, 77, 92	57.1	Lr33	6, 61, X-4	44.4
Lr12	6, 77, X-4	55.6	Lr34	6, 77, 192, X-68	52.6
Lr13	6, 62, X-4	38.4	Lr37	77, 92, 123, 149, 192	48.0
Lr14a	6, 61, 149	48.4	-	-	-

<sup>†</sup> seven isolates from each line were tested on the eight standard wheat leaf rust differential varieties (Johnson and Browder 1964)

<sup>‡</sup> sum of the frequencies of the races found on indicated near-isogenic lines

## DISCUSSION

Winter wheat varieties selected for leaf rust resistance have been grown in the eastern part of Ukrainian forest-steppe over quite a long period of time. This is a situation that may be expected to result in an accumulation of virulence alleles in the local population of *P. recondita* f. sp. *tritici*. Most of the Thatcher near-isogenic wheat lines appeared susceptible in a natural leaf rust epiphytotic in the eastern part of the forest-steppe region in 2007. However, the near-isogenic lines with Lr9, Lr19, Lr24, Lr25,

and Lr28 showed little or no leaf rust infection in the field plots in 2004, indicating that virulence to these resistance genes is lacking in the population of *P. recondita* f. sp. *tritici* at that location. In addition, seedlings of near-isogenic lines with Lr9, Lr19, Lr24, Lr25, and Lr28 developed little or no leaf rust when inoculated with bulk collections of the fungus urediniospores from nine different Ukrainian varieties of winter wheat in the eastern part of the forest-steppe region. These results are consistent with the virulence surveys of 2002 and 2003 in the eastern part of the

Table 4. Frequency of wheat leaf rust races<sup>†</sup> identified in collections<sup>‡</sup> from near-isogenic Thatcher lines in the central part of Ukrainian forest-steppe region in 2007

Race	Frequency [%]	Race	Frequency [%]
6	27.8	161	0.8
61	6.8	163	0.8
62	0.8	172	0.8
77	18.0	192	6.0
92	4.5	X-4 <sup>§</sup>	9.8
123	6.0	X-37 <sup>§</sup>	0.8
144	3.0	X-68 <sup>§</sup>	0.8
149	13.5		

<sup>†</sup> races were identified using the 8 standard wheat leaf rust differential varieties (Johnson and Browder 1964)

<sup>‡</sup> A total of 133 single-uredinial isolates were tested

<sup>§</sup> X races indicate previously unidentified races found in Ukraine that are not included in the international register of wheat leaf rust races (Johnson and Browder 1964)

forest-steppe region (Elyasi-Gomari and Panteleev 2006). Virulence to Lr9, Lr24, Lr25 and Lr28 was not found among races of *P. recondita* f. sp. *tritici* collected in Ukraine in 2002 and 2003. Virulence to Lr19 was infrequent in 2003 and 2004, being found mainly among isolates of previously unidentified races of leaf rust (Elyasi-Gomari and Panteleev 2005, 2006).

Near-isogenic lines with Lr27+31, Lr35, and Lr36 appeared resistant with leaf rust infection of 10% or less in a natural leaf rust epiphytotic in the eastern part of the forest-steppe region in 2007. The near-isogenic line with Lr26 appeared moderately susceptible. The lines with Lr26 and Lr27+31 also developed less severe leaf rust infection than the fully susceptible lines when inoculated with spores collected from Ukrainian winter wheat varieties in the eastern part of the forest-steppe region, which suggests that virulence to Lr26 and Lr27+31 is still relatively low there.

In the central part of Ukrainian forest-steppe diversity of cultivated wheat varieties is much wider than in the eastern part. A higher diversity of resistance genotypes is beneficial, because it does not impose as much selection pressure for the accumulation of specific virulence genes in the pathogen population. Many of the near-isogenic Thatcher lines exposed to the natural epiphytotic in field plots in the central part of the forest-steppe region developed less leaf rust than those exposed to the leaf rust population in the eastern part of the forest-steppe region in 2007. For example, lines with Lr9, Lr19, Lr23, Lr24, Lr25, Lr28, Lr29, and Lr37 were rated very resistant, and lines with Lr18, Lr21, Lr22a, Lr27+31, and Lr36 were rated resistant in 2007 in the central part of the forest-steppe region. Virulence to these resistance genes previously was reported lacking in the Ukrainian leaf rust population (Lesovaya 2004).

Resistance gene Lr26 was effective and widely used in the former USSR starting in the 1970s. Lr26 lost much of its effectiveness in the 1990s, particularly in Ukraine (Lesovoj 1997). The decline in effectiveness of Lr26 can be attributed to the increased use of wheat varieties with the 1B/1R translocation from rye, which carries Lr26 in addition to the genes Sr31 for stem rust resistance, Yr9 for yellow rust resistance and *Pm8* for powdery mildew resistance. In the current study, the near-isogenic line with Lr26 developed moderate levels of infection compared to most of the near-isogenic lines in the eastern part of the forest-steppe region. In the central part of the forest-steppe region the Lr26 near-isogenic line showed less infection and was rated moderately resistant or resistant. The three most common leaf rust races isolated from near-isogenic Thatcher lines in 2007 from field plots in the central part of the forest-steppe region (races 6, 77 and 149) occurred among isolates from 15, 14, and 10 different near-isogenic lines, respectively, but races 6, 77, and 149 did not occur among the isolates from the Lr26 line. This suggests that the leaf rust races favoured by selection in recent years in the central part of the forest-steppe region may lack virulence to Lr26. These results indicate that Lr26 regained some of its effectiveness in Ukraine in recent years, although it is not as effectiveness that had been in the 1970s.

It was noted that the greatest effectiveness of resistance to leaf rust in wheat can be attributed to resistance genes derived from wild relatives of wheat rather than from genes originating from *Triticum aestivum* (Goel and Saini 2001; Menon and Formar 2001; Vlasenko *et al.* 2000). For example, Lr9 was transferred to wheat from *T. umbellulatum*, Lr19, Lr24 and Lr29 were from *Agropyron elongatum*, Lr21, Lr22 and Lr32 genes were from *T. tauschii*, and Lr28, Lr35 and Lr36 were from *T. speltooides*. Our results confirm that most of these genes still provide highly effective resistance against leaf rust in Ukraine. On the other hand, genes such as Lr2c, Lr3, Lr3ka, Lr10, Lr16, Lr30 and Lr37 have been no longer effective in Ukraine and should be withdrawn from breeding programs or supplemented with more effective resistance genes. This is also true for Lr23, which formerly provided valuable resistance in Ukraine (Kolmer 2002), but now is ineffective in the eastern part of the forest-steppe region although it remained effective in 2007 in the central part.

In 2007 most common races in the central part of the forest-steppe region were races 6, 77, 149, and X-4. Race X-4 is a new race that was first discovered by the scientists of the Institute for Plant Protection (Kiev, Ukraine) on the territory of Ukraine. Up to the late 1990s 19 new races were identified in Ukraine that were not listed in the International Catalogue for leaf rust races. Between 1996 and 2004 the list of such races reached 68 (Lesovaya 2004; Lesovoj and Panteleev 2000). No new races were added to the list in 2007. Some of the races not listed in the International Catalogue may be referred to as "one-day" races that were identified only once and did not remain at detectable levels in the *P. recondita* f. sp. *tritici* population. A small number of the new races, however, was found repeatedly in the population over the period of some years. Among these are X-37 race (first discovered in 1997) and X-68 (first discovered in 2003). Both race X-37 and race X-68 were identified as single isolates collected in 2007.

The level of virulence complexity in the pathogen population can be represented by the ratio of highly virulent races: moderately virulent races: relatively avirulent races. According to Voronkova (1980), the number of virulent races in the leaf rust population was almost three times lower than the number of avirulent and moderately virulent races. This ratio was observed in 2002 with highly virulent: moderately virulent: avirulent races occurring at a ratio of 18 : 18 : 10 and in 2003 with a ratio of 14 : 12 : 10. In 2007 the ratio of races was almost 1 : 1 instead of 1 : 3. This might reflect a small number of races found in 2007, 15, compared to 36 and 46 races found in 2002 and 2003 in Ukraine. It appears that the numbers of virulent races isolated in recent surveys in Ukraine have not declined as much as the number of moderately virulent and avirulent races identified in the surveys. The changes in the *P. recondita* f. sp. *tritici* population could have been caused by changes in the resistant genotypes of the most commonly grown wheat cultivars or as a consequence of some environmental changes (in particular, 2002–2003 winter) that might have changed the survival of virulent and avirulent races in ways that were not fully understood. The racial composition and virulence of *P. recondita* f. sp. *tritici* populations has influenced most by temperature and relative

humidity (Alekseeva *et al.* 1990). Lower than normal summer temperatures and high relative humidity increased the survival of virulent races relative to survival of avirulent races. In the summer of 2007 humidity was high and temperatures were under 15–20°C. Precipitation was greater than normal at the time of wheat flowering and temperatures dropped, especially at night. These conditions benefited survival of the virulent races. The majority of wheat varieties grown in the central part of Ukrainian forest-steppe have resistance genes that are ineffective against the most common races 6, 77, 149, and X-4.

There were some notable differences between the frequencies of leaf rust races identified in the central part of the forest-steppe region in 2007 and the frequencies of races found in the eastern part in 2002 and 2003 (Elyasi-Gomari and Panteleev 2006). The two most common races in the eastern part were race 61 at 24.8% in 2002 and 24.0% in 2003 and race 149 at 23.8% in 2002 and 22.0% in 2003. Both of these races were found at considerably lower frequencies in the central part in 2007; race 61 occurred at 6.8% and race 149 occurred at 13.5%. Race 184 was relatively common in the eastern part of the forest-steppe region at 15.6% in 2002 and 11.5% in 2003, but race 184 was not found in the central part in 2007. On the other hand, races 6 and 77 were more common in the central part in 2007 than in the eastern part in 2002 and 2003. Race 6 occurred at 27.8% in 2007 but at only 0.2% and 1.2% in the eastern part of the forest-steppe region in 2002 and 2003. Race 77, which is virulent on all 8 of the standard differentials of Johnson and Browder (Johnson and Browder 1964), occurred at 18.0% in the central part in 2007 but occurred at 10.6% in 2002 and 7.8% in 2003 in the eastern part of the forest-steppe region. Also, race 57 occurred at 5.7% in 2002 and 12.9% in 2003 in the east part but was not found in the central part of the forest-stepper region in 2007. Thus, the composition of the leaf rust populations appears to differ between the eastern and central parts of the forest-steppe region of Ukraine in addition to changing from year to 3 years in response to the use of resistant wheat varieties in the two areas. This shows that continued regional surveys of virulence in *P. recondita* f. sp. *tritici* are necessary to support programs of breeding wheat cultivars with effective leaf rust resistance in Ukraine.

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## POLISH SUMMARY

### WIRULENCJA *PUCCINIA RECONDITA* F. SP. *TRITICI* W STOSUNKU DO PSZENICY OZIMEJ NA UKRAINIE W 2007 ROKU

Thatcher i 36 blisko-izogenicznych linii Thatcher z genami Lr warunkującymi odporność na *Puccinia recondita* f. sp. *tritici* wysadzano indywidualnie do wazonów na poletkach doświadczalnych w każdej z lokalizacji we wschodniej i centralnej części w rejonie las-step na Ukra-

inie, gdzie były eksponowane na naturalną epifitozę rdzy. Nasilenie choroby na liniach wskazywało, że Lr9, Lr19, Lr24, Lr25 i Lr28 warunkowały wysoce efektywną odporność w obydwóch lokalizacjach. Linie z genami Lr27 + Lr31, Lr35 i Lr36 były odporne we wschodniej lokalizacji i wysoce odporne w centralnej lokalizacji. Całościowe kolekcje *P. recondita* z pól z dziewięcioma ukraińskimi odmianami pszenicy we wschodniej lokalizacji użyto do inokulacji siewek 36. blisko-izogenicznych linii Thatcher. Na liniach z Lr9, Lr19, Lr24, Lr25 i Lr28 nie było, lub prawie nie było uredinów. Ogółem 133 jednozarodnikowych izolatów uzyskanych z 19 wrażliwych, blisko-izogenicznych linii Thatcher na polowych poletkach w centralnej części regionu las-step określono do rasy, przy zastosowaniu ośmiu standardowych linii różnicujących Johnso-na i Brondera. Najpospolitszymi rasami były: 6 (27,8%), 77 (18,0%), 149 (13,5%) i X-4 (9,8%). Najpospolitszych ras nie znaleziono na linii z Lr26 i może ona nie wykazywać wirulencji w stosunku do tej linii.