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Leaf Rust Resistance in Common Wheat Varieties and Lines from the Collection of the Vavilov Plant Industry Institute Carrying Alien Genetic Material

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Abstract—Leaf rust resistance was estimated in 83 common wheat accessions carrying alien genetic material from the collection of the Vavilov Institute. Eight accessions with seedling resistance and 27 accessions with adult plant resistance were found. Analysis with molecular markers revealed genes highly and moderately efficient in Russia—*Lr24*, *Lr39*, *Lr21*, and *Lr37*—and a rye translocation 1AL.1RS. The accessions containing effective *Lr* genes are promising donors in Russian breeding programs. The lines raised with the use of *T. timopheevii* were heterogeneous for resistance. No molecular markers of the *Lr50* gene known for this species were detected there. These lines demand further examination and selection.

Keywords: common wheat, leaf rust, resistance, molecular markers, *Lr* genes, alien genetic material
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INTRODUCTION

Leaf rust (the caused agent is *Puccinia triticina* Eriks.) is a common disease of wheat in all regions of Russia, which can lead to a significant loss of crops yield during epiphytoties. An environmentally safe method of protection against this disease is the cultivation of resistant varieties. The results of screening for the resistance to leaf rust of soft wheat varieties recommended for growing in Russia indicate demonstrable progress in breeding over the past ten years (Novozhylov et al., 1998; Gultyaeva et al., 2014a). There was a significant increase in the State Register of Selection Achievements of the Russian Federation of winter varieties with field resistance and spring ones with seedling resistance, while using molecular markers it was shown that many of them are protected by genes *Lr19* and *Lr9* (Gultyaeva et al., 2009b, 2014). The widespread cultivation of such varieties in Western Siberia, the Urals, and the Volga region led to the loss of their stability (Meshkova et al., 2008). In this respect, it is relevant to increase the diversity for *Lr*-genes in the domestic varieties of wheat and determine the strategy for their allocation in the regions.

To date, 67 *Lr*-genes were identified in wheat worldwide, more than 50% of which are alien (McIntosh et al., 2012). To identify most of them, molecular markers were developed that allow controlling the transfer of *Lr*-genes and significantly speeding up the creation of resistant varieties.

The wheat collection of the Vavilov Plant Industry Institute contains a large number of accessions obtained with the participation of different species of wheat, goatgrass, rye, and bluegrass, and were included in the collection over the years. These accessions may be of interest for breeding as sources of known effective alien *Lr* genes not previously used in Russia and those identified for the first time.

The purpose of this work is to characterize the varieties and lines of wheat from the collection of the Vavilov Plant Industry Institute, which carry foreign genetic material, for resistance to the leaf rust pathogen and identification of the *Lr* genes in them.

MATERIALS AND METHODS

The research material included 83 varieties and lines of wheat from the collection of the Vavilov Plant Industry Institute (41 winter and 42 spring types), obtained with the participation of *T. timopheevii* (Zhuk.) Zhuk. ($2n = 4x = 28$, *GGAA*), *Aegilops tauschii* Coss. ($2n = 2x = 14$, *DD*), *Ae. speltoides* Tausch ($2n = 2x = 14$, *SS*), *Ae. ventricosa* Tausch ($2n = 4x = 28$, $D^vD^vN^vN^v$)), *Triticum timopheevii* ssp. *armeniacum* (= *Triticum araraticum* Jakubz.) ($2n = 4x = 28$, *GGAA*), *Thinopyrum ponticum* (= *Agropyron elongatum*), and the synthetic species *T. migushovae* Zhir. ($2n = 6x = 42$, A^bA^bGGDD). The synthetic species was created by E.G. Zhirov at the Krasnodar Agricultural Research Institute by

Table 1. Type of response of test-clones of *P. triticina* when inoculating isogenic Tc*Lr* lines

Test-clone	Type of reaction in Tc*Lr*-lines, points															
	1	2a	2b	2c	3a	3bg	3ka	9	14b	15	19	20	23	24	26	28
kLr9	3	3	3	3	3	3	3	3	3	3	0	3	X	0–1	0	0
kLr19	3	3	3	3	3	3	3	0	3	3	3	3	3	1	0	0
k43	3	3	3	3	3	3	3	0	3	3	0	3	3	1–2	3	0
k18	0	0	3	3	3	3	3	0	3	3	0	0	3	0–1	3	0
kP19	3	0	0	3	3	3	3	0	3	3	0	0	1–2	0–1	3	0
k70	0	0	0	0	3	3	3	0	3	0	0	3	2–3	0–1	3	0
k60	3	3	3	3	0	0	0–1	0	3	3	0	3	3	0–1	0	0

crossing the natural hulless mutant *T. militinae* Zhuk. et Migusch., selected from the population of species *T. timopheevii*, with *Ae. tauschii* (Dorofeev et al., 1987).

The studied accessions were evaluated for resistance to leaf rust in the phase of seedlings and adult plants. Resistance in the seedling stage (the first leaf phase) were studied by the laboratory inoculation of leaf segments (Mikhailova et al., 2003) and infecting the intact plants. The type of response was taken into account on the eighth day after inoculation according to the scale of Mines and Jackson with the following score; 0, absence of symptoms or necrosis without pustules; 1, very small pustules surrounded by necrosis (R); 2, medium-sized pustules surrounded by necrosis or chlorosis (MR); 3, medium-sized pustules without necrosis (MS); 4, large pustules without necrosis (S); and X, different types of pustules on one and the same leaf, chloroses, and necroses are present (M).

The resistance of adult plants was studied in 2013–2014 in the experimental field of the Vavilov Plant Industry Institute (St. Petersburg, Pushkin) under an artificial inoculation by spraying the experimental plots with a suspension of isolates from the north western population of the fungus *P. triticina*. The diseases severity of leaf rust was evaluated by the scale of Peterson et al. (Peterson et al., 1948), and the type of reaction by the scale of Mains and Jackson. During the growing season, several records were carried out: the first one after the first symptoms of the disease and the following ones every seven days. The main indicator of resistance consisted in the data of the last record, when there was the strongest manifestation of the disease (*Metody*..., 1988).

Identification of *Lr* genes was carried out using the phytopathological test and molecular markers. For the phytopathologic studies, seven isolates of leaf rust were selected. The characteristics of the fungal test-clones for virulence to 16 isogenic Tc*Lr* lines are presented in Table 1. Isolate kLr9 was selected from the Omsk population in 2010, kLr19 from the Nizhny Novgorod population in 2012, k43 from the Omsk population in 2012, k18 from the Saratov population in 2011, kP19 from the Nizhny Novgorod population in 2011, k70 from the Tambov population in 2012, and k60 from the Kaliningrad population in 2012.

Using PCR markers, we identified 12 high and partially effective alien genes *Lr9*, *Lr19*, *Lr21*, *Lr24*, *Lr28*, *Lr29*, *Lr35*, *Lr37*, *Lr39/41*, *Lr47*, *Lr50*, and *Lr66*, as well as wheat-rye translocation 1BL.1RS (with genes *Lr26/Sr31/Yr9/Pm8*) and 1AL.1RS (Table 2). DNA extraction was carried out from the leaves of 7–10-day-old seedlings as described by Dorokhov and Cloquet (1997). DNA amplification was carried out according to the protocols shown in the literature (Table 2), modified when necessary. The amplified fragments were separated by electrophoresis in 1.5% agarose gel in a 1× TBE buffer, and the gels were stained with ethidium bromide and photographed under ultraviolet light.

RESULTS

The study of seedling resistance revealed eight accessions: Cutless (k-62517), KS90WGRC10 (k-62377), KS93U149 (k-62382), KS93U62 (k-63933), KS93U50 (k-63937), KS92WGRC22 (k-65156), KS96WGRC38 (k-65157), and KS96WGRC40 (k-65158), all from the United States, and immune to leaf rust throughout the growing season (Table 3). All the other studied accessions were characterized by varying degrees of susceptibility in the seedling stage and adult plant one.

By the results of the evaluation in the field conditions of the North West, variety Hadden (k-54855, United States), line IT-5 (k-50851, Russia), hybrid Cheyenne × *T. timopheevii* (k-45678, Canada), and variety Brigadier (k-63322, France) were assigned to the highly resistant group (no disease symptoms). The group of resistant varieties comprised (lesion up to 5%) Vostorg (k-64584, Russia), which was marked with a moderately susceptible response type X (MS), as well as accessions with the susceptible type (a score of 3–4 (S)): Wisc. 245 (k-43577), ND600 (k-60781), and IL-1/Chinese*2/*T. timopheevii* (k-45165), Allard 52-1-1-17-1 (k-49928), and KS86WGRC02 (k-62373), all from the United States; and AC Minto (k-62878, Canada), Alert (k-63901), and Beaufort (k-63920) from the

Table 2. PCR markers used to identify alien *Lr* genes

Gene, transloca-tion	Source species	Primers	Nucleotide sequence (5'–3')	Amplicon size, bp	Literary source
Lr9	*Aegilops umbellulata*	SCS5F SCS5R	TGCGCCCTTCAAAGGAAG TGCGCCCTTCTGAACTGTAT	550	Gupta et al., 2005
Lrl9	*Agropyron elongatum*	SCS265F SCS265R	GGCGGATAAGCAGAGCAGAG GGCGGATAAGTGGGTTATGG	512	Gupta et al., 2006
Lr21	*Aegilops tauschii*	Lr21F Lr21R	CGCTTTTACCGAGATTGGTC TCTGGTATCTCACGAAGCCTT	669	http://maswheat.ucdavis.edu/protocols/Lr21/index.htm
Lr24	*Agropyron elongatum*	Sr24#12F Sr24#12L	CACCCGTGACATGCTCGTA AACAGGAAATGAGCAACGATGT	500	Mago et al., 2005
		SCS73F SCS73R	TCGTCCAGATCAGAATGTG CTCGT GATTAGCAGTGAG	719	Cherukuri et al., 2003; Prabhu et al., 2004
Lr28	*Aegilops speltoides*	SCS421F SCS421L	ACAAGGTAAGTCTCCACCCA AGTCGACCGAGATTTTAACC	570	Cherukuri et al., 2005
Lr29	*Agropyron elongatum*	Lr29F24 F Lr29F24 L	GTGACCTCAGGCAATGCACACAGT GTGACCTCAGAACCGATGTCCATC	900	Procunier et al., 1995
Lr35	*Aegilops speltoides*	Sr39F2 Sr39R3	AGAGAGAGTAGAAGAGCT AGAGAGAGAGCATCCACC	900	Gold et al., 1999
		BCD260F1 35R2	GAAGTTAAAGAGGTCTTGAC TTTTGAGAATCAGTCATCAC	931	Seyfarth et al., 1999
Lr37	*Aegilops ventricosa*	Ventriup LN2	AGGGGCTACTGACCAAGGCT T GCAGCTACAGCAGTATGTACACAAAA	259	Helguera et al., 2003
Lr39 (=*Lr41*)	*Aegilops tauschii*	GDM35-L GDM35-R	CCTGCTCTGCCCTAGATACG ATGTGAATGTGATGCATGCA	190	http://maswheat.ucdavis.edu/protocols/Lr39/index.htm
Lr47	*Aegilops speltoides*	PS10R PS10L	GCTGATGACCCTGACCGGT TCTTCATGCCCGGTCGGGT	282	Helguera et al., 2000
Lr50	*Triticum timopheevii* ssp. *armeniacum*	GDM87-L GDM87-R	AATAATGTGGCAGACAGTCTTGG CCAAGCCCCAATCTCTCTCT	139	http://maswheat.ucdavis.edu/protocols/Lr50/index.htm
		WMS382-F WMS382-R	GTCAGATAACGCCGTCCAAT CTACGTGCACCATTTTG	110	
Lr66	*Aegilops speltoides*	16-S13F 16-S13R	GGTGAACGCTAAACCCAGGTAACC CAACCTGGGAAGATGCTGAG	695	Marais et al., 2009
1BL.1RS/ 1AL.1RS	*Secale cereale*	SCM9F SCM9R	TGACAACCC CCTTTCCCTCGT TCATCGACGCTAAGGAGGACCC	207/228	Weng et al., 2007

Table 3. Characteristics of common wheat accessions for resistance to leaf rust pathogen in the phase of seedlings and adult plants (experimental field of the Vavilov Plant Industry Institute, Pushkin, 2013, 2014)

VIR catalog no.	Accession name	Origin	Alien species in pedigree	Type of reaction of seedlings when inoculated with test-clones							Disease development in the field (%) and type of reaction		Identified *Lr* genes and transloca-tions	Information on the availability of *Lr* genes by GRIS***
				kLr9	kLr19	k43	k18	kP19	k70	k60	2013	2014		
							Spring wheat							
62517	Cutless	United States	*Ae. tauschii*	R	R	R	R	R	R	R	0	0	*Lr21*	*Lr21*
60781	ND600	″	″	S	R	R	S	R	S	R	1S	1S		*Lr21*
54855	Hadden	″	*T. timopheevii*	S	S	S	S	S	S	S	0	0		*Lr13*
50851	Line IT-5	Russia	″	MS	MS	S	S	MR	MS	R	0	0		
50847	Line IT-1	″	″	S	S	S	S	S	S	S	0, 5S**	0, 5S**		*LrTt1LrTt2*
50852	Line IT-6	″	″	MR	S	S	R	R	R	R	0, 5S**	0		
50857	Line IT-13a	″	″	S	S	S	S	S	S	S	0, 1S**	0, 1S**		
50858	Line IT-15	″	″	S	R	MS	S	S	S	MS	0	0, 1S**		
50849	Line IT-3	″	″	S	S	S	S	S	S	S	1MR	1–5MR, 10–15MR**		*LrTt1LrTt2*
50853	Line IT-7	″	″	MR	MR	S	R	R	X	S	0, 5S**	0, 5S, 20–30S**		
50850	Line IT-4	″	″	S	S	S	S	S	S	S	0, 70S**	0.50–70S**		
50854	Line IT-8	″	″	S	MS	S	S	S	S	S	10S	0.30–50S**		
61518	Line 36	Estonia	″	R	R	S	R	R	S	R	0, 5S, 30–40S**	0, 10S, 30–40S**		
62878	AC Minto	Canada	*Ae. tauschii*	R	MR	R	MR	R	R	MR	1S	5S		*Lr11 Lr13 Lr22a*
65264	–	Mexico	″	S	S	S	R	R	S	S	5S	5S		
43577	Wise. 245	United States	*T. timopheevii*	S	–	S	S	S	S	S	0, 1S	5S		*Lr12*
45165	IL-1/Chinese*2/ *T. timopheevii*	Canada	″	S	R	S	R	S	S	S	5S	5MS		
49928	Allard 52-1-1-17-1	United States	″	S	S	S	S	S	S	S	5S	5S		*Lr12*
43091	Blue A	Canada	*Ag. elongatum*	S	S	S	R	S	S	S	10MS	30M		

Table 3. (Contd.)

VIR catalog no.	Accession name	Origin	Alien species in pedigree	Type of reaction of seedlings when inoculated with test-clones							Disease development in the field (%) and type of reaction		Identified *Lr* genes and trans-locations	Information on the availability of *Lr* genes by GRIS***
				kLr9	kLr19	k43	k18	kP19	k70	k60	2013	2014		
							Winter wheat							
62377	KS90WGRC10	United States	*Ae. tauschii*	R	R	R	R	R	R	R	0	0	*Lr39* 1AL.1RS	*Lr39*
62382	KS93U149	"	*Ae. tauschii* *Ag. elongatum*	R	R	R	R	R	R	R	–	0	*Lr24* 1AL.1RS	*Lr24 Lr41*
63933	KS93U62	"	"	R	R	R	R	R	R	R	0	0	*Lr24*, *Lr39* 1AL.1RS	*Lr24 Lr39*
63937	KS93U50	"	"	R	R	R	R	R	R	R	0	0	*Lr24* 1AL.1RS	*Lr24 Lr42*
65156	KS92WGRC 22	"	"	R	R	R	R	R	R	R	0	0	*Lr24* 1AL.1RS	*Lr24*
65158	KS96WGRC 40	"	*Ae. tauschii*	R	R	R	R	R	R	R	0	–	1AL.1RS	*Lr39*
65157	KS96WGRC38	"	*Ae. tauschii* *T. timopheevii* ssp. *armeniacum*	R	R	MR	R	R	R	MR	–	0	1AL.1RS	*Lr41 Lr50* *1AL.1RS*
63322	Brigadier	France	*Ae. ventricosa*	R	R	R	S	S	S	R	0	–	1BL.1RS (*Lr26*) *Lr37*	*Lr13 Lr26 Lr37*
45678	Hybrid (Cheyenne × *T. timopheevii*)	Canada	*T. timopheevii*	S	S	S	S	S	S	S	0	–		
64308	@Фишт	Russia	*T. migushovae*	S	S	S	S	S	S	S	1S	0		
64584	@Восторг	"	"	R	R	R	S	S	S	R	1S	5MR	IBL.IRS (*Lr26*)	
63901	Alert	United Kingdom	*Ae. ventricosa*	R	S	R	R	S	R	–	0	5S	*Lr37*	
63920	Beaufort	"	"	R	R	R	S	S	R	R	0	5S	IBL.IRS (*Lr26*) *Lr37*	*Lr1 Lr26 Lr37*
62373	KS86WGRC02	United States	*Ae. tauschii*	S	S	S	S	R	S	R	5S	–	*Lr21*	*Lr21 Lr 41*
63300	Arche	France	*Ae. ventricosa*	R	R	S	S	S	S	S	1S	10S	*Lr37*	*Lr13 Lr37*
63031	Steele	United States	*Ae. tauschii*	S	S	S	R	R	X	S	10S	15S		*Lr2a, Lr10 Lr21*
62811	Centurion	France	*Ae. ventricosa*	S	S	S	S	S	S	S	5S	20S	*Lr37*	

* Results of the last census; ** Heterogeneity of the accession for resistance to leaf rust; *** GRIS, Genetic Resources Information System for Wheat and Triticale (http://www.wheatpedigree.net); "–", no data.

United Kingdom. Accessions Archer (k-63300, France) and Steele (k-63031, United States) were characterized by moderate resistance (disease development 15%, response type S). Moderate susceptibility (disease development of 20–30%) was detected in the winter variety Centurion (k-62811, France) and the wheat-bluegrass substituted wheat line Blue A (k-43091, Canada), where it had a lower response type (M).

The high heterogeneity for resistance to leaf rust was observed in eight introgressive lines, created at the Vavilov Plant Industry Institute by N.A. Skurygina (1984) with the use of *T. timopheevii*, and line 36 (k-61518) from Estonia. These lines contained both plants without symptoms of the disease and plants infected to varying degrees (Table 3). In 2013–2014, the maximum development of the disease was not more than 5% in the infected plants of lines IT-1 (k-50847), IT-6 (k-50852), IT-13a (k-50857), and IT-15 (k-50858); up to 10–15% in line IT-3 (k-50849), which, in contrast to other lines, was characterized by moderate resistance of the reaction type (2); the disease development did not exceed 40% in lines 36 and IT-7 (k-50853) and 70% in lines IT-4 (k-50850) and IT-8 (k-50854) (Table 3).

All the other accessions studied under field conditions showed high susceptibility to leaf rust. Disease development of 50–60% characterized accessions KS86WGRC05 (k-62375) and KS86WGRC07 (k-62376) from the United States and PPG 64 (k-40230, Russia); 70–80%, Wb.58633 (k-45164, Canada), Dipka (k-60340, the Republic of South Africa), Amidon (k-62515, United States), and Fleischman 481 (k-43231, Hungary), as well as wheat-bluegrass hybrids created in Russia and Germany: PPG 599 (k-38289), PPG 1 (k-40229), PPG 54/49 (k-40697), PPG 60/49 (k-40859), PPG 59/49 (k-40860), PPG 56/49 (k-40870), PPG 55/49 (k-40871), PPG 29 (k-48704), PPG 5 (k-54691), PPG 113 (k-58539), PPG 115 (k-58540); 90–100%, Timstein (k-38498), Bledsoe (k-44405), Idaed 59C (k-44456), Idaed 59B, (k-45670), Molly (k-63555), KS86WGRC04 (k-62374), KS89WGRC03 (k-62715), KS89WGRC06 (k-63875), and U1865-1-4-1 (k-63938), all from the United States; Wb.60414 (k-45162) and Pewter (k-49440, k-45182) from Canada; N43 (k-47033, Brazil); South Africa 43 (k-45295) and Gouritz (k-64137) from the Republic of South Africa; 690 F4 Sel.D.l. (k-49432, Kenya); Titan (k-58433, Australia); UH 96 (k-60551, Czechoslovakia until 1992); Livanjka (k-60991, Yugoslavia until 1990); and Gartus 598 (k-59398), Saratovskaya 73 (k-64556), Zhirovka (k-63377), L-500 (k-62903), line IT-2 (k-50848), line IT-11a (k-50855), line IL-6 (k-60773), PPG 186 (k-40231), and PPG 347 (k-58541), all from Russia.

With the use of test-clones, it was revealed that the studied accessions of common wheat do not have partially effective alien genes *Lr9* and *Lr19*; at the same time, it was demonstrated that the winter varieties Vostorg, Brigadier, and Beaufort have gene *Lr26*.

Molecular genetic screening of introgression accessions did not find markers of genes *Lr9*, *Lr19*, *Lr29*, *Lr35*, *Lr47*, *Lr50*, and *Lr66*. Marker GDM35 of gene *Lr39* was revealed in lines KS90WGRC10 and KS93U62; markers Sr24#12 and SCS73 of gene *Lr24* were revealed in lines KS93U149, KS93U62, KS93U50, and KS92WGRC22; marker Lr21F/R of gene *Lr21* were revealed in accessions KS86WGRC02 and Cutless; and marker Ventriup/LN2 of gene *Lr37* was found in varieties Brigadier, Alert, Beauford, Arche, and Centurion. The amplification the product size of 207 bp obtained using marker SCM9 and indicating the presence of 1BL.1RS with gene *Lr26* was observed in the Brigadier, Vostorg, and Beaufort varieties, and a size of 228 bp (translocation 1AL.1RS) in lines KS90WGRC10, KS93U149, KS93U62, KS93U50, KS92WGRC22, KS96WGRC40, and KS96WGRC38. Line Blue A was revealed to have an amplification product obtained using marker SCS421 of gene *Lr28*, which was slightly different in size from the control line.

DISCUSSION

In modern times, the most effective genes in all regions of Russia are *Lr24*, *Lr28*, *Lr29*, *Lr39* (= *Lr41*) and *Lr47*, but none of them has been identified in recommended for growing varieties (Gultyaeva et al., 2009a, b, 2014a; Zhemchuzhina and Kurkova, 2010). The studied accessions in the collection revealed carriers of genes *Lr24* and *Lr39* individually and in combination (Table 3).

An accession of *Ae. tauschii* TA2460 was the source of gene *Lr39* for lines KS90WGRC10 and KS93U62, and North American winter varieties TAM200 and Century were the source of bluegrass gene *Lr24* for KS93U149, KS93U62, KS93U50, and KS92WGRC22. In turn, the latter gene was obtained from variety Amigo as part of the chromosomal segment of bluegrass 3Ae#1L. Wheat-rye translocation T1AL.1RS was transferred from variety Amigo into all the lines mentioned above, as well as lines KS96WGRC40 and KS96WGRC38 (Jiang et al., 1994). It should be noted that the marker of gene *Lr39* was not detected in line KS93U149, although the same accession of *Ae. tauschii* TA2460 was one of its parent forms.

Gene *Lr39* was found mostly in the North American varieties, and variety Thunderbolt was the first whose genotype was introduced with this gene. This variety was grown in large areas in several states, and in 2002 virulent isolates were first marked (http://maswheat.ucdavis.edu/protocols/*Lr39*/index.htm). Gene *Lr24* is widespread in wheat varieties of the North American and Australian breeding; however, due to the non-optimal areas occupied by varieties with this gene, it has lost some of its effectiveness in these countries (McIntosh et al, 1995). So far, it remains effective in Western Europe and Russia (Mesterházy et al., 2000; Zhemchuzhina and Kurkova, 2010; Tyryshkin et al., 2014; Gultyaeva et al., 2014b).

In wheat-bluegrass substituted line Blue A, in which a pair of chromosomes *4D* is replaced by *4Ael* (Zeven, 1991), a DNA fragment was identified slightly different in size from the marker of gene *Lr28* originating from *Ae. speltoides*. In 2013–2014, in the field conditions, the lesion of this line varied from 10 to 30% with response type X, and line Tc*Lr28* was immune (0%). In the phase of seedlings, most isolates of *P. triticina* were avirulent on leaves of line Tc*Lr28* but virulent in line Blue A, which confirms the lack of gene *Lr28* in it.

The group of genes characterized as partially effective in Russia are *Lr9*, *Lr19*, *Lr25*, *Lr27* + *Lr31*, *Lr36*, *Lr38*, *Lr42*, *Lr45*, *Lr49*, and *Lr50*. The virulence of pathogen strains to lines with genes *Lr25*, *Lr36*, *Lr38*, *Lr42*, *Lr45*, *Lr49*, and *Lr50* occurs sporadically, at different times and in different regions, and does not exceed 15%. Virulence to tester lines Tc*Lr19* and Tc*Lr9* is observed in those regions with high concentration of varieties—carriers of genes *Lr9* and *Lr19* (Meshkova et al., 2008). The phytopathological tests and molecular markers did not reveal accessions with these genes in the studied set. According to the pedigree, the accession of KS96WGRC38 may have gene *Lr50* whose donor could have been the accession TA895 of wild Ararat wheat *T. araraticum* (Brown-Guedira et al., 1999). However, the use of SSR-markers *GDM87* and *WMS382* did not confirm the presence of this gene in KS96WGRC38. Gene *Lr50* is characterized as partially effective in North America and is mainly used in breeding in pyramiding with other *Lr*-genes (http://maswheat.ucdavis.edu/protocols/Lr50/index.htm).

All of the above identified *Lr* genes belong to the seedling group whose effect is manifested in all phases of wheat ontogeny starting with the first leaf. Genes *Lr21* and *Lr37*, identified in some accessions of the studied set, refer to the resistance genes of adult plants; their effect was observed in the later stages of ontogeny, such as after booting. According to the Catalogue of Gene Symbols for Wheat (McIntosh et al., 2012), this group also includes genes *Lr12*, *Lr13*, *Lr22a*, *Lr22b*, *Lr34*, *Lr35*, *Lr46*, *Lr48*, and *Lr67*.

Gene *Lr21* belongs to the group of highly efficient genes in the United States and Canada (McIntosh et al., 1995). In Western Europe, the disease severity on line Tc*Lr21* varied from 0 to 100% depending on the year and country (Mesterházy et al., 2000; Hanzalová et al., 2008). In the seedling stage, gene *Lr21* was described as inefficient in Russian populations of *P. triticina* (Gultyaeva et al., 2009a, b; Zhemchuzhina and Kurkova, 2010), but in adult plant stage in the North West in the period from 2002 to 2014, line Tc*Lr21* was moderately resistant (lesion from 5 to 30%), as well as line KS89WGRC07 previously described as a donor of gene *Lr40* (in the present period *Lr40* = *Lr21*) (McIntosh et al., 1995). Using a molecular marker, it was seen that both this line and variety Cutless have gene *Lr21*, but it was not found in Steele and ND 600. According to the information base Genetic Resources Information System for Wheat and Triticale, ND 600 is a synonymous name of variety Cutless, while in the collection of wheat of the Vavilov Plant Industry Institute these accessions have different numbers. For resistance to leaf rust, their differences were revealed both in the phase of seedlings and adult plants. Variety Cutless refers to the immune group throughout the growing season, and ND 600 turned out to be heterogeneous when inoculated with clones in the phase of seedlings, while in the field conditions its leaves were observed with individual fungal pustules (growth of 1%). This accession was created using an almost isogenic line of the Thatcher RL-6043 variety, the source of gene *Lr21* (McIntosh et al., 1995), which was confirmed only for the Cutless variety.

Until recently, gene *Lr37* was a highly efficient gene for the resistance of adult plants worldwide (McIntosh et al, 1995). Virulence to it was first described in Australia in 2002. To date, this gene has lost its efficiency in Western Europe, due to massive cultivation of varieties carrying it (Serfling et al., 2011). In Russia, disease severity of line Tc*Lr37* varies in the regions. In the North West, it varies depending on the year from 5 to 30%. Varieties of winter Brigadier, Alert, Beaufort, Arche, and Centurion wheat, containing this gene, were infected from 5 to 20%, which is probably due to the presence of additional *Lr* genes in their genotypes (Table 3).

Of some interest for breeding may be a series of IT lines, obtained at the Vavilov Plant Industry Institute in 1970 by crossing common wheat with the *T. timopheevii* species and described as resistant to leaf rust (Skurygina, 1984). The performance of many lines was noted in this analysis (Table 3). According to Skurygina (1984), all these lines have two dominant genes, *LrTt1* and *LrTt2*, and additionally, according to R.A. McIntosh, gene *Lr18* (Skurygina, 1989). Field estimation of the lines in the North West region in 2013–2014 showed that most of the lines are heterogeneous for resistance. Of these, it is necessary to select resistant plants and use the molecular and cytological methods to identify resistance genes in them.

Using a universal marker SCM9, which exposes translocations 1BL.1RS from variety Kavkaz and 1AL.1RS from variety Amigo, accessions carrying these translocations were found (Table 3). The massive use of gene *Lr26* in the selection at the end of the 1960s and the subsequent breeding of varieties homogeneous for this gene over large areas led to the formation of a powerful selective background for the accumulation of virulent clones. Currently, clones of the fungus, virulent to gene *Lr26*, are widespread in all regions of Russia. Nevertheless, it should be noted that translocation 1BL.1RS carries (except for resistance genes) genes that increase the grain yield and drought tolerance by increasing the root mass (Kim et al., 2004). In this respect, breeders are seeking efficient combinations of gene *Lr26* with other *Lr* genes. One good example is the use of combination *Lr19* + *26* (Sibikeev et al., 2011).

Despite the fact that no known *Lr* genes were found in translocation 1AL. 1RS, varieties carrying it are characterized by a certain level of resistance (Weng et al., 2007). This is confirmed in the present analysis—the majority of accessions with this translocation were resistant. Among the zoned varieties, translocation 1AL.1RS was found only in variety Bogdanka.

Thus, as a result of the given screening for resistance to leaf rust, we identified accessions—carriers of alien genes which can be used in domestic breeding. However, it is necessary to develop a scientifically reasoned strategy for their allocation in the Russian regions, so as not to reproduce the situation that occurred with genes *Lr19* and *Lr9*.

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