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ORIGINAL ARTICLE

Postulation of leaf rust resistance genes of 20 wheat cultivars in southern Russia

Galina Vladimirovna Volkova, Olga Alexandrovna Kudinova*, Olga Feodorovna Vaganova

Ministry of Science and Higher Education of the Russian Federation, All-Russian Research Institute of Biological Plant Protection, Krasnodar, Russia

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*Corresponding address:
alosa@list.ru

Abstract

Gene postulation is one of the fastest and most cost-effective methods for identifying seedling leaf rust resistance genes in wheat cultivars. Many researchers use this approach to identify *Lr* genes in wheat cultivars. The purpose of our research was to identify seedling leaf rust resistance genes in 20 wheat cultivars from different breeding centers of Russia, Ukraine and Germany. Forty-two near isogenic Thatcher lines and 10 *Puccinia triticina* isolates were used for gene postulation. When assessing the infection types to cultivars and lines, a scale was used, according to Oelke and Kolmer. In 20 wheat cultivars 19 *Lr* genes were postulated: *2c, 3, 10, 3bg, 3ka, 14a, 17, 18, 23, 25, 26, 30, 33, 40, 44, 50, B, Exch, Kanred.* The most common for cultivars was the *Lr10* gene. In five cultivars, showing high field resistance, most postulated seedling genes (*Lr2c*, *Lr3, Lr10, Lr14a, Lr26, Lr33)* were not effective in the adult stage. It is possible that resistance of such cultivars is associated with APR genes, the postulation of which requires an expansion in the number and spectrum of *P. triticina* isolate virulence. Most of the studied cultivars (60%) have recently been entered into the register (2015–2019) and in the field show a stable or moderately susceptible response to *P. triticina* infection, despite the fact that the *Lr* genes postulated in them were not effective in the adult stage. The data obtained indicated a variety of genotypes of the studied cultivars, as well as the tendency of breeders to use the effect of pyramiding ineffective genes, which can prolong the resistance of the cultivar. Annual monitoring of varieties is necessary in each region, especially when reacting with a medium susceptible type (MS), which may indicate the initial stage of resistance loss.

Keywords: *Lr* genes, *Puccinia triticina*, resistance cultivars, winter wheat

Introduction

Leaf rust (*Puccinia triticina* Erikss.) is one of the most common and harmful diseases of winter wheat in all grain-producing regions of the world. In Russia, the disease is especially common in the southern region, which is the country's leading grain producer. In this region, leaf rust is found everywhere and occurs almost annually in winter wheat crops, depending on the prevailing weather conditions (Volkova *et al.* 2019). Even though progress has been made in studying the structure and variability of leaf rust pathogen populations of the fungus *P. triticina* and the success of practical breeding for resistance, this disease leads to a loss of 15–25% of the crop yield (Sanin and Nazarova 2010). Yield losses from leaf rust are very significant even in developed countries with a high level of agriculture and chemicalization of production (Shcherbik and Kovalenko 2011).

The most economical and bio-safe method of protecting wheat from a pathogen is the cultivation of rust-resistant cultivars. It is important to know the genetics of wheat resistance. This is necessary to draw up various displacement strategies in each grain-sowing region. Gene postulation is one of the fastest methods for identifying seedling leaf rust resistance genes in winter wheat cultivars. This approach is based on the principle of interaction of the parasite and the host according to "gene-for-gene" type (Flor 1971). The presence of resistance genes is postulated based on the expression of infectious types of wheat differentiator lines in response to infection with fungal isolates of different virulence (Wamishe *et al.* 2004). With a similar reaction of the isogenic line and cultivar to the defeat by most fungal isolates with different virulence, the *Lr* gene of the line and cultivar may coincide (Wamishe and Milus 2004). Many researchers use this approach to identify *Lr* genes in wheat cultivars. For example, scientists from Ethiopia and Germany tested 36 winter wheat cultivars using 31 *P. triticina* isolates. It was established that *Lr*-genes: *1, 2c, 3, 3ka, 9, 10, 14a, 14b, 13, 16, 18, 21, 23, 27 + 31, 30, 37* and *44* were postulated in Ethiopic wheat cultivars, and *Lr9, Lr20* and *Lr21* – in German wheat cultivars (Mebrate *et al.* 2008). In 66 cultivars from Argentina, using 17 different leaf rust pathotypes, 11 different genes were postulated*: Lr1, Lr3a, Lr3ka, Lr9, Lr10, Lr16, Lr17, Lr19, Lr24, Lr26,* and *Lr4* (Vanzetti *et al.* 2011). This method, in combination with the use of molecular markers, can also be used to postulate the genes of adult plants (APR genes) (Wei *et al.* 2015; Li *et al.* 2018; Baidya *et al.* 2019). A lot of work on the postulation of seedling leaf rust resistance genes has been done in China (Li *et al.* 2010; Li *et al.* 2016; Gebrewahid *et al.* 2017). A similar approach, combined with the use of molecular markers, has been used by scientists from Egypt (Abouzied *et al.* 2017). In Russia, such studies were first conducted at the All-Russian Research Institute of Biological Plant Protection (Anpilogova *et al.* 2011). Seedling resistance genes to *P. triticina* were postulated in 18 released winter wheat cultivars. It was found that most of them were ineffective against the North Caucasian pathogen population. In 2014, we carried out a phytopathological assessment of 12 bread winter wheat cultivars using 16 pathogen isolates. Eight cultivars succeeded in postulating *Lr* genes*: 1+, 2a, 3ka, 15, 16, 23, 33, 34* (Volkova and Vaganova 2016).

The aim of our study was to identify seedling leaf rust resistance genes in 20 wheat cultivars using 10 *P. triticina* phenotypes with different virulence.

Materials and Methods

Field studies were carried out in 2017 on the experimental field of the All-Russian Research Institute of Biological Plant Protection.

In our study we used 18 winter and two spring soft and bread wheat cultivars of foreign and Russian breeding (Table 1), from the collection of the Federal Research Center «N.I. Vavilov All-Russian Institute of Plant Genetic Resources» (VIR) as well as those of economic importance (Anisimovka, Anka, Antonina, Argonavt, Bagira, Bogdanka, Wintergold, Eremeevna, Krucha, Odari, Olkhon, Tulaykovskaya 110, Shef, Eirena, Ekada-113, Etude, Yubilyarka, Yakhont, Vidrada, Sidor Kovpak). Cultivar testing for pathogen infection was performed using 10 *P. triticina* phenotypes and 42 near isogenic Thatcher lines.

For testing wheat cultivars, 10 *P. triticina* phenotypes with different virulence were selected (Table 2). Each phenotype was assigned a four-letter code, according to the nomenclature of Long and Kolmer (Long and Kolmer 1989). Seven to nine day-old seedlings of 20 cultivars and 42 isogenic lines were separately inoculated with a spore suspension of each fungal isolate (from a spray) and placed in a humid chamber at 20°C for 16 h. Then, the inoculated plants were returned to greenhouse conditions.

The assessment was carried out on the 12th day after inoculation using the Long and Kolmer scale (17): 0 = absence of hypersensitive flecks, necrosis, or uredinia, 0; = weak hypersensitive flecks, ; = distinct hypersensitive flecks, 1 = small uredinia surrounded by distinct necrosis, 2 = small uredinia, surrounded by distinct chlorosis, 3 = moderate uredinia without chlorosis and necrosis, 4 = very large uredinia without chlorosis and necrosis. A mixture of two or more infection types (IT) was recorded as the IT prevailing first. The designations + and – are additional designations of IT from 0 to 4 and indicate larger or smaller pustules, in contrast to normal ones, respectively. DT from 0 to 2+ is understood as low, 3-4 – high.

In the field, wheat cultivars and lines were sown on plots in 6 rows 1 m long. The distance between plots was 0.5 m. In each plot there were 50–60 plants. Infection was carried out by a natural population of the fungus in the presence of drip-liquid moisture (Anpilogova and Volkova 2000). The degree of leaf rust damage and the types of reaction were taken into account 10–14 days after inoculation, with repeated counting every 10 days as urediniogenesis increased. When assessing damage types, the following scale was used, according to Oelke and Kolmer (2004): 0 = no flecks or uredinia, TR = insignificant level of uredinia, R = small uredinia with necrosis, M = a mixture of small and large uredinia with chlorosis, MR = moderate size uredinia with necrosis, MS = moderate size uredinia with chlorosis, S = large uredinia.

Results

Table 2 shows the infectious types of isogenic lines obtained by inoculation with isolates of the North Caucasian population of *P. triticina* in the seedling phase. Table 3 shows the infectious types of cultivars

Table 1. List of winter wheat cultivars used for *Lr* resistance gene postulation

Cultivar	Wheat form	Country of origin	Year of entering the State Register of the Russian Federation	Originator
Argonavt	winter durum	Ukraine	2012	Plant Breeding and Genetics Institute of the Ukrainian Academy of Agrarian Sciences
Wintergold	winter durum	Germany	–	–
Yakhont	winter durum	Russia	2018	Federal State Budgetary Scientific Institution Agrarian Scientific Center «Donskoy»
Etude	winter bread	Russia	2019	
Shef	winter bread	Russia	2019	
Yubilyarka	winter durum	Russia	2019	
Eirena	winter durum	Russia	2017	
Olkhon	winter bread	Russia	2014	Federal State Budgetary Scientific Institution National Grain Center named after P.P. Lukyanenko
Eremeevna	winter bread	Russia	2015	
Antonina	winter bread	Russia	2016	
Anka	winter bread	Russia	2016	
Krucha	winter durum	Russia	2015	
Odari	winter durum	Russia	2017	
Bagira	winter bread	Russia	2013	Federal State Budgetary Scientific Institution North Caucasus Federal Agrarian Research Center
Anisimovka	winter bread	Russia	–	
Tulaykovskaya 110	spring bread	Russia	2015	Federal State Budgetary Scientific Institution Samara Research Scientific Institute of Agriculture named after N.M. Tulaykov
Bogdanka	winter bread	Russia	2009	Federal State Budgetary Scientific Institution Belgorod Federal Agrarian Research Center of Russian Academy of Science
Vidrada	winter bread	Ukraine	2011	Belotserkovskaya Experimental Breeding Station of the Institute of Sugar Beet of the Ukrainian Academy of Agrarian Science
Sidor Kovpak	winter bread	Ukraine	–	Poltava State Agrarian Academy
Ekada 113	spring bread	Russia	2014	Federal State Budgetary Scientific Institution Bashkir Agricultural Research Institute

˝–˝ unknown

infected with the same isolates of the North Caucasian population of *P. triticina*. The presence of seedling leaf rust resistance genes in wheat cultivars was postulated based on a comparison of their high and low ITs with infection types to isogenic lines of the Thatcher cultivar.

Seedling resistance

All studied isolates were avirulent to 11 lines, carrying high-effective *Lr* genes*: 9, 15, 19, 24, 29, 38, 41, 42, 43, 47, W.*

The cultivar Shef showed a susceptible reaction to all isolates, with the exception of HHTG and PHRT.

Table 2. Seedling reaction of near isogenic wheat lines (*Lr*) on 10 *Puccinia triticina* isolates (climate chamber, 2017)

Lr gene	Isolates										Field damage
	MCPB	FGTD	CGPD	TGPD	PDLG	THRS	PBSS	LHLH	HHTG	PHRT	
1	3	0	2	3	3	3	3	3	2	3	80S
2a	1	0	0	3	0	3	0	0	3	0	50MS
2c	3	3	1	3	3	3	3	2	2	3	60S
3	3	3	3	3	3	3	3	2	3	3	80S
3bg	1	0	3	3	3	3	3	2	3	2	90S
3ka	3	3	3	0	3	3	3	3	3	3	70MS
9	0	0	0	0	0	0	0	0	0	0	0
10	0	1	1	0	3	3	2	0	3	3	90S
11	1	3	1	0	3	3	3	0	3	3	80S
14a	0	3	3	0	2	3	3	0	0	3	40S
14b	3	2	2	1	3	3	3	3	3	3	60MS
15	1	1	1	1	0	1	1	0	1	1	20MS
16	1	3	3	3	3	3	1	3	3	3	60MS
17	3	3	3	3	3	0	3	2	3	0	10MR
18	1	3	0	0	0	0	0	0	0	3	1MR
19	0	0	0	0	0	0	0	0	0	0	1R
20	0	1	0	0	2	3	0	1	3	3	30MS
21	1	1	1	1	1	3	2	3	3	2	15MR
23	3	3	3	3	3	3	2	3	3	3	30MS
24	1	0	0	0	0	2	1	0	2	1	R
25	0	1	1	1	3	3	2	3	2	1	20MR
26	3	0	0	0	3	3	0	3	3	3	70MS
28	3	2	0	0	3	3	0	0	3	2	10R
29	0	0	1	0	1	0	0	1	0	0	R
30	3	3	3	2	3	3	2	0	3	3	50S
32	1	1	3	1	1	1	0	0	1	2	20MR
33	1	3	3	1	2	3	3	3	2	1	40S
34	2	1	2	3	3	3	1	0	0	2	50S
36	1	1	3	2	1	3	1	3	3	3	5R
38	0	0	1	1	0	1	0	1	2	1	10R
40	3	3	3	3	3	3	2	3	3	1	30MS
41	1	2	2	0	0	0	0	2	0	0	10R
42	0	0	0	1	0	1	0	1	0	0	0
43	0	0	0	0	0	1	0	0	0	0	0
44	2	1	3	3	3	3	0	3	1	3	20MR
45	0	0	0	3	0	0	0	0	1	1	5R
47	0	0	0	0	0	0	0	0	0	0	R
B	0	1	0	3	2	3	1	2	0	3	60S
W	1	1	1	0	1	1	1	1	0	1	10MR
Exch	1	1	0	0	0	3	0	1	3	2	50S
Kanr	1	3	1	1	1	3	0	0	3	3	60S
50	0	2	3	1	0	2	0	2	3	1	0

S = large uredinia, MS = moderate size uredinia with chlorosis, R = small uredinia with necrosis, MR = moderate size uredinia with necrosis, 0 = no flecks or uredinia

Table 3. Seedling reaction of 20 winter wheat cultivars, inoculated with 10 virulent *Puccinia triticina* isolates (climate chamber, 2017)

Cultivar	MCPB	FGTD	CGPD	TGPD	PDLG	THRS	PBSS	LHLH	HHTG	PHRT	Field damage
Argonavt	0	2	3	3	3	3	3	0	3	3	20MS
Wintergold	2	3	3	3	3	3	2	0	0	2	10 MR
Yakhont	1	2	3	3	3	0	0	2	2	2	10MS
Etude	3	0	3	3	3	3	1	3	3	3	5MS
Shef	3	3	3	3	3	3	3	3	2	2	10R
Yubilyarka	1	3	3	3	2	3	3	3	2	1	5R
Olkhon	0	0	0	0	0	0	1	0	0	3	1R
Eremeevna	1	0	1	1	3	3	2	3	3	3	5R
Antonina	3	0	3	2	3	3	1	0	3	3	5MR
Anka	2	3	2	1	1	3	0	0	3	1	10R
Krucha	3	3	3	3	3	3	3	0	3	2	5MS
Odari	3	3	3	3	1	3	3	3	0	3	5R
Bagira	1	2	2	0	3	3	0	0	0	0	10MS
Anisimovka	0	2	1	0	0	1	0	0	0	0	10MS
Eirena	3	3	3	0	3	3	3	3	1	3	30MS
Tulaykovskaya 110	0	0	1	0	0	0	2	0	0	0	30MS
Bogdanka	1	3	2	1	2	0	1	0	0	0	0
Vidrada	3	3	3	3	2	3	3	0	3	1	5R
Sidor Kovpak	3	3	3	3	3	3	3	0	2	3	1R
Ekada 113	0	0	0	0	0	0	3	0	0	0	10MR

MS = moderate size uredinia with chlorosis, R = small uredinia with necrosis, MR = moderate size uredinia with necrosis, 0 = no flecks or uredinia

A similar reaction to isolates was observed in *Lr2c*, which showed low IT (2) to HHTG and high IT (3) to most isolates. *Lr40* also exhibited avirulence to PHRT in combination with susceptibility to most *P. triticina* isolates. This suggests the presence of *Lr2c* and *Lr40* in Shef.

The cultivar Krucha showed a stable response to LHLH and PHRT isolates (IT 0, 2), and it was susceptible to other isolates. Resistance to LHLH and susceptibility to other isolates was observed in the line with the *Lr3* gene. Low IT (2, 0) to LHLH and PHRT and high IT (3) to most isolates were shown by the line with the *Lr17* gene. A similar reaction of the cultivar and these lines makes it possible to postulate the *Lr3* and *Lr17* genes in Krucha.

Differentiating isolates were not found for the cultivar Anisimovka and Tulaykovskaya 110. Presumably they may contain *Lr* genes*: 9, 29, 42, 43, 47*.

Cultivar Argonavt had a low IT (0, 2) for MCPB, FGTD and LHLH isolates and a high IT (3) for CGPD, TGPD, PDLG, THRS, PBSS, HHTG and PHRT isolates. The MCPB, FGTD, and LHLH isolates were avirulent to the line with the *Lr3bg* gene and virulent to the remaining isolates, with the exception of PHRT, which suggests the presence of *Lr3bg* in Argonavt. PHRT was virulent to *Lr10*, and MCPB. FGTD and LHLH were avirulent to it. Argonavt probably also contains *Lr10*.

The PDLG, THRS, LHLH, HHTG, and PHRT isolates showed virulence for the cultivar Eremeevna, and a stable reaction was observed for the isolates MCPB, FGTD, CGPD, TGPD, and PBSS (IT 0, 1, 2). The PDLG, THRS, HHTG, and PHRT isolates were also virulent to *Lr10*, which suggests the presence of this gene in the cultivar Eremeevna. The FGTD, CGPD, TGPD, and PBSS isolates were avirulent to *Lr26*; therefore, Eremeevna may also contain *Lr26*.

Cultivar Antonina showed a stable response to the isolates FGTD, TGPD, PBSS and LHLH, and the rest of the isolates were susceptible. These isolates were avirulent to *Lr10*, which makes it possible to postulate this gene in Antonina. The TGPD, PBSS, and LHLH isolates showed avirulence to *Lr30*, while MCPB, CGPD, PDLG, THRS, HHTG, and PHRT were virulent to it. Perhaps *Lr30* is also present in Antonina.

Odari showed low IT (0.1) for PDLG and HHTG isolates and high IT (3) for other isolates. Isolates PDLG and HHTG showed avirulence to *Lr10* and *Lr14a*, which were susceptible to most other isolates. This allows us to postulate *Lr10* and *Lr14a* in the cultivar.

Olkhon was susceptible only to the PHRT isolate, and showed a stable reaction to the others (IT 0, 1). A combination of virulence to PHRT and resistance to most other isolates, with the exception of FGTD, was observed in *Lr18*. Olkhon, which probably contains *Lr18*. FGTD, and like most isolates, was resistant to *LrB*, and PHRT was virulent to it. Probably, cultivar Olkhon also contains *LrB*.

The cultivar Wintergold showed high IT (3) for FGTD, CGPD, TGPD, PDLG, THRS isolates and low IT (0.2) for MCPB, PBSS, LHLH, HHTG and PHRT. The MCPB and PBSS isolates were avirulent to *Lr16*, while FGTD, CGPD, TGPD, PDLG, and THRS were virulent to it. Wintergold may contain *Lr16*. The PBSS, PHRT, and HHTG isolates showed avirulence to *Lr44*, while CGPD, TGPD, PDLG, and THRS were virulent to the line with this gene. This also makes it possible to postulate *Lr44* in Wintergold. The MCPB, LHLH, and PHRT isolates were avirulent to *Lr3bg*, while CGPD, TGPD, PDLG, and THRS were virulent to the line with this gene, which allows us to postulate *Lr3bg* in the Wintergold cultivar.

Yakhont was resistant (IT 0, 1, 2) to isolates MCPB, FGTD, THRS, PBSS, LHLH, HHTG and PHRT and susceptible (IT 3) to CGPD, TGPD and PDLG. The CGPD, TGPD and PDLG were also susceptible to *Lr44*, while isolates MCPB, FGTD, THRS, PBSS, LHLH and PHRT were resistant to *Lr50*, which allows us to postulate *Lr44* and *Lr50* in Yakhont.

The cultivar Etude showed low IT (0.1) for FGTD and PBSS and high IT (3) for other isolates. PBSS was avirulent to *Lr23*, and the remaining isolates were virulent to the line with this gene. Therefore, *Lr23* can be postulated in Etude. FGTD and PBSS were also avirulent to *Lr44*, and most of the remaining isolates were virulent to it. Perhaps the cultivar also contains *Lr44*.

The cultivar Yubilyarka showed stable response (IT 1, 2) to MCPB, PDLG, HHTG and PHRT and was susceptible (IT 3) to other isolates. MCPB, PDLG, and HHTG were avirulent to *Lr14a*, and isolates FGTD, CGPD, THRS, PBSS, and HHTG were virulent to *Lr14a*. It is possible that Yubilyarka contains *Lr14a*. MCPB, PDLG, HHTG, and PHRT were also avirulent to *Lr33*, and the FGTD, CGPD, THRS, PBSS, and LHLH isolates caused a susceptible response in this line. Therefore, the presence of *Lr33* can be assumed in Yubilyarka.

The cultivar Anka showed resistance to most isolates (MCPB, CGPD, TGPD, PDLG, PBSS, LHLH and PHRT) and virulence to FGTD, THRS and HHTG. A similar reaction of isolates was observed in lines with the resistance genes *LrExch* and *LrKanred*. It is likely that the Anka contains these genes.

Bagira also showed a steady response to most isolates, and only PDLG and THRS were virulent. PDLG and THRS which were virulent to *Lr25* and most others, with the exception of LHLH, were resistant to this line. This gives reason to postulate *Lr25* in the cultivar. LHLH, similar to most isolates, was resistant to *Lr10*, while PDLG and THRS were susceptible to it. Therefore, Bagira may also contain *Lr10*.

The cultivar Eirena showed a susceptible response to most isolates, with the exception of TGPD and HHTG. TGPD was resistant to *Lr3ka*, and the remaining isolates were virulent to it. Therefore, the presence of *Lr3ka* in the cultivar is likely. HHTG was avirulent to *Lr2c*, and most of the remaining isolates were virulent to the line with this gene. It is possible that *Lr2c* is also present in Eirena.

Cultivars Bogdanka and Ekada 113 were resistant to most isolates, with the exception of FGTD, which was virulent to Bogdanka, and PBSS, virulent to Ekada 113. Perhaps their resistance was due to the presence of one or more highly resistant *Lr* genes*: 9, 24, 29, 38, 41, 42, 43, 47, W*.

The cultivar Vidrada showed low IT (0, 1, 2) for PDLG, LHLH and PHRT isolates and high IT (3) for other isolates. LHLH was avirulent to *Lr3*, which was susceptible to most other isolates. Probably Vidrada contains *Lr3*. LHLH and PHRT were avirulent to *Lr17*, and to the remaining *Lr17* isolates, they were mostly susceptible. Therefore, the cultivar may also contain *Lr17*.

Sidor Kovpak was susceptible to most *P. triticina* isolates, with the exception of LHLH (IT 0) and HHTG (IT 2). LHLH and HHTG were avirulent to *Lr2c*, and the remaining isolates were usually virulent to this gene. This makes it possible to postulate *Lr2c* in Sidor Kovpak.

Adult plant resistance

In the field, the cultivar Bogdanka showed absolute resistance, and in the juvenile phase only one isolate was found that was virulent to this cultivar. Most likely, this cultivar is protected by effective genes of race-specific and age-related resistance.

Six cultivars (Yubilyarka, Olkhon, Yeremeyevna, Odari, Vidrada and Sidor Kovpak) showed high adult resistance (1R – 5R).

Five cultivars (Wintergold, Shef, Antonina, Anka, Ekada 113) showed moderate resistance in the field (5MR, 10R, 10MR). In this case, only Ecada 113 possessed effective genes for juvenile resistance, which work in adulthood as well. In the cultivar Anka, which was resistant to most isolates, *LrExch* and *LrKanred*, not effective in the field, were postulated. Perhaps the resistance of the cultivar was due to the genes for age resistance or their combination. Cultivars Wintergold, Shef and Antonina, which were susceptible to most isolates, are thought to have field ineffective seedling *Lr* genes*: 2c*, *3bg, 10, 16, 30, 40* (30MS – 90S).

The group of cultivars Yakhont, Etude, Krucha, Bagira, Anisimovka, despite a low percentage of the degree of disease damage (5–10%), had a susceptible type of reaction in the field (MS – moderate size of uredinia with chlorosis), which may indicate the effect of gene pyramiding. Differentiating isolates were not found for Anisimovka, which indicates the presence of resistance genes that are effective in the adult stage as well, which nevertheless begin to lose their effectiveness (this is indicated by the susceptible type of reaction). A similar reaction in the field was shown by most of the lines with the genes *Lr17, Lr23, Lr25, , Lr44*, which are postulated in the cultivars Yakhont, Etude, Krucha and Bagira.

Cultivars Argonavt, Eirena and Tulaykovskaya 110 in the field were moderately susceptible to *P. triticina* (20S – 30S), but have a different genetic basis. Differentiating isolates were not found for Tulaykovskaya 110, which may indicate the presence of one or more genes from among 11 lines with *Lr* genes, to which no isolates were found.

In cultivars Argonavt and Eirena, field-ineffective seedling genes *Lr2c, Lr3ka, Lr3bg*, and *Lr10* were postulated.

Discussion

In 20 winter wheat cultivars from different breeding centers of Russia, Ukraine and Germany, 19 resistance genes *Lr* were postulated: *2c, 3, 10, 3bg, 3ka, 14a, 17, 18, 23, 25, 26, 30, 33, 40, 44, 50, B, Exch, Kanred.* The *Lr10* gene was the most common in cultivars (Argonavt, Antonina, Eremeevna, Odari, Bagira). Long-term studies of E.I. Gultyaeva (Gultyaeva 2018) confirm, with the help of molecular markers, the wide distribution of the ineffective seedling *Lr10* gene in Russian cultivars. The presence of *Lr10* in the cultivars Bagira and Antonina is also confirmed by it with the help of molecular markers.

For two cultivars (Tulaykovskaya 110 and Anisimovka) no differentiating isolates were found. Moreover, in the field, cultivars were moderately susceptible, with a low degree of damage, which may indicate the presence of several additional genes that give the effect of pyramiding. Tulaykovskaya 110 was developed with the participation of *Elytrigia intermedia* (wheatgrass intermediate), from which the effective *LrAg* gene was introgressed into soft wheat (Sochalova and Lichenko 2013).

The cultivar Bogdanka was the only studied cultivar that showed absolute resistance in the field and low IT (0, 1, 2) to all isolates except FGTD. According to Kozub *et al*. (2012), this cultivar has rye translocation on chromosome 1A (1AL/1RS), which is rare for Russian varieties. Soft wheat cultivars carrying the wheat rye translocation 1AL/1RS contains a combination of genes effective against several diseases (Crespo-Herrera *et al.* 2017).

Cultivars Yubilyarka, Yeremeyevna, Odari, Vidrada and Sidor Kovpak, which demonstrated high field resistance, showed a high IT (3) to most isolates in the seedling phase. Most seedling genes postulated in these cultivars (*Lr2c, Lr3, Lr 10, Lr 14a, Lr 26, Lr 33*) were ineffective in the field (40S – 90S). In the cultivar Olkhon, *Lr18* provided resistance in the seedling phase, which was also effective in the adult stage. Resistance of the remaining cultivars may be associated with adult plant resistance genes.

Most of the studied cultivars have recently been entered into the State Register of the Russian Federation (2015–2019) and in the field show a stable or moderately susceptible reaction, despite the fact that the *Lr* genes postulated in them are not effective in the adult stage of plants. Therefore, annual monitoring of the resistance of cultivars is required, especially with a medium susceptible type of reaction (MS), since this indicates the initial stage of resistance loss.

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