Breeding of bread wheat for leaf rust resistance in Russia

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Abstract. Leaf rust, caused by the fungus *Puccinia triticina* Erikss., is one of the most common diseases of wheat in Russia. The paper reviews *Lr*-genes diversity in Russian commercial wheat varieties. Two hundred and sixty-four winter and one hundred and forty-three spring wheat varieties indexed by the State Register of Breeding Achievements in 2005-2018 were studied. It was found that among new varieties, as many as 5% of winter wheat and 30% of spring wheat possess effective seedling resistance. The wide presence of *Lr19* and *Lr9* genes was detected in the spring wheat. Besides, the high resistance to leaf rust was found in spring wheat varieties with new alien *Lr* genes (originated from *Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey and *Aegilops speltoides* Tausch. Over 40% of winter wheat varieties have different levels of field resistance as well. The molecular screening revealed three varieties with effective adult plant resistance gene *Lr37*. Other winter wheat varieties include a range of ineffective genes (*Lr1*, *Lr3*, *Lr10*, *Lr26*, and *Lr34*), alone or in various combinations.

1 Introduction

Wheat is an important crop, and leaf rust, caused by the fungus *Puccinia triticina* Erikss., is one of the most common diseases of wheat in Russia [1]. Main grain production in Russia (about 75% of the grain-growing area) is concentrated in the North Caucasus, Central Black Soil, Central, Volga, Volga-Vyatka, Ural and West Siberia regions. In the period between 1990 and 2000 severe epidemics of leaf rust were reported for 2-3 times causing 30-35% of yield loss in the North Caucasian region. Five to 7 epidemics caused 20-30% of yield loss in the Central and Volga regions. In the Central Black Soil Region, the epidemics occurred up to 4 years in a decade and caused 15-20% of yield loss. Severe disease development was observed every two years and caused 15-20% of yield loss in the Volgo-Vyatka and Ural regions [2]. Since 2010, leaf rust incidents have been decreased significantly in all regions of Russia. The depression of the leaf rust development might be caused by climate change and undesirable conditions for pathogen development. Alternatively, a widespread practice of No-Till in arable farming might have caused the spread of other hemibiotroph-induced diseases such as septorioasis and tan spot. Despite the existing environmental problems and common wheat-growing practices, Russian breeders have made a great effort in the design of the rust-resistant varieties. In addition, immunological and genetic protection has contributed to the reduction of leaf rust severity.

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Breeding for resistance to leaf rust has been done for over a half-century in Russia. In 1990-2000 the strategy of deployment of varieties with different bases for resistance involving utilization of major genes, introgression of major genes from wild relatives, alien translocations and slow rusting was adopted in the most of Russian Breeding Centers. This approach denies the domination of a single variety, as occurred in the past period [3]. Since 1995 the All-Russian Institute of Plant Protection (VIZR) has been annually evaluating new varieties for leaf rust resistance. During the same period our laboratory has been conducting seedling resistance studies of common wheat varieties recommended for the cultivation in Russia. We found the increasing number of resistant varieties in 2000 as compared to 1990s. Early studies (before 1995) of 61 winter and 100 spring wheat varieties revealed only 4% of resistant bread wheat varieties. The similar proportion of bread spring (121) and winter (62) varieties in 2005 showed 1.8% of winter and 15% of spring wheat varieties resistant to leaf rust [4].

The State Register of Breeding Achievements permitted to use 264 new varieties of winter wheat and 143 of spring wheat in the period between 2005 and 2018. The paper reviews the studies of Russian commercial wheat varieties for leaf rust resistance and characterises the identification of Lr-genes.

2 Materials and methods

Two hundred and sixty-four winter and one hundred and forty-three spring wheat varieties were used in this study.

Leaf rust infection was evaluated for 4 isolates with different virulence/avirulence combinations at the seedling stage. All isolates were avirulent to Lr24 and Lr29, and virulent to Thatcher lines (Tc) with Lr1, Lr2b, Lr2c, Lr3a, Lr3bg, Lr3ka, Lr10, Lr14a, Lr14b, Lr18, and Lr30. The isolates varied in their virulence to Lr2a, Lr9, Lr15, Lr16, Lr19, Lr20, and Lr26. Ten-fourteen days old seedlings were used in this study. Infection types were recorded according to Mains & Jackson [5]. Infection type “2” suggested allocation of the seedlings to the resistant group, while infection type “3” meant the susceptible group. The molecular markers were used for identification of 20 genes (Lr1, Lr3a, Lr9, Lr10, Lr19, Lr20, Lr21, Lr24, Lr25, Lr26, Lr28, Lr29, Lr34, Lr35, Lr37, Lr41, Lr47, Lr51, LrSp, and Lr6Ag1). [6, https://maswheat.ucdavis.edu].

3 Results and Discussion

It was found that among the new varieties, as many as 5% of winter and 30% of spring wheat possess seedling resistance. Besides, over 40% of winter wheat varieties had different levels of field resistance.

Presence of Lr19 and Lr9 genes was detected widely in the spring wheat indexed in the State Register and recommended for growing in Russia (Table 1). As many as 7% of the varieties carried Lr19 and 9% carry Lr9. (Table 2). The first variety L503 with Lr19 gene was included into the State Register in 1993 and variety Tertsiya with gene Lr9 in 1995. The effectiveness of Lr19 and Lr9 was lost in the Volga region in the middle of 1990s and in the Ural and West Siberian regions in 2007, respectively. Our study suggests using a gene combination such as Lr19 or Lr9 with Lr26 to provide high effectiveness to combat virulent isolates of leaf rust. Spring wheat varieties Omskaya 37, Omskaya 38 and Omskaya 41 with genes Lr19+Lr26 and variety Silach with genes Lr9+Lr26 were highly resistant to the leaf rust at the seedling and the adult plant stages. Besides, the high resistance to the leaf rust was found in the spring wheat varieties with new alien Lr genes. New resistance genes Lr6Ag1 and Lr6Ag2 from Thinopyrum


intermedium (Host) Barkworth & D.R. Dewey were found in varieties Belyanka, Favorit, Lebedushka, Voevoda (Lr6Agi1), Tulaikovskaya 5, 10, 100, and Tulaikovskaya zolotistaya (Lr6Agi2). The varieties have been recommended for cultivation in Volga regions. The LrSp gene is not identical to the known effective Lr genes. It was transferred from Aegilops speltoides Tausch. and identified in the variety Chelyaba 75. Currently, this variety is recommended for cultivation in the Ural region.

Table 1. Wheat varieties with high or partial effective Lr genes

| Variety | Year a | Region b | Variety | Year | Regions |
|---------|--------|----------|---------|------|---------|
| Tertsya | 1995   | WS ES U  | L 503 (+Lr10) | 1993 | LV MV   |
| Tuleevskaya | 2002 | WS U  | Samsar | 1994 | MV |
| Splav | 2002 | NW | L 505 (+Lr10) | 1996 | LV VV U |
| Duet (+Lr10) | 2003 | WS U | Volgouralskaya | 2001 | MV |
| Chelyaba 2 (+Lr10) | 2005 | U | Dobrunya | 2002 | LV |
| Pamyati Ryuba | 2006 | WS U | Yuliya | 2002 | MV |
| Udacha | 2006 | WS | Ariya | 2004 | U |
| Nemchinovskaya 24 | 2006 | C, VV | Ecada 6 | 2005 | MV |
| Alexandrina | 2007 | WS | Kinelskaya 61 (+Lr10) | 2005 | MV |
| Kinel’skaya otrada | 2009 | MV | Kinelskaya Niva | 2007 | MV U |
| Novosibirskaya 44 (+Lr1, Lr10) | 2009 | WS | Lebedushka (+Lr6Agi1) | 2009 | LV |
| Sibakovskaya yubileinaya (+Lr1, Lr10) | 2010 | WS | Omskaya 37 (+Lr26) | 2009 | WS |
| Chelyaba yubileinaya | 2010 | WS | Tulaikovskaya 108 (+Lr?) | 2014 | LV U |
| Mariya 1 (+Lr10) | 2011 | WS | Kinelskaya yubileinaya | 2016 | MV U |
| Altayskay 110 (+Lr10) | 2011 | WS | Ulyanovskaya 105 | 2017 | MV U |
| Apasovka (+Lr10) | 2012 | WS | Tulaikovskaya 5 (+Lr10, Lr34) | 2001 | MV U |
| Novosibirskaya 18 (+Lr10) | 2012 | WS ES | Tulaikovskaya 10 | 2003 | MV VV U |
| Sibirskaya 17 | 2013 | WS | Tulaikovskaya 100 | 2007 | MV |
| Nemchinovskaya 17 | 2013 | C | Tulaikovskaya zolotistaya | 2006 | MV LV U |
| Sibirskiy Alyans (+Lr1) | 2012 | WS ES | Tulaikovskaya 100 | 2007 | MV |
| Zauralochka (+Lr10) | 2014 | WS | Tulaikovskaya 100 | 2007 | MV |
| Kinelskaya 2010 | 2014 | MV U | Belyanka | 1999 | LV |
| Chelyaba rannaya (+Lr10) | 2016 | U | Favorit | 2007 | CBE LV MV U |
| Stolupinskaya (+Lr10) | 2017 | WS | Voevoda | 2008 | LV |
| Челяб 75 (+Lr1, Lr10) | 2012 | U | Kanyuk (+1AL/1RS, Lr20) | 2016 | C |
| KBC Akvilon | 2013 | C | CBE |

Table 1. Wheat varieties with high or partial effective Lr genes

*year of admission for use;

regional regions recommended for cultivation of wheat variety.

Thus, 20% of spring wheat varieties with seedling resistance carry highly or partially effective major genes and indexed by the State Register. One-third of the varieties carries effective Lr genes, however, they are not identical to those registered in the Catalogue.

Winter wheat varieties demonstrated the various responses to leaf rust within wheat-growing region. More than half of the studied varieties originated from North-Caucasian
breeding program. They showed a certain level of resistance at the adult plant stage under the field conditions.

**Table 2. Distribution of Lr genes in Russian bread wheat varieties (%)**

| Wheat             | Number of varieties | Genes | IAL   |
|-------------------|---------------------|-------|-------|
|                   |                     | Lr9   | Lr19  |
| Winter            | 294                 | 0     | 0     |
|                    |                     | Lr24  | Lr6Ag1|
|                    |                     | Lr6Ag2| LrSp  |
|                    |                     | Lr1   | Lr10  |
|                    |                     | Lr20  | Lr26  |
|                    |                     | Lr34  | Lr37  |
|                    |                     | 1AL   | 1     |
|                    |                     |       |       |
|                    | *Varieties recommended for cultivation in Russia |       |       |
| Winter            | 213                 | 8,9   | 6,6   |
|                    |                     | 0,9   | 1,9   |
|                    |                     | 0,5   | 14,5  |
|                    |                     | 3,5   | 42,7  |
|                    |                     | 1,4   | 7,5   |
|                    |                     | 6,6   | 0     |
|                    |                     | 0,5   |       |
| *Varieties recommended for cultivation in European regions* | | | | | |
| Winter            | 96                  | 3     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 12    | 9     |
|                    |                     | 0     | 5     |
|                    |                     | 21    | 18    |
|                    |                     | 0     | 16    |
|                    |                     | 46    | 0,5   |
|                    |                     | 1     |       |
| Spring            | 42                  | 0     | 5     |
|                    |                     | 5     | 2     |
|                    |                     | 2     | 2     |
|                    |                     | 12    | 31    |
|                    |                     | 19    | 7     |
|                    |                     | 5     | 0     |
| *Varieties recommended for cultivation in North Caucasus* | | | | | |
| Winter            | 183                 | 0     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 21    | 18    |
|                    |                     | 0     | 16    |
|                    |                     | 46    | 0,5   |
|                    |                     | 1     |       |
| Spring            | 9                   | 0     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 11    | 55    |
|                    |                     | 0     | 22    |
|                    |                     | 0     | 0     |
| *Varieties recommended for cultivation in Volga regions* | | | | | |
| Winter            | 124                 | 0     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 7     | 13    |
|                    |                     | 0     | 5     |
|                    |                     | 27    | 0     |
|                    |                     | 0     |       |
| Spring            | 78                  | 5     | 14    |
|                    |                     | 0     | 5     |
|                    |                     | 4     | 0     |
|                    |                     | 9     | 37    |
|                    |                     | 0     | 6     |
|                    |                     | 8     | 0     |
| *Varieties recommended for cultivation in Ural region* | | | | | |
| Spring            | 74                  | 11    | 9     |
|                    |                     | 0     | 0     |
|                    |                     | 4     | 1     |
|                    |                     | 9     | 42    |
|                    |                     | 0     | 11    |
|                    |                     | 7     | 0     |
| *Varieties recommended for cultivation in Western Siberia* | | | | | |
| Spring            | 79                  | 15    | 2     |
|                    |                     | 0     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 17    | 47    |
|                    |                     | 0     | 7     |
|                    |                     | 9     | 0     |
| *Varieties recommended for cultivation in Eastern Siberia and Far East* | | | | | |
| Spring            | 38                  | 3     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 0     | 0     |
|                    |                     | 21    | 50    |
|                    |                     | 0     | 3     |
|                    |                     | 10    | 0     |
|                    |                     | 0     |       |

* translocation from *Secale cereale* L.

The molecular screening revealed as many as three varieties (Morozko, Graf, Svarog) with an effective adult plant resistance gene *Lr37*. In Russia other winter wheat varieties carry the wide range of ineffective genes, namely *Lr1, Lr3, Lr10, Lr26* and *Lr34* (Table 2). They have either a single gene or various genes combinations. Probably the resistance of these varieties at the adult plant stage is provided by a combination of minor genes.

And though development of resistant varieties using different combinations of racespecific *Lr* genes is challenged by completely or partial loss of their effectiveness, there is still a worldwide interest to this approach. Creation of varieties with the different combinations of *Lr* genes increases the chances to improve the genetic protection of wheat and limits the overcoming wheat resistance. Monitoring of the rust population has been performed across the country and there are reliable data on the structure on the pathogen population and effectiveness of *Lr* genes. In particular, it has been found that the virulence genes of the leaf rust population differs remarkably in West Siberia when compared to the European regions of Russia, as confirmed by phenotypic and molecular analyses. This phenomenon may be largely explained by the high diversity of wheat varieties grown under different climate conditions linked to the usage of a wide range of donors of resistance.

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