Potato Breeding for Resistance to Globodera Rostochiensis in the Republic of North Ossetia-Alania

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Abstract. Potatoes are a strategically important agricultural crop. Potatoes, a staple food in the North Caucasus, is used for fodder and technical purposes. It is grown in the mountains and foothills. For potato growing in the Caucasus region, the potential danger is represented by external and internal quarantine pest: Golden nematode. Infestation of fields with this pest reduces the area of potato production. Fighting them with chemicals pollutes the environment. For food security and reducing environmental pollution, it is necessary to create sustainable productive varieties adapted to the conditions of the North Caucasus. Potato breeding in North Caucasus Institute of Hill and Mountain Agriculture has been conducted since 1928. Since 1991, breeding has been conducted for resistance to Golden nematode. Stable varieties and hybrids were created: Vladikavkazsky, Bars, Shcherbininsky, hybrids 04.573/1, 03.560/4. In practical breeding, foreign and domestic varieties were used as parent forms in the genome of which there are dominant resistance genes: Hertha, Sante, Romano, Saphir, Premier, Kristall, Ausonia, Impala, Kadria, Hydra, Carlena, 71.17.06. Molecular screening of 45 samples of 5 hybrid combinations; Roko x Romano, Vladikavkaz x Prolisok, Nikulin x Ausonia, Roko x Adretta, Bars x Adretta revealed donor genotypes with resistance genes (HI, GroI-4). The hybrids are characterized by their economic and valuable characteristics.

1. Introduction
Potatoes are the main insurance crop of agriculture in North Ossetia, an irreplaceable food product, and are also used for fodder and technical purposes. The main potato plantings are concentrated in unique ecological zones of mountains and foothills with a temperate continental climate and with sharp fluctuations in meteorological conditions. Potato plants and tubers rich in vital substances attract various pests. Diseases and pests reduce the yield and quality of tubers. The fight against them only with chemical preparations leads to violations of the ecological balance of the environment: pollution of the atmosphere, soil, and water [1]. Therefore, the priority direction in potato breeding for the conditions of the North Caucasus is the cultivation and creation of high-yielding potato varieties that are resistant to fungal, viral, bacterial diseases, pests and abiotic factors [2]. In Europe, significant damage to potato production is caused by the Golden cyst-forming potato nematode (CFN), Globodera rostochiensis (Wollenweber) Behrens, pale potato nematode Globodera pallida (Stone) Behrens, and the recently appeared Colombian root-knot nematode Meloidogyne chiiwoodi. The Columbian root-knot nematode, which affects the roots and tubers of the potato plant, develops on...
Solanaceae, Gramíneae, Umbrella, Lily, Cruciferae, alfalfa, clover, carrots, peas, and is found in Belgium, Germany, France, the Netherlands, Mexico, the United States, and Argentina [3]. In Europe, 3 pathotypes of the pale potato nematode Globodera pallida (Stone) Behrens are common. At this time, neither the Columbian root-knot nematode nor the pale potato nematode have been identified in Russia. On the territory of the Russian Federation, out of 5 species of Golden potato nematode, one Rol pathotype was found [4, 5].

Potato nematode pathogens, getting into the soil with diseased tubers, multiply rapidly. In areas infected with potato nematode, the commercial yield decreases by 20-90%, and in some years, with a high density of the parasite in the soil, the crop dies completely. At the end of the growing season, the sparsity of plantings reaches 25%. Males are mobile and have a worm-like shape. By the time the crop Matures, the bodies of dying females that end their cycle in development form dark brown spherical cysts filled with eggs. Eggs and larvae remain viable for up to 10 years [6]. Potato nematode control is mainly reduced to agrotechnical, chemical and integrated methods. It is proved that the use of crop rotations with no more than 20% of potatoes is effective for controlling cystic nematodes with a low degree of soil contamination. Well clear the soil of potato nematodes, winter crops, oats, legumes, oatmeal mixtures, buckwheat, peas, cucumbers, lettuce, cabbage, surepka, rapeseed, corn land for decades become unsuitable for cultivation of this crop [7].

One of the methods that helps reduce the spread of pathogens and pests of potatoes is weed eradication [8]. If the soil is strongly infected with potato nematode, a chemical control method is used. The use of nematicides, carbanation chlorpicrin, percalcide, is undesirable, since this is a costly and polluting means [7].

Compliance with external and internal quarantine in the country ensured the penetration of only one pathotype of the Golden nematode. Even strict compliance with quarantine measures does not exclude the penetration and spread of new types of potato nematodes on the territory of Russia. Therefore, to reduce the harmfulness and spread of nematodes, it is more rational to create and use domestic resistant varieties. According to many authors, nematode-resistant varieties have an active form of immunity. Only 11.9% pass the entire development cycle on the roots of resistant varieties, and 96.1% of larvae pass on the roots of susceptible varieties. Only males pass the entire development cycle on stable varieties [7]. Taking into account the threat of reducing the area of potato cultivation, due to the spread and appearance of new races of Golden nematode, the import of new types of nematodes, there is a need to create competitive nematode-resistant domestic varieties adapted to the conditions of potato cultivation areas [9]. In the North Caucasus region, the number of cultivated foreign varieties exceeds the number of domestic ones. The following varieties are allowed to be used: the Netherlands – 23, Germany – 10, France – 4, Ukraine – 1. There are only 28 Russian varieties approved for use in the region. Thus, due to climate changes that contribute to the emergence and expansion of phytopathogen ranges, due to the import of seeds from countries with intensive potato cultivation, and the import of new pathotypes from other regions of the Russian Federation, it is important to search for and create nematode-resistant potato varieties adapted to the conditions of the region. As a result, North Caucasus Institute of Hill and Mountain Agriculture is breeding resistant varieties to the potato nematode S. rostochiensis [10].

The purpose of breeding in the North Caucasus Institute of Hill and Mountain Agriculture is to create productive varieties that combine resistance to Golden potato nematode, Phytophthora, viruses and abiotic environmental factors of the North Caucasus region. One of the tasks is to search for donor samples among collection varieties and interspecific hybrids for involvement in hybridization, and to search for stable hybrids in nurseries of the main and competitive tests based on genetic and molecular analysis. Modern varieties are descendants of resistant samples of S. tuberosum ssp., S. andigenum, and S. vernei that transmit the dominant H1 resistance allele, and the GroY1 genes from S. kurtzianum, S. vernei, Gro I-4 – from S. spaggiannii, S. chacoense, and S. vernei [11, 12, 13]. Foreign and domestic breeders have created and identified the original nematode-resistant forms, and given a combination assessment of these samples. For successful work, it is advisable to use the selected material to create nematode-resistant hybrids with economically valuable traits. Using molecular
markers, it became possible to select resistant forms to the pathotypes of the Golden and pale nematode that are potentially harmful to Russian potato production [14,15].

2. Materials and methods
Breeding research on the creation of nematode-resistant varieties has been carried out since 1991 in North Caucasus Institute of Hill and Mountain Agriculture. Breeding work is carried out in the foothill, steppe and mountain zones of North Ossetia. An important factor in the formation of crop yields, against the background of soil fertility, is played by air temperature, soil, and precipitation. The maximum temperature of the soil and air is observed in July–August. The amount of precipitation in the Republic, as well as the sum of effective temperatures, varies significantly. If the sum of temperatures from the lowlands to the mountains decreases, the amount of precipitation increases – from 450 mm in the North to 1000 mm in the highlands. In the foothill zone at an altitude of 600 m above sea level, an average of 660 mm of precipitation falls per year, the maximum of which falls in May–June. The moisture coefficient is 0.36–0.45 [16]. In the foothill zone of unstable moisture, the soil cover is represented by pre-Caucasian common chernozems, and in the zone of sufficient moisture by leached chernozems and meadow chernozem soils, underlain by pebbles at a depth of 25–80 cm [16]. The research program is carried out according to the selection scheme developed in the North Caucasus Institute of Hill and Mountain Agriculture, and in accordance with the guidelines for potato technology (Russian Potato Research Center), methods of testing for distinctness, uniformity and stability [17,18]. In the field, during the growing season, collection varieties and hybrids from nurseries were evaluated based on economically valuable characteristics: productivity, resistance to viral and fungal diseases, heat and drought. The assessment of suitability for nutrition and processing was carried out according to the following parameters: the content of starch, dry matter and darkening of raw and cooked tuber pulp.

3. Results and discussion
In the course of breeding work, a gene pool of resistance to the Golden potato nematode was created. To obtain successful results, the breeding work was based on the study of the pedigree of the original forms [19]. To create nematode-resistant varieties Vladikavkazsky, Bars, Shcherbininsky, hybrids 04.573/1, 03.560/4, 07.600/1, 07.600/3 nematode-resistant foreign and domestic varieties were used, in the pedigree of which there is a Globodera rostochitnsis-resistant S. andigenum. It was found that when studying the pedigree of varieties Shcherbininsky, Vladikavkazsky, Bars, hybrids 04.573/1, 03.560/4, the parent forms were obtained mainly by the pedigree method. Consequently, the genome of these samples is characterized by a variety, a combination of genes, including wild species that cause resistance to certain phytopathogens. During the selection process, promising hybrid samples were tested at the all-Russian potato testing point for stability in laboratory and field conditions, and were determined to be resistant to quarantine objects.

Using molecular screening of 45 potato samples from 5 hybrid combinations; Roko x Romano, Vladikavkaz x Prolisok, Nikulin x Ausonia Bars x Adretta, it was found that forms with H1 resistance genes of the cultural species S. andigenum Juz Et Buk and the wild species S. stoloniferum were used in the selection of these hybrids. 24 % of the analyzed objects have the Gro1 gene from the species S. spegazzinis, which controls resistance to all five pathotypes of the Golden potato nematode. A combination of H1 resistance genes with Gro1-4 was detected in 6 hybrids. The pale potato nematode resistance gene (Gpa-2) was detected in 5 samples. The identified samples, carriers of resistance genes, are of particular interest for practical breeding: as future varieties and as donors for hybrid crosses. During the growing season, the selected genotypes were evaluated for their resistance to viral and fungal diseases, and their economically valuable qualities in the field conditions of the foothill zone.
Table 1. Characteristics of hybrids resistant to potato cyst nematode. Average years 2016-2018.

| Hybrid     | Yield, t/ha | Marketability, % | The average weight of a single marketable tuber | Darkening raw flesh of tuber, score | Stability, point, phytophthora alternaria |
|------------|-------------|------------------|-------------------------------------------------|-----------------------------------|------------------------------------------|
| 04.573/1   | 30.7        | 86               | 94                                              | 7                                 | 7                                        |
| 03.560/4   | 28.5        | 90               | 90                                              | 7                                 | 7                                        |
| 4/II       | 15.0        | 99               | 64                                              | 5                                 | 3                                        |
| 2/II       | 8.1         | 93               | 93                                              | 2                                 | 2                                        |
| 5/II       | 20.7        | 78               | 65                                              | 3                                 | 7                                        |
| 43/II      | 15.6        | 98               | 148                                             | 5                                 | 5                                        |
| 52/II      | 14.5        | 82               | 100                                             | 3                                 | 5                                        |
| 71/I       | 21.7        | 77               | 80                                              | 5                                 | 7                                        |
| 44/I       | 28.4        | 78               | 111                                             | 3                                 | 7                                        |
| 65/I       | 36.6        | 99               | 90                                              | 7                                 | 8                                        |
| 118/III    | 28.5        | 84               | 75                                              | 6                                 | 7                                        |
| 35/II      | 32.5*       | 98               | 92                                              | 5                                 | 7                                        |

As can be seen from the data in the table, hybrids 0.573/1, 03.560/4, 35/II, 65/II with a high rating of resistance to Phytophthora — 7 points, formed a high yield of tubers from 28.5 to 36.6 t/ha. Hybrids with low resistance to late blight, the yield is two times lower. Darkening of the raw pulp of tubers — from 2 points to 7. The degree of darkening of raw flesh is not related to nematode resistance.

Field observations during the growing season showed that potato nematode-resistant forms are often not resistant to viral diseases and to Phytophthora. Hybrids with high yield and relatively high resistance to Phytophthora were selected for further testing in breeding nurseries. All nematode-resistant hybrids, including those that are unstable to Phytophthora, will be used in backcrossing and saturating crosses.

4. Conclusion
In order to prevent the spread of the Golden potato nematode in the North Caucasus, we recommend cultivating resistant varieties adapted to the conditions of the North Caucasus. The use of genetic and molecular selection of potatoes allowed us to create a collection of forms with resistance genes to all pathotypes of Golden and pale potato nematodes, which will allow us to conduct resistance selection ahead of time. Hybrids 04.573/1, 03.560/4 that have passed preliminary and state testing at the all-Russian point for testing potatoes for cancer and potato nematode are being prepared for transfer to the State variety testing. Documents confirming sustainability are stored in the laboratory of potato breeding, seed production and biotechnology.

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