Protection of potatoes from late blight in Sakhalin

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Abstract. The article presents long-term studies on the study of agrotechnical and chemical measures to combat potato late blight in the Sakhalin region. At the initial stage of work (1951-1966), the local population of the fungus *Phytophtora infestans* was studied, and a method for short-term prognosis of the disease was developed. For the first time, a complex of agrotechnical and chemical measures was developed: preplant germination and treatment of tubers with microelements (Cu, B, Mn); joint application of fertilizers and copper sulfate; double spraying of potato seedlings with microelements; fungicide treatments; removal of tops on seed plots before harvesting; post-harvest planting of seed material. Between 1996 and 2019 the improvement of disease control measures was carried out on the basis of the use of chemical and biological agents. In 1996-2003 among the studied modern fungicides, the most effective were systemic preparations (Acrobat MC, Ordan), as well as the combined use of Ordan with the biological product Planriz and Sodium Humate, which made it possible to reduce the development of the disease by 24.2-69.1% and increase the yield by 17.3-48.9%. According to the results of research in 2016-2019. Innovative combined action fungicides Infinito and Consento had the maximum protective effect against fungal infection. The use of drugs under production conditions made it possible to reduce the degree of damage to the vegetative mass by the pathogen by 56.5-60.0%, and increase the yield by 31.2-36.5%. Technical efficiency corresponded to 67-71%. The studied biopreparations (Trichocin, Vitaplan) are recommended for prophylactic treatment of potatoes in the initial period of vegetation.

1. Introduction
Late blight (*Phytophtora infestans*) of potatoes in the southern regions of Sakhalin is the most harmful disease. The monsoon climate of the island contributes to the development and mass spread of the disease. The local pathogen population is characterized by high genetic diversity, includes all known virulence genes, both types of sexual compatibility (A1 and A2), and is highly aggressive [1-2]. This, in turn, contributes to the emergence of new highly pathogenic races, which cause a rapid loss of resistance in cultivated varieties [3]. In the years of epiphytoties, yield losses can reach up to 60% or more [1].

Potato protection from the disease includes a set of protective measures: agrotechnical, chemical, biological, the use of activators of plant systemic resistance [4]. The main method is the use of chemicals. At the same time, it was found that repeated treatments with fungicides lead to the emergence of resistance to phytopathogens, which reduces the effectiveness of protective measures [5].
In modern conditions, much attention is paid to the greening of protection systems using phytoregulators. Their use reduces environmental pollution, increases stress resistance to abiotic factors, increases productivity, and at the same time reduces the cost of crop cultivation [6-7].

The purpose of the research is to develop and improve evidence-based measures to combat potato late blight based on the study of fungicides and new generation phytoregulators.

2. Materials and methods

The work was carried out from 1951 to 1966. on the experimental field of the Sakhalin Regional Agricultural Station; from 1996 to 2019 at FGBNU SakhNIISH. The research material was:

- Chemical preparations of the contact mechanism of action: Copper oxychloride - 0.5-1.0% solution, AB preparation - 25 kg/ha (mixture of copper sulphate and chalk), Kuprikol - 5 l/ha (copper oxychloride 200 g/l), Cineb - 0.5 % (zinc ethylene-bis-dithiocarbamate 800 g/kg), Figon - 0.5% (2,3-dichloro-1,4-naphthoquinone 500 g/l), Polyramp - 1.5 kg/ha (polycarbocin 700 g/kg), Shirlan - 0.4 l/ha (fluazinam 500 g/l).
- Systemic preparations: Cuprozan - 0.5% (copper oxychloride 650 g/l + cineb 150 g/l), Acrobat MC - 2 kg/ha (mancozeb 600 g/kg + dimethomorph 90 g/kg), Sandofan - 2 kg/ha (oxadixyl 640 g/kg), Ordan - 1.3 kg/ha (copper chloride 689 g/kg + cyxomaxanil 42 g/kg), Profit Gold MC - 0.6 kg/ha (flumoxadone 250 g/l + cyxomaxanil 250 g/l).
- Combined action: Aviksil - 1.5-1.8 kg/ha (oxadixyl 100 g/kg + polycarbacin 800 g/kg), Oxyhom - 2.1 kg/ha (copper hydroxide 670 g/kg + oxadixyl 130 g/kg), Ridomil Gold MC – 2.5 kg/ha (mancozeb 640 g/kg + mfenoxam 40 g/kg), Infinito – 1.6 l/ha (propanocarb hydrochloride 62.5 g/l + fluopicolide 62.5 g/l), Consento – 2 l/ha (propanocarb hydrochloride 375 g/l + fenamidone 75 g/l).
- Biological products: Alirin-B – 60 g/ha (Bacillus subtilis (V-10 VIZR strain) titer 10^{11} CFU/g), Vitaplan – 80 g/ha (Bacillus subtilis (VKM-V-2604D strain) titer 10^{10} CFU/g + Bacillus subtilis (strain VKM-B-2605D) titer 10^{10} CFU/g), Planriz – 0.3 l/ha (Pseudomonas fluorescens (strain AP-33) titer 10^{9} CFU/g), Trichocin – 80 g/ha (Trichoderma harzianum titer 10^{10} CFU/g).
- Natural growth stimulator: Sodium humate – 0.5 kg/t (tuber treatment) and 1.2 kg/ha.

Field tests of protective equipment were carried out on late blight resistant varieties: Berlichingen, Local scarlet, Sakhalin 4, Priekulsky early, Zhukovsky early, Lasunok, Zekura.

The soil of experimental plots with the content of nutrients: nitrate nitrogen 4.2-4.5 mg, ammonia nitrogen - 1.0-2.3 mg, mobile phosphorus and potassium, respectively - 17.5-31.0 and 7.2-23.5 per 100 g of absolutely dry soil; pH 4.2-4.8.

The climatic conditions during the research period were generally characterized by a moderate temperature regime in July-August (15.5-17.3 ˚C), excessive precipitation in the second half of summer (82-112 mm), high relative air humidity (90-100%), which contributed to the annual manifestation of late blight on potatoes. Potato harvesting, as a rule, took place under conditions of excessive waterlogging of the soil, which caused mass infection of tubers with a fungal infection.

Experiments on the study of protective equipment were laid according to generally accepted methods [8-10].

Experimental schemes included the following options: control (without treatments), standard (fungicide used in the farms of the region at the time of the study), the test preparations were used at doses recommended by the manufacturers. The first treatments were carried out according to the signal of STAZR (Sakhalin Regional Plant Protection Station), the subsequent ones, depending on the timing of the onset of the disease and weather conditions. Agricultural technology is generally accepted in the field during the years of research [11].

Field observations of late blight were carried out in dynamics every 10 days from the onset of the disease. The leaf damage was recorded on a 5-point scale: 1 point - single spots on 1-2 leaves, 2 points
- up to 1/3 of the bush leaves are affected, 3 points - about 1/2 of the bush leaf surface is affected, 2/3 of the surface of the leaves of the bush, 5 points - complete death of the tops. The yield was recorded by the method of continuous harvesting on the accounting plot according to the method of VNIKKh [9]. Mathematical processing of experimental data was carried out by the dispersion method [10]. According to the variants of the experiment, the economic one was determined [12].

3. Results

Currently, the main method of combating late blight is the use of fungicides with different mechanisms of action [13]. For the first time on Sakhalin, the study of chemical preparations against the disease was carried out by N.A. Nikiforova in 1951-1953, on the experimental field of the Sakhalin branch of the USSR Academy of Sciences. The most effective among the studied pesticides were Copper oxychloride and Preparation AB. With a triple treatment with fungicides, the potato yield increased by 40–69% [14]. Scientific work on the development of measures to combat potato late blight was continued in 1959-1966. Based on the results of the studies, it was found that the population of the fungus Phytophthora infestans on Sakhalin is represented by a number of aggressive races that can successfully overwinter on infected tubers and serve as a source of primary infection; developed a method for short-term prognosis of the disease. In 1962, for the timely signaling of chemical treatments against phytophthora, a forecast service was organized in the region, which still exists. A set of agrotechnical and chemical measures has been developed to reduce the severity of the disease [1;15]:

- Planting at the optimum time of vernalized tubers treated with trace elements of copper 0.02%, boron 0.05%, manganese 0.1%.
- When planting, the application of finely ground copper sulphate at the rate of 6 kg/ha together with fertilizers.
- Double treatment of crops with trace elements of copper 0.02%, boron 0.05%, manganese 0.1% in the first decade of germination and after 7-10 days with simultaneous loosening of row spacing.
- Three to four times fungicide treatment, of which the first should be carried out according to the forecast, the second - in 5-7 days, the subsequent ones depending on the spread of the disease.
- In the first two treatments, Bordeaux liquid substitutes were used: Kuprozan 0.5%, Kuprikol 0.8%, Cineb 0.5%, Figon 0.5%, copper oxychloride 1% or 0.5% (depending on the percentage of the active substance).
- Removal of haulm from seed plots 10-14 days before harvest.
- Post-harvest greening of seed.

The use of this system to combat phytophthora in the general complex of agrotechnical measures for the cultivation of potatoes fully paid off at the state farms of the Sakhalin Region. Additional income per 1 ha was 1120 rubles.

In subsequent years, the improvement of protective measures against fungal infection was carried out as modern pesticides, phytoregulators, and the development of new technological methods for growing potatoes appeared. So, in 1996-2000. in the department of potato growing of the Federal State Budgetary Scientific Institution SakhNIISH, new fungicides were tested: Acrobat MTs, Avixila, Sandofana, Ridomil Golda MTs. The most effective in the fight against the disease was the contact-systemic drug Acrobat MC. Three times spraying of plants with a fungicide provided the least development of the disease at the end of the growing season - 69.1% (100% in the control) and high yield - 21.6 t/ha (higher than the control by 9.0 t/ha). It is still successfully used in agriculture of the region [16].

In modern conditions, in the system of protective measures against potato late blight, it is important to use biological preparations to improve plant adaptation to adverse factors, increase crop yields and
improve product quality [17-19]. In this regard, in 2001-2003, for the first time, not only new chemicals were included in the research: Ordan, Poliram, Oksihom, but also biological products: Planriz, Sodium Humate. The use of the fungicide Ordana both in its pure form and in alternation with biological preparations Planriz and Sodium Humate reduced the development of the disease by 24.2–30.2% (reference Acrobat MTs – 48.2%), increased the yield by 17.3–35.5% [20].

Between 2016 and 2019 the following fungicides were studied: Shirlana, Profit Gold, Infinito, Consento, phytoregulators: Alirina-B, Vitaplana, Trichocin. According to the research results, the innovative drugs of the combined action Infinito and Consento provided the greatest efficiency in the fight against the disease (table 1).

**Table 1.** The defeat of potato plants by late blight, depending on the use of biological products and fungicides (average for 2017-2018), %.

| Drug treatment options | July 31 - August 01 | August 06 - August 09 | August 13 - August 17 | August 23 - August 24 |
|------------------------|---------------------|-----------------------|-----------------------|-----------------------|
| Control (water)        | 15.3 3.3            | 76.2 30.6             | 100 76.2              | 100 100              |
| Etalon - Acrobat MC    | 0 0                 | 17.8 3.5              | 33.8 7.1              | 54.7 12.6            |
| Consento - Consento    | 0 0                 | 5.1 1.0               | 17.3 3.6              | 24.4 5.0             |
| Infinito - Infinito     | 0 0                 | 3.8 0.8               | 6.9 1.4               | 12.0 2.4             |

Possessing antisporulant properties, these preparations, under conditions of moderate development of the disease, restrained the spread of infection by 27.9-42.7%, reduced the degree of damage to the vegetative mass by 6.2-10.2%, increased the yield by 21.0-23.0%, and the marketability of tubers by 2.2-3.8% (figure 1).

**Figure 1.** Potato yield depending on the use of effective fungicides.

A production test of fungicides (2019) under conditions of a strong development of the disease confirmed their high efficiency, reduced the development of the disease by 56.5-60.0%, and increased potato yield by 32.0-36.5%. The technical efficiency of potato treatments with preparations was 67-71%. Received additional income from 73 to 154 thousand rubles/ha.
4. Discussion
The study of biological products (Alirina-B, Trichocin, Vitaplan) showed that their use in its pure form did not have a protective effect against the pathogen Phytophthora infestans. It was established that they restrained the development of the disease only in the early stages of its appearance. In this regard, these preparations are recommended for preventive treatments during the period of full germination of potatoes, which allows to reduce the cost of pesticides and obtain more environmentally friendly products. In the future, in conditions of intensive distribution and development, it is necessary to carry out treatments with chemical means of protection.

Currently, in the production of potatoes in the region, a set of measures to protect potatoes against late blight, along with new fungicides, includes the use of modern chemical disinfectants for preplant treatment of tubers (Maxim 0.4 l/t, Prestige 0.7-1.0 l/t, Tecto 0.09-0.12 l/t), for desiccation of tops of the tank mix Reglon Super 2 l/ha with Shirlan 0.2 l/ha.

5. Conclusion
Based on the results of many years of scientific research, a set of protective measures has been developed to combat potato late blight. Under the conditions of epiphytotic development of the disease, along with generally accepted technological methods (preplant germination, treatment of tubers with microelements, phytoregulators, fungicides, desiccation of tops, etc.), the use of chemicals is a prerequisite for effective protection of potatoes on Sakhalin. Among the studied pesticides, the systemic fungicides Acrobat MC, Ordan, as well as the alternation of Ordan with the biological preparation Planriz and Sodium Humate had a high protective effect against fungal infection. At the same time, there was a decrease in the degree of defeat of tops by potagen by 24.2-69.1%, an increase in yield by 17.3-48.9%. On a high infectious background, the innovative fungicides of the combined action Infinito and Consento were characterized by the greatest protective effect against late blight. Processing (3-4 times) of industrial plantings of potatoes made it possible to reduce the damage of the vegetative mass by 56.5-60.0%, to increase the yield by 31.2-36.5%. Additional income from the use of drugs ranged from 73 to 154 thousand rubles/ha. The studied biological products (Trichocin, Vitaplan) are recommended to be used as preventive treatments in the first half of the growing season in order to reduce the pesticide load and total production costs.

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