Biological Products for Integrated Protection Systems for Greenhouse Vegetables and Ware Potatoes

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Abstract. The article presents research materials on the widespread use of multifunctional biological products against fungal and bacterial pathogens on the main vegetable crops cultivated in greenhouses and on potatoes. For protected ground crops: cucumber, tomato, eggplant, protection systems have been developed that help protect plants from diseases during the entire growing season. The introduction of these systems into production makes it possible to completely reduce or minimize the use of chemical plant protection products on these crops and thereby reduce the negative impact on the environment, as well as improve the quality and safety of crop products. The article presents the main biological products that are included in the potato protection system, including Kartofin, SK and Sternifag, SP.

1. Introduction

Phytosanitary stabilization of agroecosystems is based on the use of integrated plant protection systems, which are based on resistant varieties and the use of multifunctional biological products for pest and disease control [1].

This is especially important in the production of fresh vegetable products in greenhouses, which must be protected by mass breeding and introduction of entomophages, as well as the widespread use of a modern range of biological products.

Currently, in the Russian Federation, a little more than 2% of the cultivated area is treated with biological plant protection products. At the same time, the volume of use of biological agents in the USA is 20 times more, and in the EU countries – almost 40 times more than in the Russian Federation [2]. The state catalog of pesticides and agrochemicals permitted for use on the territory of the Russian Federation includes: Alirin-B, Gamair, Vitaplan, Trichocin, Sternifag, Fitosporin, Baktofit, Pseudobacterin and Rizoplan (Planriz) [3].

The use of entomophages and microbiological preparations form the basis of the protection system for vegetable, flower and ornamental crops in cultivation facilities in protected ground [4]. At the same time, the use of chemicals is limited to the minimum required level.

Currently, greenhouse complexes are mainly used for the production of vegetable products: cucumbers, tomatoes and green crops; there is also an increase in the area occupied by the cultivation of peppers and eggplants. The presence of large closed areas for the cultivation of vegetable, flower and ornamental crops with the specified parameters of the microclimate for the appropriate crop (high
temperatures and air humidity) contribute to the rapid and mass reproduction of pests and diseases in greenhouses and greenhouses, which requires effective measures to protect the crop.

Also, the task was set to expand the range of biological means of protecting potatoes, which is the second bread in our country, to protect it from harmful objects in integrated protection systems.

2. Materials and methods
The basis of research on the assessment of systems for the integrated protection of vegetable and ornamental crops in cultivation facilities of protected ground and the protection of ware potatoes was a modern range of biological products permitted for use in the Russian Federation. The assessment of the biological effectiveness of biological products in integrated protection systems was carried out in accordance with the “Guidelines for Registration Tests of Fungicides in Agriculture” (St. Petersburg, 2009) and “Guidelines for Registration Tests of Insecticides, Acaricides, Molluscicides and Rodenticides in Agriculture” (St. Petersburg, 2009).

The systems for the protection of crops, which are given below, included highly effective biological products developed by the Federal State Budget Scientific Institution “All-Russian Institute of Plant Protection” (FGBNU VIZR) together with the group of companies “Agrobiotekhnologia”. The basis for the protection of these crops from diseases is formed by multifunctional biological products, such as: Alirin-B, SP; Gamair, SP; Glyokladin, SP; Mikosar, SP.

Biological product Alirin-B SP based on the bacterium Bacillus subtilis is designed to protect tomatoes and cucumbers of protected ground from pathogens of root rot and wilting, as well as late blight, ascochitosis, powdery mildew, alternaria, anthracnose, gray rot.

Biological product Trichocin SP based on fungi of the genus Trichoderma harzianum, strain G30 VIZR is a highly effective biological fungicide for suppressing the development and spread of pathogens of root and root rot, wilting of lettuce and green crops, as well as seedlings of flower and indoor flower and ornamental plants. The development of new biological products based on fungi is being actively pursued in other countries [5, 6].

Biopreparation Glyokladin, SP is created on the basis of the soil fungus Trichoderma harzianum with a targeted action to suppress the development and spread of pathogens of root and root rot, wilting of tomato and cucumber in protected ground, seedlings of vegetable, flower crops, indoor flower and ornamental plants.

Biological bactericide Gamair, SP effectively suppresses bacterial diseases: bacterial cancer, soft rot, necrosis of the heart of the stem, angular bacterial spotting. The drug is active against a number of phytopathogenic fungi of the genera Fusarium, Ascoyta, Verticillium, Rhizoctonia.

Biopreparation Mikosar, SP biological fungicide and bactericide based on a mixture of the bacterium Bacillus subtilis and the soil fungus Trencherman harzianum to protect tomatoes and cucumbers in protected ground from pathogens of root rot and wilting. It also inhibits the development of late blight, ascochitosis, powdery mildew, alternaria, anthracnose, gray rot, bacterial cancer, soft rot, necrosis of the heart of the stems, angular bacterial spot.

Studies of the effect of these drugs on pathogens of greenhouse and greenhouse crops made it possible to develop systems for their effective protection, which are presented in the next section.

3. Results and discussion
The worked out technological regulations for the use of a set of biological products for the protection of tomato, cucumber, and eggplant crops from a complex of fungal and bacterial diseases have made it possible to propose effective protection systems that provide high biological and economic efficiency in the practice of agricultural production.

The systems for the integrated protection of greenhouse crops from root rot, late blight and tracheomycotic wilt include seed treatment. They are soaked with exposure for at least 10 minutes in the working fluid, at the rate of consumption of the biological product Alirin-B, SP – 2 g per 1 kg of seeds. The consumption rate of the working fluid during treatments is 1 liter per 1 kg of seeds.
The following are the plant protection systems of crops during their growing season. Table 1 presents a system of cucumber plant protection using multifunctional biological products.

Before sowing or before planting seedlings in a greenhouse, they are treated with a biological product Glyokladin, SP. The regulations and methods of its application are presented in Table 1.

**Table 1.** System of cucumber protection from diseases in protected ground on coconut, peat or mineral wool substrates.

| Activity                                                                 | Way of treatment          | Biofungicide                  | Consumption of the preparation, g/ha. | Treatment costs 1 ha/rub. |
|-------------------------------------------------------------------------|----------------------------|--------------------------------|--------------------------------------|---------------------------|
| After disinfection, apply the antagonist fungus to glass and structures  | Wet processing or cold fog | Glyokladin, SP                | 60                                   | 5500                      |
| *(Trichoderma harzianum VIZR-18)*                                       | aeration                   |                                |                                      |                           |
| Application to the substrate before sowing seedlings                     | Saturation of the blocks   | Glyokladin, SP                | 30 by 25 thousand blocks             | 2750                      |
| Application to the substrate for seedlings at the stage of 1-2 leaves    | with a solution             |                                |                                      |                           |
| Before planting plants in a permanent place add to the substrate         | Adding water                | Alirin-B, SP                  | 30 by 25 thousand blocks             | 2175                      |
| (to mineral wool mats only 5-6 days after planting)                      |                            |                                |                                      |                           |
| After planting the plants in the substrate, the first month              | Drip watering              | Alirin-B, SP + Gamair, SP     | 60 + 60                              | 8700                      |
|                                                                         |                            | or Alirin-B, SP, mod.         | 60 + 120 g                           | 5670                      |
| 2nd month of vegetation, introduction into the substrate                 | Drip watering              | Alirin-B, SP + Gamair, SP     | 60 + 60                              | 8700                      |
|                                                                         |                            | or Mycozar, SP                | 60 + 120                             | 5670                      |
|                                                                         |                            | or Alirin-B, SP, mod.         |                                      |                           |
| 3rd month of vegetation, introduction into the substrate                 | Drip watering              | Alirin-B, SP + Gamair, SP     | 60 + 60                              | 8700                      |
|                                                                         |                            | or Mycozar, SP                | 60 + 120                             | 5670                      |
|                                                                         |                            | or Alirin-B, SP, mod.         |                                      |                           |
| 4th month of vegetation, introduction into the substrate                 | Drip watering              | Alirin-B, SP + Gamair, SP     | 60 + 60                              | 8700                      |
|                                                                         |                            | or Mycozar, SP                | 60 + 120                             | 5670                      |
|                                                                         |                            | or Alirin-B, SP, mod.         |                                      |                           |
| Leaf treatment during vegetation (from gray rot)                         | Spraying                   | Glyokladin, SP or Mycozar, SP | 60                                   | 5500                      |
|                                                                         |                            |                                | 200                                  | 7400                      |
| Leaf spraying during vegetation (from powdery mildew and ascochitis)     | Spraying                   | Alirin-B, SP, mod. or Mycozar, SP | 120 g                                | 5670                      |
|                                                                         |                            |                                | + 1 kg CO(NH$_2$)$_2$ + 1 kg MgSO$_4$ | 7400                      |
| Average cost of a complex of treatments                                 | Alirin-B, SP + Gamair, SP  | 61895                         |                                      |                           |
|                                                                         | Mycozar, SP                | 47425                         |                                      |                           |
|                                                                         | Alirin-B, SP, mod.         | 49775                         |                                      |                           |
|                                                                         | Glyokladin, SP             | 19250                         |                                      |                           |
Glyokladin, SP effectively suppresses root rot, white and gray rot, late blight. The biological product Alirin-B, SP is also used against root rot. It is applied directly to the substrate on which the culture is grown. Tests have shown high efficiency of cucumber culture protection when the above preparations are used in the system.

Drip irrigation under the root in the soil is done when the first signs of the disease appear, and then this technological operation is carried out with an interval of 10–20 days at a drug consumption rate of 60–120 g/ha and a working fluid consumption of 500–3000 l/ha.

Spraying of vegetative plants is carried out when the first symptoms of one of the diseases appear, each spraying with an interval of 10–20 days at a flow rate of the working fluid of 500–3000 l/ha.

To combat bacterial cancer, late blight, white and gray rot, the biological product Gamair, SP, is included in the integrated protection system, which is used in conjunction with Alirin-B, SP in the presented sequence of mandatory technological operations. Gamair, SP is also used for pre-sowing soaking of seeds in the working liquid of the suspension of the drug and the consumption rate of 1–2 g/kg. The duration of soaking is 1–2 hours, followed by drying, the rate of consumption of the working fluid is 1 l/kg of seeds.

It is also necessary to spray growing plants when the first symptoms of one of the listed diseases appear. Preparations, method of processing and consumption rates of preparations are indicated in table 2.

The system of protection of tomatoes from diseases is presented in table 2. Until the 4th month of the growing season of tomatoes, protection measures are similar to the protection of cucumber plants, therefore, they are not indicated.

Table 2. System of protection of tomato from diseases in protected ground on coconut, peat or mineral wool substrates.

| Activity                                      | Way of treatment | Biofungicide                  | Consumption of the preparation, g/ha. | Treatment costs 1 ha/rub. |
|-----------------------------------------------|------------------|-------------------------------|--------------------------------------|---------------------------|
| Application technology and preparations up to the 4th month of tomato vegetation are similar to those presented in Table 1 for cucumber plant treatments |                   |                               |                        |                          |
| 4 month of vegetation, introduction into the substrate | Drip watering    | Alirin-B, SP + Gamair, SP or Mycozar, SP or Alirin-B, SP, mod. | 90 + 90 90 + 300 90 + 180 | 13050 11100 8505 |
| 5 month of vegetation, introduction into the substrate | Drip watering    | Alirin-B, SP + Gamair, SP or Mycozar, SP or Alirin-B, SP, mod. | 60 + 60 60 + 200 60 + 120 | 8700 7400 5670 |
| 6 month of vegetation, introduction into the substrate | Drip watering    | Alirin-B, SP + Gamair, SP or Mycozar, SP or Alirin-B, SP, mod. | 90 + 90 90 + 300 90 + 180 | 13050 11100 8505 |
| Leaf treatment during vegetation (from gray rot) | Spraying         | Glyokladin, SP or Mycozar, SP | 60 200 | 5500 7400 |
| Leaf treatment during vegetation (from powdery mildew) | Spraying         | Alirin-B, SP, mod. or Mycozar, SP | 120 g 200 g | 5670 7400 |
| Average cost of a complex of treatments         |                   |                               |                        |                          |
|                                               |                   | Alirin-B, SP + Gamair, SP or Mycozar, SP or Alirin-B, SP, mod. | 60900 66600 45360 13750 |
Table 3 presents the developed system of protection against pathogens for the eggplant culture. The technology of protecting eggplant plants from diseases as well as in tomatoes until the 4th month is similar to the protection of cucumber plants, which is given in table 1, and for 4 and 5 months it is similar to the protection of tomatoes, therefore it is not repeated in table 3.

Table 3. System of protection of eggplant from diseases in protected ground on coconut, peat or mineral wool substrates.

| Activity | Way of treatment | Biofungicide | Consumption of the preparation, g/ha. | Treatment costs 1 ha/rub. |
|----------|------------------|--------------|-------------------------------------|--------------------------|
| 6 month of vegetation, introduction into the substrate | Drip watering | Alirin-B, SP + Gamair, SP | 90 + 90 | 13050 |
| | | or Mycozar, SP | 90 + 300 | 11100 |
| | | or Alirin-B, SP, mod. | 90 + 180 | 8505 |
| | | Glyokladin, SP | 60 | 5500 |
| 7 and 9 month of vegetation, introduction into the substrate | Drip watering, every month | Alirin-B, SP + Gamair, SP | 60 + 60 | 17400 |
| | | or Mycozar, SP | 60 + 200 | 14800 |
| | | or Alirin-B, SP, mod. | 60 + 120 | 11240 |
| 8 and 10 month of vegetation, introduction into the substrate | Drip watering, every month | Alirin-B, SP + Gamair, SP | 90 + 90 | 26100 |
| | | or Mycozar, SP | 90 + 300 | 22200 |
| | | or Alirin-B, SP, mod. | 90 + 180 | 17010 |
| Leaf treatment during vegetation (from gray rot) | Spraying, twice during vegetation | Glyokladin, SP or Mycozar, SP | 60 + 60 | 11100 |
| | | or Alirin-B, SP, mod. | 200 | 7400 |
| Leaf treatment during vegetation (from powdery mildew) | Spraying, twice during vegetation | Alirin-B, SP, mod. or Mycozar, SP | 120 g + 120 g | 11340 |
| | | or Alirin-B, SP, mod. | 200 g | 7400 |
| Average cost of a complex of treatments | Alirin-B, SP + Gamair, SP | | | 135215 |
| | | Mycozar, SP | | 114025 |
| | | Alirin-B, SP, mod. | | 103400 |
| | | Glyokladin, SP | | 30350 |

The application technology and preparations up to the 4th month of the growing season are similar to the treatments of cucumber plants presented in table 1, for the 4th and 5th months they are similar to the treatments of tomatoes and are presented in table 2.

Integrated protection systems of the crops under consideration must, in addition to drugs used against pathogens, also include a complex of biological preparations aimed at combating pests that cause significant harm to greenhouse plants.

For example, nematode preparations are used to control the soil stages of pests in the greenhouses of botanical gardens [7]. The drugs Nemabakt and Antonem F were developed at the FGBNU VIZR and contain 5 million nematodes in 1 g of a foam sponge. The application rate for one potted plant is 50 thousand, and for 1 m² of soil 1 million individuals. A single treatment with nematode preparations in the specified rates allows keeping the number of thrips in greenhouses at a low level. The death of the pest with a single treatment reaches 95% [8].

Another important crop on which previously developed and tested new biological products are already being applied is potato.
To create a basis for the implementation of national programs in the field of organic production and production of ecologically improved agricultural products, a biologized system for protecting potatoes from a complex of diseases has been proposed.

The biologized potato protection system provides for the widespread use of biological products at all stages of the potato cultivation technological chain from planting to harvesting.

The pre-planting treatment of tubers using the dressing technology provides for the treatment with a biological product Vitaplan, SP at a consumption rate of 20 g/t of seeds together with a chemical dressing agent.

For several years, FGBNU VIZR has been successfully developing biological preparations that have a depressing effect on harmful objects in the soil and a positive effect on cultivated plants [9]. To suppress the complex of phytopathogenic infections in the soil and overwintered on plant residues, the biological product Sternifag, SP, is included in the protection system at a consumption rate of 80 g / ha, which is used before planting by spraying the soil with subsequent incorporation into the soil. It should be noted that the biological product is compatible for use with herbicides and insecticides and incompatible with fungicides. When preparing a tank mixture with a biological product, the chemical is first introduced with constant stirring, and then the biological product is added. When germinating seedlings and tops of up to 15 cm against scab, Alternaria and powdery mildew, together with herbicidal treatment, seedlings are sprayed with the biological product Alirin-B, Zh at a rate of 3 l/ha, the flow rate of the working fluid is 300 l/ha. In the phase of budding of potatoes against Alternaria, root and root rot, it is necessary to spray with a biological product Vitaplan, SP at a consumption rate of 80 g/ha. Another application scheme: the biological product Vitaplan, SP with a consumption rate of 40 g/ha, together with a chemical fungicide, the consumption rate of which is reduced by 50%. In the phase of flowering potatoes against alternaria, rhizoctonia, late blight, it is necessary to use the biological product Trichocin, SP at a consumption rate of 40 g/ha and a working fluid flow rate of 300-400 l/ha. To increase the efficiency of the deposition of a biological product along the tiers of plants when spraying, it is better to use sprayers with a double spray torch. It is also advisable to combine the use of a biological product with foliar feeding or processing with humates.

In the tubers ripening phase, it is necessary to spray potato plantings with Vitaplan, SP biopreparation at a biological product consumption rate of 80 g/ha and a working fluid flow rate of 400 l/ha. No later than two weeks before harvesting, against Alternaria, scab, root rot, bacterial infection, it is necessary to spray the potato plantings with the bio-preparation Alirin-B, Zh at a consumption rate of 3 l/ha or with a biological product Vitaplan at a rate of 80 g/ha.

Currently, a new biological product has been developed and is being tested for the protection of potatoes from fungal and bacterial diseases Kartofin, SK [10]. Tests to assess the biological effectiveness of the new biological product Kartofin, SK and to work out the regulations for its use were carried out in the Belgorod region in the fields of the Agrobiotekhnologiya Scientific Research Center, LLC using the Fritella potato variety of the Russian Potato Research Center selection.

Tests of Kartofin, SK in the technological process of pre-planting treatment by dressing tubers and spraying vegetative plants showed that with the development of the stem form of rhizoctonia in the control 5.5%, the effectiveness of the drug was 72.7%, at a rate of application of 0.1 l/t + 0, 3 l/ha. The efficiency of the standard - Alirin-B, Zh was lower and amounted to 63.6%.

The increase in the yield of potatoes when treating tubers and with 3-fold spraying of plants with the drug Kartofin, SK was 46.4%, which significantly exceeded this indicator in the Alirin-B, Zh standard – 13.0%.

Thus, the test of the preparation Kartofin, SK as a fungicide, at rates of application of 0.1 l/t when dressing and 0.3 l/ha when spraying potato plants, showed that it exceeded standard preparation Alirin-B, Zh. The increase in the yield of potatoes, in relation to the control, in experiments with treatments with Kartofin, SK was – 46.4%, and when using the preparation – standard Alirin-B, Zh, the increase in yield was significantly lower – 13.0%.
4. Conclusion
A modern assortment of biological products included in the systems of protecting vegetable crops in protected ground, with the joint use of entomophages, provides effective protection of cultivated crops without the use of chemical plant protection agents and allows improving their quality and safety, as well as reducing the pesticide load on the soil.

The proposed system of protection of ware potatoes based on the use of poly-functional biological products, allows you to obtain products with improved environmental and consumer characteristics.

The assessment of the protective effect of the new biological product Kartofin, SK against alternaria and rhizoctoniae has been carried out, which has shown its high biological effectiveness.

When using the new biological product Kartofin, SK, the resulting increase in yield was 3.5 times higher than that of the standard drug Alirin-B, Zh.

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