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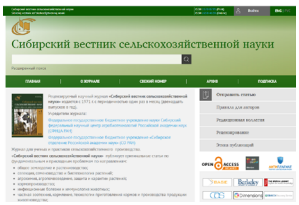
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DEAR COLLEAGUES!

Here is the anniversary issue of the journal "Siberian Herald of Agricultural Science," dedicated to the 10th anniversary of the establishment of the Laboratory of Biological Control of Phytophages and Phytopathogens within the Siberian Federal Scientific Centre of Agricultural Sciences of the Russian Academy of Sciences and the 55th anniversary of the founding of the Biomethod Laboratory at the Siberian Research Institute of Soil Management and Chemicalization of Agriculture SB RAS.

The primary focus of the Laboratory of Biological Control of Phytophages and Phytopathogens is the development of environmentally safe plant protection products aimed at biologically regulating the phytosanitary status of agrocenoses and managing the adaptive potential of agricultural crops under the conditions of Western Siberia. The laboratory staff are engaged in cutting-edge scientific research focused on the search for, isolation, and selection of promising entomopathogens, antagonistic microbes, and entomoacariphages, which serve as the basis for the development of biological plant protection agents. In the field of basic research, studies are being conducted on the mechanisms by which microbiological agents affect phytophagous insects and plant pathogens, and molecular methods for diagnosing plant pathogens and specific arthropod species are being developed. Promising areas of research include the development of cultivation technologies and the application of new, highly effective biological agents under conditions typical of the Siberian region. To achieve these objectives, the laboratory has established collections of live microbial cultures (antagonistic microbes, entomopathogens, and phytopathogens), insects, and mites (phytophages, entomo- and acarophages, and forage species).

I would like to note separately that our achievements today are a continuation of the path begun by our predecessors. In particular, the history of the development of biological plant protection methods in Siberia is linked to the establishment in 1971 of the Biomethod Laboratory at the Siberian Branch of the All-Union Academy of Agricultural Sciences (VASKhNIL). The research interests of the staff at this laboratory, established 55 years ago, focused on studying entomopathogens of various origins and developing biological control agents based on them.

The anniversary issue of the journal features a review article on the main stages of the Biomethod Laboratory's work. The issue also includes articles by our colleagues from the leading Russian research institutions, presenting priority areas of scientific research in the field of biological plant protection. The publications present historical information and describe the current state of development of various methods and means of biological control, including an assessment of the role of entomophages in agro- and biocenoses, prospects for the use of entomopathogens, new species, and strains of antagonistic microbes to control plant pests, and the definition of the role of scientists in fostering ecological thinking among young professionals.

I would like to express my deep gratitude to all my colleagues who accepted our invitation and contributed to this anniversary issue of the journal, demonstrating a high level of professionalism, a commitment to the biomethod, and a willingness to share their knowledge and experience in one of the highest-priority areas of applied science in Russia.

Sincerely, Head of the Laboratory of Biological Control of Phytophages and Phytopathogens SFSCA RAS, Candidate of Science in Agriculture, Associate Professor Andreeva I.V.

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История лаборатории биометода в Сибири

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Представлены исторические данные о создании в 1971 г. первой в Сибири лаборатории биометода в Сибирском отделении ВАСХНИЛ. Описаны направления научно-исследовательской работы ее сотрудников в области биологической защиты растений: изучение энтомопатогенных организмов различной природы (вирусов, бактерий, грибов), вызывающих заболевания и гибель насекомых-вредителей, создание биопрепаратов на их основе для контроля численности фитофагов, а также хищных грибов, перспективных для контроля размножения галловых нематод. Проведена большая работа по изучению спектра и механизма инсектицидного действия различных штаммов и подвидов бактерии *Bacillus thuringiensis,* а также промышленно выпускаемых бактериальных препаратов. Детально изучены вирусы гранулеза и полиэдроза чешуекрылых насекомых – вредителей сельскохозяйственных и лесных культур. Энтомопатогенные грибы представляли интерес для создания искусственных эпизоотий в популяциях вредителей и биопрепаратов на их основе. Важное значение имели экспериментальные работы по поиску, изучению и применению энтомофторовых грибов, вызывающих гибель сосущих вредителей в условиях защищенного и открытого грунта. В связи с проблемой вредоносности галловых нематод были развернуты исследования хищных грибов, выделены перспективные виды и штаммы, созданы и оценены опытные образцы биопрепаратов на их основе. Заслуживают внимания разработки технологии ловчих культур на посадках капусты и рапса для борьбы с крестоцветными блошками, а также отладка оптимальных режимов работы аэрозольных генераторов для внесения биологических препаратов в агроценозы. На базе различных хозяйств Новосибирской области проведены полевые испытания биопрепаратов для регуляции численности вредителей, показана их высокая эффективность.

Ключевые слова: биологическая защита растений, энтомопатогены, биопрепараты, хищные грибы, лабораторные и полевые исследования, научные достижения

History of the biomethod laboratory in Siberia

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Historical data is presented on the establishment in 1971 of the first biomethod laboratory in Siberia at the Siberian branch of VASKhNIL.The directions of the scientific research work of its employees in the field of biological plant protection are described: the study of entomopathogenic organisms of various kinds (viruses, bacteria, fungi) that cause diseases and death in pest insects, the creation of biopreparations based on them to control the population of phytophagous insects, as well as predatory fungi, promising for controlling the reproduction of gall nematodes. Extensive work has been carried out to study the spectrum and mechanism of insecticidal action of various strains and subspecies of the bacterium *Bacillus thuringiensis*, as well as the industrially produced bacterial preparations. Viruses of granulosis and polyhedrosis of lepidopterous insects – pests of agricultural and forest crops – have

been studied in detail. Entomopathogenic fungi were of interest for creating artificial epizootics in pest populations and biopreparations based on them. Experimental work on the search, study, and application of entomophthoraceous fungi, which cause the death of sucking pests under protected and open-field conditions, was of significant importance. In connection with the problem of the harmfulness of gall nematodes, research on predatory fungi was conducted, promising species and strains were identified, and experimental samples of biopreparations based on them were created and evaluated. Worth noting are the developments in the technology of trap crops in cabbage and rapeseed plantings to control cruciferous flea beetles, as well as the adjustment of optimal operating modes of aerosol generators for applying biological preparations in agrocenoses. Field trials of biopreparations for pest population control were conducted at various farms in the Novosibirsk region, demonstrating their high effectiveness.

Keywords: biological plant protection, entomopathogens, biopreparations, predatory fungi, laboratory and field studies, scientific achievements

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Biological plant protection based on the principles of biocenotic balance is the most appealing alternative to chemical pesticides. Natural agents (entomophages and herbivores, entomopathogens, and antagonist microorganisms) can effectively control the populations of pests, plant disease agents, and weeds, reducing pesticide load in bio- and agrocenoses [1, 2]. Directions in biological plant protection in our country began to be actively developed in the 1960s. Research on the use of entomophages (mainly used in greenhouse conditions) and the study of entomopathogenic organisms, which serve as the basis for creating insecticidal biopreparations, was intensified.

The history of the development of biological plant protection in Siberia is connected with the establishment in 1971 of a biomethod laboratory to address plant protection issues set by the State Committee for Science and Technology under the USSR Council of Ministers [3]. The laboratory was headed by Candidate of Biological Sciences Vladimir Vasilyevich Guly, who had previously worked as a research associate in the virology lab at the Biological Institute of the Siberian Branch of the Russian Academy of Sciences. Initially, the laboratory was located in Novosibirsk at the Plant Protection Station. Later, it was moved to the village of Ogurtsovo (Novosibirsk region). Only in 1975, after the construction of the scientific town of the Siberian Branch of VASKhNIL (Krasnoobsk) was completed, did the laboratory become part of the Siberian Research Institute of Chemicalization (SibNIIKhim).

Some of the first to start working in the lab were young scientists N.I. Severina (Ermakova), T.V. Andreeva (Teplyakova), L.N. Spichen-

ko (Filimonova), and M.V. Shternshis. By the mid-1970s, the lab team was almost completely formed. It included M.N. Aleyeva, L.N. Chukanova, M.Ts. Rakshaina, G.M. Ivanov, A.N. Baranov, Yu.P. Bukharov, L.A. Krupko, E.V. Koltunov, A. Mikhalev, V. Mishchenko, S. Moshegov, and others.

The research interests of the lab staff were mainly practical and focused on studying entomopathogens of various types and developing biopreparations based on them, aimed at controlling the population of dangerous agricultural pests.

The development of microbiological methods for controlling harmful insects is largely connected to the discovery, study, and use of the bacterium *Bacillus thuringiensis*[1]. The period starting from the 1960s can be called a stage of intensive development of bacterial preparations and their introduction into agricultural production. The creation of the first bacterial preparations in our country, dendrobacillin (1958) and entobacterin (1959), served as a stimulus for expanding research into various strains of this entomopathogenic bacterium. This field remains relevant even today [4]. In the biomethods lab, a significant contribution to the study of various subspecies and the mechanism of action of *B. thuringiensis* was made by V.V. Guliy, G.M. Ivanov, M.V. Shternshis, L.K. Kameneck, and other staff members.

Lyudmila Kirillovna Kameneck studied the structure, properties, and mechanism of action of *B. thuringiensis* deltaendotoxin on insects. Her research focused on various lepidopterans (like the gypsy moth, bee moth, whitethorn butterfly, cabbage white butterfly, and others) and hymenopterans (such as the common pine sawfly) pests[2]. The research results conducted at the laboratory formed the basis of her PhD thesis (supervised by V.V. Guly and M.V. Shternshis). Later, after successfully defending her dissertation for the Doctor of Science degree[3], Lyudmila Kirillovna headed the biochemistry department at the Ulyanovsk State University for many years.

Research by the Candidate Science in Biology Georgy Matveevich Ivanov focuses on finding ways to increase the biological activity of crystalliferous bacteria *B. thuringiensis*, particularly using chemical compounds of non-biological origin to control toxin biosynthesis. Using *B. thuringiensis* var. *insectus* as an example, it was shown that amino derivatives of acridine cause a long-term modification in the bacterial culture, which manifests as an increased synthesis of delta-endotoxin crystals, determining the effectiveness of this bacterium[4].

The research on developing the methods for working with bacterial cultures was groundbreaking. V.V. Guliy and L.I. Burtseva (a staff member of the Biological Institute of the Siberian Branch of the USSR Academy of Sciences) developed a method that allows quite clearly differentiating vegetative cells, spores, and *B. thuringiensis* endotoxin crystals in smears, intended for analyzing pure cultures and pathological material[5].

A lot of work has been done to study the spectrum of insecticidal activity of various strains and subspecies of *B. thuringiensis* and commercially produced bacterial preparations. In Lyd-

[1]*Chil-Akopyan L.A., Afrikyan E.G.* Entomopathogenic bacteria as a basis for biological plant protection products // Entomopathogenic bacteria and their role in plant protection: collection of scientific papers, Siberian Branch of VASKHNIL. Novosibirsk, 1987, pp. 4–22.

[2]*Kamenek L.K.* On the mechanism of action of *Bacillus thuringiensis*-based preparations on insect pests // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim). Novosibirsk, 1980, Issue 1 (35), pp. 3–4.

[3]*Kamenek L.K.* Delta-endotoxin of *Bacillus thuringiensis*: structure, properties, and use in plant protection: abstract of a dissertation for the degree of Doctor of Biological Sciences. Moscow, 1998, 40 p.

[4]*Ivanov G.M.* Long-term modification in crystal-forming bacteria induced by acridine derivatives // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim). Novosibirsk, 1978, Issue 30, pp. 22–26.

[5]*Burtseva L.I., Guliy V.V.* Fluorescent microscopy of *Bacillus thuringiensis* cultures // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim). Novosibirsk, 1973, Issue 6, p. 15.

ia Nikolaevna Spichenko's article[6], it is noted that the endotoxin produced by *B. thuringiensis* does not dissolve in the gut juice of older cabbage moth caterpillars and does not cause them toxicity. To increase the effectiveness of the entomopathogen, it was suggested to pre-break the toxin before use, which helped to expand its range of action. Also, experiments conducted with industrial strains of *B. thuringiensis* var. *galleria* (entobacterin) revealed differences in the insecticidal spectrum against various phytophages and between different strains[7].

Research by the Candidate of Science in Biology Margarita Vladimirovna Shternshis on the creation and improvement of preparative forms of bacterial preparations, as well as the search for ways to increase the effectiveness of biopreparations, in particular using activating additives of various origins, had great practical significance. So, a major success of Margarita Vladimirovna's work together with other colleagues was the creation of two new forms of bacterial preparations, which are not only more biologically active but also more stable, maintaining their activity for twice as long or more compared to standard forms[8].

In the 1970s, staff members of the laboratory N.I. Severin, L.N. Spichenko, Z.N. Alekseeva, and L.A. Krupko conducted field tests of biopreparations to control pest populations on various farms in the Novosibirsk region. As a result, Zinaida Nikolaevna Alekseeva and Lyudmila Alexandrovna Krupko proved the high effectiveness of bacterial drugs – entobacterin, dendrobacillin, insektin, bitoxibacillin – against the dangerous polyphagous pest – the meadow moth. It has been found that these drugs affect not only the larvae but also the adult insects. When butterflies were treated in lab conditions, the bio-preparations reduced the females' fertility and caused their death[9]. Research by Z.N. Alekseeva also showed that bacterial preparations did not have ovicidal effects but significantly impacted the survival of caterpillars that hatched from treated eggs of the gypsy moth and the meadow moth. This made it possible to increase the effectiveness of protective measures by carrying out treatments earlier[10].

To reduce the damage caused by leaf-eating pests (mainly lepidopterans) on cabbage (the main vegetable grown in Siberia), they used biopreparations of various types – viral (Virin-EKS), bacterial (Entobacterin), fungal (Boverin), as well as their mixtures[11].

The study of entomopathogenic viruses under the guidance of V.V. Guliy was carried out by E.V. Koltunov, N.I. Ermakova, M.V. Shternshis, L.A. Krupko, and others. In the very first years of the lab, a collection of entomopathogenic viruses was created, which allowed for various research on developing microbial plant protection agents against pests[12]. V.V. Guliy and

[6]*Spichenko L.N.* On the reasons for the resistance of the cabbage moth *(Mamestra brassicae) to Bacillus thuringiensis* Berl. cultures // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim). Novosibirsk, 1973, Issue 6, pp. 9–10.

[7]*Spichenko L.N., Skvortsova M.M., Guliy V.V.* Insecticidal activity of industrial strains of *Bacillus thuringiensis* var. *galleria* against certain harmful insects // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim). Novosibirsk, 1976, Issue 16, pp. 34–39.

[8]*Sternshis M.V.* Microbiological control of pests of agricultural crops in Siberia and the Far East. Moscow: Agropromizdat, 1988. 128 p.

[9]*Alekseeva Z.N., Krupko L.A.* Microbiological control of certain species of lepidopteran insects at the adult stage // Fauna and Ecology of Arthropods of Siberia: Proceedings of the 5th Meeting of Entomologists of Siberia. Novosibirsk: Nauka, 1981, pp. 119–121.

[10]*Alekseeva Z.N.* The effect of biological preparations on the hatching rate and survival of caterpillars following treatment of egg clutches // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim). Novosibirsk, 1980, Issue 1 (35), pp. 27–28.

[11]*Sternshis M.V., Spichenko L.N., Kamenek L.K., Krupko L.A.* Use of tank mixtures of microbiological insecticides on cabbage in Western Siberia. Novosibirsk, 1987, 22 p.

[12]*Guliy V.V.* A museum of entomopathogenic viruses at the Siberian Research Institute for the Chemicalization of Agriculture // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim). Novosibirsk, 1975, Issue 9, pp. 3–8.

E.V. Koltunov made a big contribution to the study of granulosis viruses of the winter cutworm and dendrophilous lepidopterans. Using the example of winter cutworm granulosis, they developed methods that helped increase the effectiveness of viral preparations when used[13]. The effects of the nuclear polyhedrosis virus on adult lepidopteran pests were also evaluated[14].

Evgeny Vladimirovich Koltunov studied insect viruses, mainly those affecting tree crop pests. In the Novosibirsk area, he identified and studied the morphology, pathogenesis, and histopathology of some granulosis viruses, including those of red-humped caterpillars, the codling moth, and other tree-dwelling insects. As a result of studying the causes of codling moth deaths during wintering, granulosis viruses and *Nosema* microsporidia were identified[15].

The scientific research of Nadezhda Ivanovna Severina (Yermakova) focused on entomopathogenic viruses that infect lepidopteran insects. She and her colleagues took a close look at the specifics of the pathogenesis of nuclear polyhedrosis in the cabbage moth[16], hereinafter – the meadow moth granulosis virus. Considerable attention was paid to studying the decline in activity of the cabbage moth polyhedrosis pathogen during storage[17]. This depends on the storage conditions of the biological material. At the time, the efficacy of the combined use of different viruses—as well as viruses in combination with other microbial agents (bacteria, protozoa, fungi)—had been virtually unstudied, which prompted experiments in this area. It was established that the combined action of two viruses—one specific to a particular phytophagous species and the other non-specific to it—enhances the virulence of the former. For example, when cabbage moth larvae were infected with nuclear polyhedrosis virus supplemented with the granulosis virus of the cabbage white butterfly, an increase in the virulence of the specific virus was observed under the influence of the other pathogenic agent[18]. At the same time, they were developing methods for breeding their hosts in lab conditions. In particular, a semi-synthetic nutrient medium was created for breeding the cabbage moth[19].

Microbiological control and insect pathology are the areas of scientific work of Svetlana Yuryevna Rybina (Guliy). Together with her colleagues, she conducted interesting studies on assessing the effects of viral and bacterial biopreparations on honeybees[20].

Entomopathogenic fungi were of interest both for creating artificial epizootics in pest populations and for developing biopreparations based on them. In their research, Candidates of Science in Biology Mela Tsydenovna Rakshaina and Nina Mikhailovna Makhova identified the role of pea aphid epizootics caused by entomophthoraceous fungi. It was shown that during the development of epizootics, pest numbers drop significantly, which allows for limiting the use of chemical plant protection products. In addition, aphid entomophthoroses

[13]*Sternshis M.V., Severina N.I., Guliy V.V.* Increasing the activity of the granulosis virus of the winter cutworm (*Agrotis segetum*) // Izvestiya SB AS SSSR (Proceedings of the Siberian Branch of the USSR Academy of Sciences), Ser. Biol., 1975, No. 3, pp. 51–55.

[14]*Guliy V.V., Shternshis M.V., Koltunov E.V.* Main results and prospects for the development of a virological method for pest control // Siberian Herald of Agricultural Science, 1976, No. 5, pp. 36–43.

[15]*Koltunov E.V.* On the causes of winter mortality of the codling moth in the Middle Ob region // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim). Novosibirsk, 1973, Issue 6, pp. 45–46.

[16]*Krupko L.A., Severina N.I.* Specifics of the pathogenesis of nuclear polyhedrosis in the cabbage moth // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1975, Issue 9, pp. 14–15.

[17]*Severina N.I.* Changes in the activity of the cabbage moth polyhedrosis pathogen during storage // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1973, Issue 6, pp. 7–8.

[18]*Severina N.I.* Combined effect of two viruses on vegetable crop pests// Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1973, Issue 6, pp. 11–12.

[19]*Severina N.I.* Polyhedrosis in cabbage moth caterpillars reared on an artificial medium// Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1975. Issue 9, pp. 11–13.

[20]*Guliy V.V., Talpalatsky P.L., Rybina S.Yu.* The impact of standard microbiological insecticidal preparations on honey bees // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1978, Issue 30, pp. 39–41.

in greenhouses were studied[21], as a result, several species of entomophthorous fungi – potential causes of epizootics among sucking pests – were isolated into culture[22]. In 1972, in the greenhouses of the Kirovets state farm, laboratory staff member Alexander Nikolaevich Baranov discovered an outbreak of entomophthorosis in spider mites, which also affected the predatory mite Phytoseiulus. A.N. Baranov also worked on modifying artificial nutrient media for entomophthorous fungi[23].

Later, Nadezhda Viktorovna Lobanova (Vasilyeva) joined the research on entomophthorous fungi. She worked on developing a product based on the fungus *Enthomophora pyriformis* and evaluating its effectiveness against various types of aphids and greenhouse whiteflies in protected ground conditions. The result of this work was the publication of recommendations for production[24].

The serious problem posed by the harmful impact of gall nematodes in greenhouse environments prompted research into their natural enemies—predatory fungi—a subject to which Tamara Vladimirovna Teplyakova (Andreeva) dedicated her entire scientific career. In the early 1970s, several species of predatory fungi—including some rarely found in the USSR—were discovered and identified in Siberia. Promising results were obtained at the Kirovets state farm in the Novosibirsk region during greenhouse trials of an experimental biological product based on the predatory fungus *Arthrobotrys oligospora* Fres., tested against the gall nematode on cucumber plants[25].

To maintain the high nematophagous potential of predatory fungi—using *Arthrobotrys oligospora* as a model—methods of stabilizing strain selection were employed; this is crucial for their industrial-scale cultivation. Overall, during the laboratory's period of operation, ten species of predatory hyphomycetes, differing in their nematophagous activity, were isolated from soils of the Middle Ob region[26]. Currently, Tamara Vladimirovna Teplyakova, Doctor of Science in Biology, works in the Mycology Laboratory of the Department of Biophysics and Environmental Research at the State Research Center of Virology and Biotechnology "Vector" (Rospotrebnadzor) in the science city of Koltsovo, Novosibirsk Region. Her productive work in this field has resulted in over 300 scientific publications, including monographs, educational and methodological materials, and patents [5–7].

Fatey Lavrentyevich Gushchin worked on developing nutrient media for predatory fungi and testing the resulting biopreparation samples in collaboration with T.V. Teplyakova; he successfully defended an original Candidate's dissertation on this subject[27].

Laboratory assistant Anatoly Mikhalev worked on another interesting and important area: the cultivation of gnotobiotic insects, which are essential for studying insect pathology and the mechanisms of interaction between

[21]*Rakshaina M.Ts.* Entomophthoralean fungi as pathogens of sucking pests in protected-ground cultivation // Protection of agricultural crops from pests and diseases in the conditions of Siberia. Novosibirsk, 1984, pp. 142–150.

[22]*Makhova N.M.* The role of entomophthoralean fungi as factors regulating aphid population densities in the Novosibirsk Region // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1980, Issue 1 (35), p. 9.

[23]*Baranov A.N., Karabatov P.A., Barannik T.A.* Influence of culture medium components on the growth and sporulation of *Entomophthora thaxteriana* Petch// Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1978, Issue 30, pp. 32–36.

[24]*Lobanova N.V., Rakshaina M.Ts., Shternshis M.V.* Production and application of Pyriformin for protecting greenhouse vegetables against pests. Novosibirsk, 1989, 22 p.

[25]*Andreeva T.V.* Predatory fungi in the control of root-knot nematodes on cucumbers // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1975, Issue 9, pp. 24–27.

[26]*Teplyakova T.V.* On the mycoflora of predatory fungi in the Novosibirsk Region // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1976, Issue 16, pp. 51–53.

[27]*Gushchin F.L.* Calculation of nutrient medium components for inducing ring formation in predatory fungi // Microbiological Plant Protection Agents: Collection of Scientific Papers. Novosibirsk, 1986, pp. 96–99.

commensal and pathogenic microflora—both with each other and with the host organism. He developed a method for rearing gnotobiotic insects on an artificial nutrient medium. Rearing germ-free *Galleria mellonella* larvae over multiple generations demonstrated that the microorganisms-free insects developed successfully on an artificial nutrient medium, completed their life cycle, and laid viable eggs[28]. Based on the results of his work, A.I. Mikhalyov prepared a good PhD dissertation, but, according to V.V. Guliy's recollection, he refused to defend it.

The originality and novelty of the research results are largely due to the lab having modern equipment, including a scanning electron microscope, which was maintained by a highly skilled electronic engineer, Yuri Petrovich Bukharov. The use of electron microscopy in the study of viruses, nematodes, and other microscopic objects significantly complemented the information obtained through light microscopy. Yuri Petrovich actively participated in the development and evaluation of the technologies for preparing and mounting specimens of the studied objects on the microscope stage[29].

The laboratory staff also included qualified research technicians who performed a vast amount of work maintaining museum cultures of microorganisms and conducting laboratory and field trials, and who made a significant contribution to the implementation of biological control methods. Valentina Petrovna Schneider, Valentina Anisimovna Gorshkova, Sergey Moshegov (laboratory assistant, graduate student), Galina Fedorova, Galina Grigorievna Sychuzhnikova, Ekaterina Vladimirovna Malomalenko, Anna Borisovna Fefilaktova, Vera Zabelina worked in the laboratory.

The effectiveness and priority status of research aimed at improving microbiological pest control methods are evidenced by the fact that the biological control laboratory obtained four inventor's certificates between 1976 and 1981. In 1975, the laboratory received its first two USSR inventor's certificates for methods of producing viral insecticides. In 1978, an inventor's certificate was obtained for a method of producing a bacterial insecticide, followed in 1981 by a patent for a "Liquid entomopathogenic mixture." Achieving such significant results was largely facilitated by the 1970 establishment—based on the museum laboratory—of a collection of microorganism cultures comprising various strains of entomopathogenic viruses, bacteria, and microsporidia, as well as entomopathogenic and nematophagous fungi useful for biological control methods. Subsequently, the collection was continuously expanded through the isolation of pathogens from natural pest populations and the exchange of microbial strains with other institutions[30]. Collaborative ties were established with Novosibirsk-based institutes of the Siberian Branch of the USSR Academy of Sciences (Institute of Biology, Institute of Cytology and Genetics, Novosibirsk Institute of Organic Chemistry, Institute of Chemical Kinetics and Combustion), as well as with institutes of all-Union significance—such as the All-Union Institute of Biological Plant Protection (Kishinev) and the All-Union Institute of Plant Protection (Leningrad), among others.

To disseminate the results of the research work, conferences of various levels addressing biological plant protection methods were organized and held at the institute with the direct participation of laboratory staff. For instance, in

[28]*Mikhalev A.I.* Production of gnotobiotic insects, using the greater wax moth *Galleria melonella* L. as an example // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1978, Issue 30, pp. 45–46.

[29]*Shiabova T.N., Bukharov Yu.P.* Methods for preparing specimens of female root-knot nematodes for examination under a scanning electron microscope // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1982, Issue 25, pp. 42–44.

[30]*Guliy V.V., Rakshaina M.Ts.* Culture collections of microorganisms pathogenic to plant pests at the Siberian Research Institute for the Chemicalization of Agriculture // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1978, Issue 30, pp. 5–9.

1985, the Siberian Branch of VASKhNIL hosted an All-Union conference on microbiological control methods, which brought together participants from various regions of the country.

During the period when V.V. Guliy headed the laboratory—from its inception until 1980—staff members published over 40 papers in leading scientific journals, such as "Izvestiya SB AS SSSR", "Siberian Herald of Agricultural Science", "Problems of Virology", "Agricultural Biology", and others. In 1981, the Siberian Branch of the "Nauka" publishing house released the monograph "Microorganisms Useful for Biological Control" by V.V. Guliy, T.V. Teplyakova, and G.M. Ivanov[31], In 1982, the book "Microbiological Control of Harmful Insects" by V.V. Guliy, G.M. Ivanov, and M.V. Shternshis was published by the Moscow publishing house "Kolos"[32].

Maryana Nikolaevna Aleeva and Lyubov Nikiforovna Chukanova advanced the use of entomophages and acariphages in plant protection. They conducted observations and experiments to determine the impact of entomophages on the population dynamics of aphids, dusky stink bugs, and lepidopteran pests affecting cabbage and other crops, and studied the feeding habits and lifespans of predatory ground beetles and parasitic insects.

In 1971, a group of entomologists led by M.N. Aleeva (Candidate of Science in Biology) organized the mass rearing of the predatory mite phytoseiulus—intended to combat spider mites—at the Kirovets state farm in the Novosibirsk Region, in collaboration with the farm's specialists and the regional plant protection station. In the process, the rearing method for the acariphage was modified (adapted), enabling more efficient use of the experimental area and rationalization of labor costs. Using this method, 5,000–6,000 predators were collected daily from 5 m² of the crop, allowing for the colonization of 1,000 m² of greenhouse space infested with spider mites[33]. The species composition of spider mite acariphages on horticultural crops has been studied, with the predatory beetle stethorus emerging as a promising species. The phenology of stethorus under Western Siberian conditions was investigated, and trials to assess its voracity were conducted on raspberries in 1972.

L.N. Chukanova studied the complex of entomophages associated with the frit fly. *Spalangia fuscipes* Nees was the most common among them. The biological characteristics of this ectoparasite were investigated under both laboratory and natural conditions in Siberia[34]. A methodology has also been developed for rearing parasites of the frit fly—trichomalus and eucoila—under laboratory conditions[35].

A complex of entomophages targeting lepidopteran pests—comprising both parasitic and predatory species—has been identified on vegetable crops, particularly cabbage[36]. Currently, there is interest in information regarding the predatory bug *Picromerus bidens* L., which, according to data from 1974, actively destroyed caterpillars on cabbage.

Between 1970 and 1973 alone, more than 150 species of entomophages and acariphages

[31] *Guliy V.V., Teplyakova T.V., Ivanov G.M.* Microorganisms useful for biological control methods. Novosibirsk: Nauka, 1981, 256 p.

[32] *Guliy V.V., Ivanov G.M., Shternshis M.V.* Microbiological control of harmful insects. Moscow: Kolos, 1982, 272 p.

[33] *Aleeva M.N., Baranov A.N.* On the methodology for the mass rearing of phytoseiulus. Biological methods for the control of agricultural crop pests // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1976, Issue 16, pp. 66–70.

[34] *Chukanova L.N., Spichenko L.N.* Entomophage of the frit fly // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1972, Issue 1–2, pp. 22–24.

[35] *Chukanova L.N.* Methodology for rearing larvae of parasites of the frit fly under laboratory conditions // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1973, Issue 6, pp. 13–15.

[36] *Aleeva M.N., Chukanova L.N.* Entomophages of lepidopteran pests of cabbage in Western Siberia// Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1976, Issue 18, pp. 28–31.

suppressing the populations of cereal and vegetable crop pests were identified, many of which were considered highly promising for use in biological control[37]. Subsequently, this research was continued by staff members in the Laboratory of Agricultural Entomology.

In 1980, SibNIIKhim was reorganized into SibNIIZKhim—the Siberian Research Institute of Agriculture and Chemicalization of Agriculture. Following V.V. Guliy's departure for Kishinev at the invitation of VNIIBZR, the laboratory was led for a time by T.V. Teplyakova, and from 1983 to 1992, it was headed by M.V. Shternshis.

In the 1980s, research on the biocontrol method also paid significant attention to searching for entomopathogenic microorganisms and screening effective strains, studying the biology and interaction mechanisms of entomopathogenic microorganisms with their hosts, developing production technologies and application methods for plant protection, creating formulations, conducting field and production trials of bioproducts, and developing usage standards for biological plant protection products for the conditions of Western Siberia.

M.V. Shternshis worked on improving the preparative forms of bacterial and viral products. This series of her work culminated in the defense of her doctoral thesis entitled "The factors for optimizing entomopathogenic preparations for plant protection" in 1988. In 1990, the laboratory team was awarded a silver medal at the VDNKH for developing a new biopreparation called LEST, and in 1993, based on the patent obtained for this product, the State Committee for Science and Technology issued a license for its mass production.

Another area of the lab's work, still relevant today, is the use of activating additives to boost the effectiveness of biopreparations. To increase the efficiency of entomopathogens, copper and magnesium sulfates were used—substances that enhance the ability of the PT main active ingredient (the protein delta-endotoxin) to disrupt oxidative phosphorylation and respiration processes in insect cells[38]. Substances that increase cell membrane permeability for biological macromolecules (dimethyl sulfoxide), substances that initiate chain free radical reactions (hydrogen peroxide, salts of divalent iron, etc.), and enzymes that break down the chitin molecules of insects and mites (chitinase) have also been tested as the activating additives for microbial insecticides[39].

Lyubov Anatolyevna Osintseva, who became a staff member of the biomethods laboratory in 1981, worked on microbiological protection of cabbage from a complex of leaf-eating pests. Together with Dmitry Alexandrovich Shtundyuk, she improved the technology for aerosol application of bacterial preparations. Using the example of treating cabbage with the biopreparation Lepidocide, a method was developed to control the distribution of bacterial spores and crystals on plants when using microbial aerosols, which made it possible to establish the optimal operating modes for aerosol generators[40]. Later on, L.A. Osintseva's scientific interests included studying and developing technology for trap crops in cabbage plantings to combat cruciferous flea beetles (1996). As a result of the completed research, recommendations were published titled "Protecting cabbage from pests, diseases, and weeds in the conservation areas of

[37]*Guliy V.V.* Main results and prospects for the biological control of insect pests of agricultural crops in Siberia and the Far East // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1976, Issue 16, pp. 13–19.

[38]*Sternshis M.V.* Improving the efficacy of microbiological control of pest insects. Novosibirsk, 1995. 194 p.

[39]*Sternshis M.V.* Enhancing the activity of entomopathogenic preparations // Agricultural Biology, 1983, No. 6, pp. 96–98.

[40]*Osintseva L.A.* A method for monitoring the distribution of bacterial spores and crystals on plants when using microbial aerosols // Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Products (SibNIIKhim), Novosibirsk, 1988, Issue 5, pp. 41–44.

the forest-steppe of Priobye"[41]. Lyubov Anatolyevna defended her candidate and doctoral dissertations on research topics in 1988 and 1998.

For a short time, Natalia Grigoryevna Vlasenko worked in the laboratory. She conducted research on the possibility of using biopreparations against rapeseed pests, studied the effects of biopreparations on the dietary needs of insect pests, and developed a method for trap crops[42]. In 1986–1987, N.G. Vlasenko and Oleg Venidiktovich Kulagin conducted the first laboratory and field experiments in Siberia to evaluate the impact of sublethal doses of Lepidocide and Bitoxibacillin on the feeding behavior of leaf-chewing pests affecting this crop. Subsequently, the results of years of research on protecting rapeseed from harmful organisms were summarized in a monograph [8].

In the late 1980s and early 1990s, I.V. Andreeva, O.G. Tomilova, and V.P. Tsvetkova—graduates of the Novosibirsk Agricultural Institute (now the Siberian State University of Engineering and Biotechnology)—joined the laboratory's research on microbiological control methods as PhD students under the supervision of M.V. Sternshis. Together with N.I. Ermakova and M.V. Sternshis, Vera Pavlovna Tsvetkova demonstrated the potential of the combined use of baculoviruses—specifically granulosis virus—and a bacterial preparation to control populations of the meadow moth[43]. Oksana Grigoryevna Tomilova has developed an expert system for protecting cabbage against pests and identified opportunities for its improvement[44]. Irina Valeryevna Andreeva investigated the microbiological control of the common spider mite in protected-ground conditions and methods for enhancing the efficacy of biopesticides through the use of tank mixtures of multiple microbial pathogens, the combined application of biopesticides with entomophages and acariphages, and the use of activating additives that boost the action of microbial agents[45]. The research conducted resulted in the successful defense of Candidate of Science dissertations by these staff members in 1993, 1995, and 1996, respectively.

In 1992, a redistribution of scientific personnel took place. A group of staff members from SibNIIZKhim, led by M.V. Shternshis, transferred to Novosibirsk State Agrarian University, where they continued their research in the field of biological plant protection alongside their teaching duties. In 1996, the Department of Biological Plant Protection was established within the Faculty of Plant Protection; M.V. Shternshis became its head and the leader of the research program on biological control methods. Subsequently, as research in this field expanded with the active participation of department staff, graduate students, and undergraduates, a scientific school dedicated to biological plant protection in Siberia was established—one that remains productive to this day. Its success is evidenced by the emergence of new specialists in the field of biological plant protection—including Candidates and Doctors of Science—as well as the publication of world-class articles [9–13], monographs [4, 14–16], industry recommendations, teaching aids, and a textbook used in the educational process. The most significant among them are: "Increasing the efficiency of microbiological control of harmful insects" (M.V. Shternshis, 1995), the series of study guides "Biological preparations in plant protection" (M.V. Shternshis, I.V. Andreeva, O.G. Tomilova, F.S.-U. Dzhalilov, 2000), and "Ento-

[41] *Osintseva L.A., Sychuzhnikova G.G.* Protection of white cabbage against pests, diseases, and weeds in environmentally sensitive cultivation zones of the Ob region forest-steppe: recommendations. Novosibirsk, 1995, 20 p.

[42] *Vlasenko N.G., Kulagin O.V.* Trap crops in a rapeseed field // Plant Protection, 1993, No. 6, p. 48.

[43] *Tsvetkova V.P.* The granulosis virus of the meadow moth as the basis for a pest-control preparation: abstract of a dissertation for the degree of Candidate of Agricultural Sciences. Novosibirsk, 1993, 18 p.

[44] *Tomilova O.G., Shternshis M.V.* Expert system for protecting cabbage from pests // Plant Protection, 1993, No. 12, pp. 30–31.

[45] *Andreeva I.V., Shternshis M.V.* Microbiological preparations against spider mites in greenhouses // Plant Protection, 1995, No. 11, pp. 41–42.

mophages in plant protection" (A.S. Babenko, M.V. Shternshis et al., 2001), "Biotechnology in plant protection" (M.V. Sternshis, O.G. Tomilova, I.V. Andreeva, 2006) and the textbook "Biological plant protection" (M.V. Sternshis, F.S.-U. Dzhalilov, I.V. Andreeva, O.G. Tomilova, 2004). The new version—a substantially revised edition of this textbook released in 2018—is reprinted annually and is in demand among both students and plant protection specialists.

Work in the biological control laboratory served as a starting point for many of its staff members to achieve significant scientific breakthroughs and gain recognition for their contributions to the field of plant protection.

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Роль ученого в формировании экологического мировоззрения в сфере защиты растений

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Формирование каждой личности начинается в детские годы, а формирование профессиональных качеств – в период обучения в вузе как необходимой части подготовки специалистов. Хорошо сформированная профессиональная идентичность помогает студентам развить осмысленное профессиональное понимание, что облегчает их переход к профессиональной деятельности и обеспечивает устойчивое развитие в этой области. Сфера деятельности выпускников по специальности «Защита растений» – динамично развивающаяся область защиты растений от различных вредных организмов (вредителей, болезней и сорняков). На протяжении всего этапа своего становления защита растений претерпевала значительные изменения, связанные как со всеобщим прогрессом, так и с экономическими и социальными изменениями в обществе. В настоящее время пришло понимание необходимости выбора экологического пути развития сферы защиты растений и перехода от интенсивного применения химических пестицидов к рациональным методам, предполагающим использование прежде всего безопасных для человека, животных и окружающей природной среды методов, которые направлены не на полное уничтожение, а на объективное регулирование численности вредных объектов. Очень важно, чтобы в эти годы рядом были наставники, которые могут увлечь и, в хорошем смысле этого слова, заразить идеями бережного, рационального и экологически безопасного вмешательства в живую оболочку планеты. На факультете защиты растений в конце XX в. сложился коллектив единомышленников, пропагандирующих биологическое направление защиты растений, сформировалась научная школа под руководством профессора, доктора биологических наук Маргариты Владимировны Штерншис. Практически всю свою профессиональную деятельность Маргарита Владимировна посвятила изучению, созданию и внедрению в производство биологических агентов регуляции численности фитофагов и фитопатогенов. Многим своим коллегам она открыла путь в большую науку – под ее научным руководством были проведены различные исследования, написаны диссертации на соискание ученой степени доктора и кандидата наук.

Ключевые слова: биологическая защита растений, макро- и микробиологические агенты, научная школа, экологическое мышление

The role of a scientist in shaping an ecological worldview in the field of plant protection

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Personal development begins in childhood, and the development of professional skills begins during the acquisition of knowledge in a chosen specialty at university as a necessary part of specialist training. A well-developed professional identity helps students develop a meaningful professional understanding, facilitating their transition to professional activity and ensuring sustainable development in this field. The field of work for graduates of the Faculty of Plant Protection is the dynamically developing field of plant protection against harmful organisms (pests, diseases, and weeds). Throughout its entire development stage, plant protection underwent significant changes related both to general progress and to economic and social changes in society. Currently, there is an understanding of the

ecological path of development of plant protection and a transition from the intensive use of chemical pesticides to rational methods using, first of all, the methods that are safe for humans, animals and the environment, which are aimed not at complete destruction, but at the objective regulation of the number of harmful objects. It is crucial to have tutors nearby during these years who could inspire and, in the best sense of the word, and infect with their ideas of careful, rational, and environmentally safe interventions in the living shell of the planet. At the Faculty of Plant Protection at the end of the 20th century, a team of like-minded people promoting the biological direction of plant protection was formed, and a scientific school was established under the leadership of Professor, Doctor of Science in Biology Margarita Vladimirovna Shernshis. Margarita Vladimirovna has devoted most of her entire professional career to the study, creation, and implementation in production of biological agents for regulating the population of phytophages and phytopathogens. She opened the path to big science for many of her colleagues – under her scientific guidance, various studies were conducted, and dissertations for the degree of Doctor and Candidate of Sciences were written.

Keywords: biological plant protection, macro- and microbiological agents, scientific school, ecological thinking

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Anniversaries always stir up memories, for it is impossible to build the future without the past…

In 1962, the first group of students was admitted to the Plant Protection Faculty at the Novosibirsk Agricultural Institute (NSKhI), and graduates received the qualification of a "research agronomist in plant protection". This government decision became a response to the catastrophic shortage of specialists in this field amidst the threat of epidemics and mass infestations of agricultural pests. In those years, in our country, the strategy for protecting plants from harmful organisms was based on using agricultural techniques and the intensive use of chemical agents. By the way, most land users follow this strategy, and currently, with active support from chemical pesticide manufacturers and dealers selling pesticides.

In Russia, an ecological approach to plant protection 'emerged' in the 1960s–70s and then further developed. At present, agriculture is actively adopting biologically based and environmentally safe technologies to produce eco-friendly crop and livestock products. It became clear how effective and beneficial a biological system for plant protection and nutrition can be. Unfortunately, so far the use of biological protection methods is mainly carried out in greenhouse conditions and, partially, in vegetable and fruit growing. However, this method is gradually becoming more and more

important in integrated plant protection and in implementing organic farming approaches.

Since 1980, Associate Professor of the Entomology Department, Candidate of Science in Agriculture Alexander Vasilyevich Shtundyuk has been teaching the course "Biological Plant Protection" at the Faculty of Plant Protection at NSKhI.

In 1992, Doctor of Biological Sciences Margarita Vladimirovna Shternshis was invited to work at the faculty. She had previously headed the biomethod laboratory at the Siberian Branch of VASKhNIL. Almost her entire professional career, Margarita Vladimirovna has been dedicated to studying, developing, and implementing biological agents to regulate the populations of phytophages and phytopathogens.

By that time, M.V. Shternshis was already a scientist of international renown: a member of the East Palaearctic Regional Section of the International Organization for Biological Control of Noxious Animals and Plants, the International Society for Invertebrate Pathology, the Russian Entomological and Russian Microbiological Societies (chair of the Siberian branch), the International Organization for Biological Plant Protection, and the Interdepartmental Commission of the Russian Academy of Agricultural Sciences on Microbiological Plant Protection Agents.

Margaryta Vladimirovna has opened the path to big science for many of her colleagues – under her scientific guidance, various studies were carried out, and dissertations were written for doctoral degrees (L.A. Osintseva, A.A. Belyaev) and candidate degrees (V.P. Tsvetkova, I.V. Andreeva, T.V. Shpatova, E.I. Shatalova). Nowadays, they teach at their alma mater and continue to conduct research in the field of biological regulation of harmful organisms.

Vera Pavlovna Tsvetkova's research work is dedicated to the biological control of the population of various phytophagous insects, including the meadow moth (*Loxostege sticticalis* L.), Colorado potato beetle (*Leptinotarsa decemlineata* Say), Italian locust (*Calliptamus italicus* L.), twospotted spider mite (*Tetranychus urticae* Koch.), codling moth (*Carpocapsa pomonella*), using micro- and macrobiological methods[1-10] [1, 2]. Research was also carried out to assess the multifunctional effects of microbiological agents (strains) and their combinations on different varieties of field and vegetable crops, as well as on introductions [3–10]. V.P. Tsvetkova has written more than 140 scientific papers and 46 educational-methodical works, and she is a co-author of two Russian patents.

[1]*Tsvetkova V.P.* The granulosis virus of the meadow moth as the basis for a pest-control preparation: Diss. … Candidate of Agricultural Sciences. Novosibirsk, 1993, 183 p.

[2]*Sternshis M.V., Ermakova N.I., Tsvetkova V.P.* Natural zeolites as carriers for a viral entomopathogenic preparation // Siberian Journal of Ecology, 1997, No. 6, pp. 585–588.

[3]*Tsvetkova V.P.* Specifics of Colorado potato beetle development in Siberia and the control of its population size // Biological Plant Protection: Achievements, Challenges, and Prospects: Conference Proceedings, Poznań, 2013, pp. 108–110.

[4]*Shternshis M., Tsvetkova V.* Comparison of some preparations for the control of Siberian population of Colorado beetle // Information Bulletin EPRSIOBC, 2007, N 37, pp. 21–24.

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[6]*Serebrov V.V., Khodyrev V.P., Gerber O.N., Tsvetkova V.P.* Prospects for the combined use of entomopathogenic fungi and chemical insecticides against the Colorado potato beetle (Leptinotarsa decemlineata) // Mycology and Phytopathology, 2005, vol. 39, No. 3, pp. 89–98.

[7]*Sternshis M.V., Tsvetkova V.P.* Microbiological method for the control of locusts // Plant Protection and Quarantine, 2002, No. 6, pp. 26–27.

[8]*Duzhak A.B., Salganik R.I., Shternshis M.V., Ermakova N.I., Tsvetkova V.P., Andreeva I.V., Kushnikova T.A.* The effect of a chitinase enzyme preparation on the efficacy of biological pest control // Siberian Journal of Ecology, 1995, No. 5, pp. 457–461.

[9]*Poddubnaya E.N., Tsvetkova V.P., Ismailov V.Ya., Zhuravlev S.V.* Pheromone monitoring of the codling moth as a basis for pest control measures in orchards of Western Siberia // Bulletin of the Novosibirsk State Agrarian University. 2008, No. 1 (7), pp. 12–22.

[10]*Tsvetkova V.P., Poddubnaya E.N., Glushak O.N.* Ecological aspects of the regulation of dangerous phytophagous pest populations in Siberia // Biological Plant Protection – The Basis for Stabilizing Agroecosystems: Proceedings of a Scientific and Practical Conference (Krasnodar, Sept. 29 – Oct. 1, 2004). Krasnodar, 2004, Issue 3, pp. 32–34.

Students always take an active part in experimental work (both lab and field). Under the scientific guidance of V.P. Tsvetkova, four of them continued their research careers after their studies and defended their PhD theses: E.N. Poddubnaya ("Improvement of the techniques and methods for controlling the codling moth on apple trees based on monitoring in the Baraba forest-steppe", 2007), N.S. Chulikova ("Biological characteristics of the Colorado potato beetle and potato protection from this phytophage in the forest-steppe of the Novosibirsk Priobye", 2013), A.A. Zenkova ("Improvement of biotechnology for the predatory mite *Phytoseiulus persimilis* Ath.-H. – a spider mite acariphage", 2019), V.S. Maslennikova ("Multifunctional effects of *Bacillus thuringiensis* strains on potatoes", 2023).

V.P. Tsvetkova continues scientific research in the field of ecological regulation of phytophagous insects and phytopathogens, involving undergraduates, master's students, and postgraduates in the work, and promoting through teaching the positive results of implementing the biological method in plant protection.

Irina Valeryevna Andreeva's scientific interests include studying the effectiveness of biopreparations and entomophages used to protect crops from pests, as well as ways to improve the biological control of phytophage populations. She is the author of more than 130 scientific papers and 20 educational-methodical works, and co-author of 5 Russian patents [11–14]. Currently, I.V. Andreeva heads the laboratory of biological control of phytophages and phytopathogens at the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences and continues research in the field of finding, developing, and implementing promising bioagents for controlling harmful organisms, involving students and graduate students in the work.

The research career of Tatyana Vladimirovna Shpatova—an Associate Professor and Candidate of Science in Agriculture—began under the guidance of M.V. Sternshis and A.A. Belyaev. She is currently engaged in studying biological agents and developing pest-control products based on them for use on berry crops, which serve as a primary source of vitamins in the Siberian climate [15–17]. Years of collaborative work with the country's leading research institution in the field of biological plant protection—the Federal Scientific Center for Biological Plant Protection (FSBSI FSCBPP, Krasnodar)—conducted under the leadership of A.M. Asaturova, have made it possible to scientifically evaluate the efficacy of biological preparations and agents under Siberian conditions in comparison with southern Russia [18, 19].

In 1996, the Federal Educational and Methodological Association gave the faculties of Russian universities the opportunity to independently develop specialization programs. The faculty team embraced this news with great enthusiasm. In the end, programs were prepared for four specializations, one of which was "Biological Plant Protection" created by M.V. Sternshis along with her students and followers. This marked the beginning of a new ecology-focused department—the Department of Biological Plant Protection—as well as a scientific laboratory for biological plant protection and biotechnology. The intake for this specialization was always intense and based on serious competition. Many students who studied in this specialization went on to complete graduate school and defend their PhD dissertations: T.V. Shpatova, L.A. Ovchinnikova, O.G. Tomilova, M.A. Vaskin, A.S. Korobeinikov, E.I. Shatalova, A.A. Lelyak, and others. Under Margarita Vladimirovna's scientific guidance, a total of 14 dissertations for the Candidate of Sciences degree and 5 doctoral dissertations were defended (L.K. Kameneck, G.V. Barayshchuk,

N.I. Ermakova, L.A. Osintseva, A.A. Belyaev).

As part of the advanced course programs developed by M.V. Sternshis and colleagues — "Insect Pathology", "Entomophages and Biopreparations", "Bioactive Substances", and "Regulation of Harmful Species" — students gained in-depth knowledge in the field of biological plant protection. During this period, the department staff also prepared the textbook "Biological Plant Protection" (2004, 2018)[11], as well as textbooks recommended by the Ministry of Agriculture of the Russian Federation for university students conducting training in agronomic specialties: "Entomophages in plant protection" (2001; the team of authors was awarded a diploma of the II degree of the Department of Personnel Policy and Education of the Russian Federation)[12], "Biopreparations in Plant Protection" (2003)[13], "Biotechnology in Plant Protection" (2006; The team of authors was awarded the third-degree diploma of the All-Russian competition "Agricultural Educational Book – 2007"[14].

The listed textbooks have become fundamental, and now students at agricultural universities in Russia study them. The textbook "Biological Plant Protection" covers the theoretical foundations of biological plant protection; it shows practical use of methods for environmentally safe suppression of pest populations, and describes the main agents of biological control of pests, diseases, and weeds in crops (microorganisms, entomophages and acariphages, biologically active substances); an assessment of the current level of development in biological plant protection is given; the increasing role of biological methods in integrated plant protection, which best meet the goals of environmental and human health protection, is shown. This textbook is republished every year and is used not only for teaching students but also by practicing agronomists.

In 2010, in the biographical directory "Who's Who in the World" (England), M.V. Sternshis was recognized as a scholar who demonstrated outstanding achievements and made a significant contribution to improving modern society. Margarita Vladimirovna promoted the use of bioagents in her work as an environmentally safe method for controlling pest populations and regularly took part in regional, all-Russian, and international conferences, meetings, forums, and symposia, actively involving her students, graduate students, and colleagues.

In 2010, M.V. Sternshis's monograph "Entomopathogens – the Basis for Biopreparations to Control Phytophage Populations" was published[15], in 2015 – the monograph "Microbiological Control of Phytophage Numbers" (co-authors: V.P. Tsvetkova, I.V. Andreeva) [20]. The books highlight the role of natural enemies (infectious diseases) in controlling the number of agricultural pests. In 2016, a collective monograph titled "Biopreparations Based on *Bacillus* Bacteria for Managing Plant Health" was published (co-authors: A.A. Belyaev, V.P. Tsvetkova, T.V. Shpatova, A.A. Lelyak, S.A. Bakhvalov) [21]. This scientific work is a summary of many years of research on evaluating the potential use of new strains *Bacillus thuringiensis*, *Bacillus subtilis* and their combinations against various harmful objects of agricultural crops.

The works of M.V. Shtternshis make a significant contribution to the development of the theoretical foundations of biological plant

[11]Biological Plant Protection: A Textbook for Higher Education Institutions / M.V. Shternshis, F.S.U. Dzhalilov, I.V. Andreeva, O.G. Tomilova. Moscow, 2004, 264 p.

[12]Entomophages in Plant Protection: A Textbook / A.S. Babenko, M.V. Shternshis, I.V. Andreeva, et al. Novosibirsk, 2001, 205 p.

[13]Biological Preparations in Plant Protection: A Textbook / M.V. Shternshis, F.S.U. Dzhalilov, I.V. Andreeva, O.G. Tomilova. Novosibirsk, 2003, 128 p.

[14]Biotechnology in Plant Protection: A Textbook / M.V. Shternshis, O.G. Tomilova, I.V. Andreeva. Novosibirsk, 2006, 199 p.

[15]*Sternshis M.V.* Entomopathogens as the basis for biological preparations for controlling phytophagous pest populations. Novosibirsk, 2010, 160 p.

protection and the creation of technologies for the use of microbiological agents[16]. Under her scientific supervision, colleagues carried out research funded by the Russian Ministry of Agriculture. In addition, for the first time among agricultural universities, she won a grant under the Federal Program "Optimization of the creation and use of biopreparations for plant protection with multifunctional properties", with which, over three years, the department staff (M.V. Sternshis, A.A. Belyaev, V.P. Tsvetkova, T.V. Shpatova) conducted research with active participation from students [22, 23].

For many years at the Novosibirsk branch of the All-Russian Scientific Research Institute of Biological Plant Protection (now FSBSI FSCBPP, Krasnodar), Margarita Vladimirovna led scientific research in the field of biological plant protection. Since 2008, she has been overseeing contract-based work with RPC "Research Center" (Koltsovo, Novosibirsk region) on testing the antagonistic properties of bioagents and proving their protective effects in field conditions on fruit, berry, vegetable, field, and decorative crops [24–30].

When transitioning to the two-level higher education system (bachelor's and master's), M.V. Shtjernshis developed her own master's program, which also turned out to be very popular with students. Later on, this program was led by Doctor of Science in Agriculture, Professor Anatoly Arkadyevich Belyaev. Under his guidance, students and graduate students conducted laboratory and test studies of the anti-stress, antagonistic, and growth-stimulating properties of biological agents, as well as tested the effectiveness of their protective action in the cultivation technologies of fruit, berry, and ornamental flower crops. In 2010, based on the results of many years of research, A.A. Belyaev defended his dissertation for the degree of Doctor of Science on the topic "Protection of raspberries from the raspberry cane midge and stem mycoses in Western Siberia"[17].

The main focus of A.A. Belyaev's scientific work is the biological justification and development of protection measures for fruit and berry crops. He has published over 200 scientific and educational-methodical works, including the monograph "Red Raspberry in the forest-steppe of Priobye"[18] and "Biopreparations based on *Bacillus* bacteria for managing plant health" [21], scientific and practical guide "Diseases and pests of garden crops of the Novosibirsk Region"[19], "Gardener and vegetable grower's handbook"[20], 12 recommendations for production. A.A. Belyaev is the author of six patents and certificates of authorship, five varieties of cultivated raspberries, and four technologies for growing and protecting fruit and berry crops from pests and diseases, approved by the Scientific and Technical Council of the Department of Agro-Industrial Complex of the Novosibirsk Region. The research results have been implemented in production and are used in the technological processes of horticultural farms in Siberia, other regions of Russia, and abroad.

Currently, a student and follower of Margarita Vladimirovna Shternshis – Doctor of Science in Biology, Professor Ivan Mikhailovich Dubovsky – continues to oversee the master's program in "Agrobiotechnology in plant protection"', adding his own new courses to it: "Methods of research in plant protection" (Prof. I.M. Dubovsky), "Biological foundations of

[16]*Tsvetkova V.P., Maslennikova V.S., Shternshis M.V.* Effect of the entomopathogenic fungus *Beauveria bassiana* Bals. Vuil. on the Colorado potato beetle *Leptinotarsa decemlineata* Say (Coleoptera: Chrysomelidae) in the Novosibirsk Region // Proceedings of the XV Congress of the Russian Entomological Society (Novosibirsk, July 31 – Aug. 6, 2017). Novosibirsk, 2017, pp. 522–523.

[17]*Belyaev A.A.* Protection of raspberries against the raspberry cane midge and stem-infecting fungal diseases in Western Siberia: abstract of a dissertation for the degree of Doctor of Agricultural Sciences. Novosibirsk, 2010, 48 p.

[18]*Belykh A.M., Baklanova G.I., Belyaev A.A.* Red raspberry in the forest-steppe of the Ob Region. Novosibirsk, 2004, 128 p.

[19]Diseases and pests of garden crops in the Novosibirsk Region: a scientific and practical guide to diagnosis, prevention, and protective measures / A.A. Belyaev, A.M. Belykh, V.P. Tsvetkova, et al. Novosibirsk, 2013, 127 p.

[20]Combating pests and diseases in gardens and vegetable plots: a reference book for gardeners and vegetable growers / L.P. Berger, V.N. Sorokopudov, E.A. Melkumova, et al. Novosibirsk, 1997, pp. 496–534.

plant health management" (Prof. A.A. Belyaev), "Technology for producing entomophages and biologically active substances" (Assoc. Prof. A.A. Zenkova), "Insect physiology and pathology" (Assoc. Prof. E.I. Shatalova).

Since 2017, the Laboratory of Biological Plant Protection and Biotechnology, led by I.M. Dubovsky, has been working on developing a bio-method. The lab staff focus on creating and improving biological products based on fungal and bacterial pathogens to protect plants from insect pests. The synergistic effect of *Bacillus thuringiensis* spores and toxins on the mortality of the Colorado potato beetle has been studied [31]. Increased effectiveness of entomopathogenic bacteria and fungi has been shown when used together with nanoparticles against the Colorado potato beetle [32]. The increased virulence of the fungus *Metarhizium robertsii* has been proven when used together with antisense DNA against the spider mite [33].

Research is also being conducted to study the mechanisms of insects developing resistance to biological insecticides based on *Bacillus thuringiensis* bacteria and fungi from the *Metarhizium* and *Beauveria* genera. Epigenetic changes and the main mechanisms of insect resistance to bacterial infection have been identified [34, 35]. The exceptional role of nonspecific esterases in insect resistance to *Bacillus thuringiensis* has been shown [36]. The development process of the fungus *Metarhizium brunneum* in the insect cuticle, as well as the insect response to infection, has been studied [37]. The role of a metalloproteinase inhibitor in insect sensitivity to fungal infection has been noted [38].

Increasing the virulence of entomopathogenic fungi and bacteria through passages in insects and genetic engineering methods is one of the research directions. A comparison was made of the life cycle strategies of *Bacillus thuringiensis* bacteria in resistant and susceptible insect populations [39]. The virulence and expression of *Bacillus thuringiensis* virulence factor genes were studied under different cultivation conditions [40].

Review articles and book chapters have been prepared on modern methods of genetic modification of plants, the role of fungal pathogens in the development of biomethods, and the physiological response of insects to the development of fungal infections [41–43].

In 2018, an RSF grant for “Microevolutionary transformations in the parasite-host system: the formation of insect defense reactions and attacking mechanisms of entomopathogens during coevolution” was awarded, as well as the Russian President's grant for “Bionanoinsecticides based on entomopathogenic microorganisms” (work on the grants was carried out under the scientific supervision of I.M. Dubovsky).

In 2019, Candidate of Science in Biology and the leading researcher at the Laboratory of Biological Plant Protection and Biotechnology, Ekaterina Valeryevna Grizanova, was awarded the President of the Russian Federation’s Prize in Science and Innovation for young scientists for discovering new mechanisms of resistance of agricultural and forest pest insects to *Bacillus thuringiensis*-based bioinsecticides.

Since 2014, the faculty/department team has been actively collaborating with the SB RAS (Institute of Animal Systematics and Ecology, Institute of Organic Chemistry, Institute of Cytology and Genetics, Central Botanical Garden) and SB RASHN (SibNIIRS, Siberian Physical and Engineering Institute of Agrarian Issues, Novosibirsk Zonal Fruit and Berry Experimental Station named after I.V. Michurin, SibNIISKhim, Siberian Research Institute of Fodder Crops, Soy Research Institute (Khakassia), SFSCA RAS). Students from the faculty have done their pre-graduation internships at these scientific organizations.

The department teachers are constantly improving and updating the teaching and methodological resources, publishing monographs, textbooks, and methodological guidelines, in-

cluding those approved by the Academic Methodological Association and the Ministry of Agriculture of the Russian Federation.

Despite all the difficulties in promoting the biopesticides and entomophages market (farmers' distrust and lack of knowledge to work with bioagents, the long latent period of bioagents, insufficient stability, viability and resistance to adverse environmental conditions, lengthy government registration process, pricing policies), the demand for organic products is growing among the country's population and the international community. Therefore, further research is needed to improve the quality and achieve consistent effectiveness of biological agents, their production technologies, and optimal application in agriculture and forestry.

The continuity between generations continues. It's encouraging that young people are choosing an environmentally friendly approach to crop production, particularly in biological plant protection, now at a new, higher level using advanced technologies, modern equipment, and based on a deep understanding of the biochemical, physiological, and genetic mechanisms of pests' resistance to various infections.

The professionalism of the team at the Department of Plant Protection at the Siberian State University of Engineering and Biotechnology allows for highly skilled training of specialists in environmentally safe plant protection, of course, with proper attention from the Government to this promising area of the crop production industry.

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К истории защиты растений и изучения энтомофагов вредителей сельскохозяйственных культур в Западной Сибири

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Приведены краткая история становления защиты растений как науки начиная с 30-х годов XX в., а также история зарождения биологической защиты растений и одного из ее направлений – использования энтомофагов. До 1929 г. организацией и проведением оперативных мероприятий, наблюдений и научных исследований по защите растений занимались Бюро по энтомологии, Бюро по микологии и фитопатологии, Сибирское энтомологическое бюро, Губернские энтомологические бюро, станции защиты растений и сельскохозяйственные опытные станции, созданные в начале XX в. научные учреждения, и другие организации. Образование в 1929 г. ВАСХНИЛ, в 1969 г. – Сибирского отделения ВАСХНИЛ, а в его составе Сибирского научно-исследовательского института химизации сельского хозяйства (СибНИИХим) позволило значительно увеличить объемы теоретических и прикладных исследований по всем направлениям сельскохозяйственной науки, включая защиту растений, повысить методический уровень исследований за счет притока новых сотрудников, обеспечения приборами и оборудованием, совершенствовать координацию научно-исследовательской работы. СибНИИХим в том числе занимался вопросами усовершенствования химических мероприятий по защите растений на основе повышения экономичности, безопасности их для полезных организмов и исключения остатков пестицидов в сельскохозяйственной продукции, изучением естественных ресурсов энтомофагов на зерновых и овощных культурах и разработкой способов их использования в комплексных системах защиты растений. Для выполнения государственного задания в течение 1971 г. в СибНИИХиме наряду с лабораториями агрохимического направления, лабораториями гербицидов, фитопатологии организованы лаборатории биометода и сельскохозяйственной энтомологии. Приведена история изучения энтомофагов – вредителей сельскохозяйственных культур в Западной Сибири.

Ключевые слова: краткая история, защита растений, вредители, биометод, энтомофаги

On the history of plant protection and the study of entomophages of agricultural pests in Western Siberia

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A brief history of the development of plant protection as a science starting from the 1930s is presented, as well as the history of the emergence of biological plant protection and one of its directions – the use of entomophages. Until 1929, the organization and conduct of operational activities, observations, and scientific research on plant protection were carried out by the Entomology Bureau, the Mycology and Phytopathology Bureau, the Siberian Entomological Bureau, the Provincial Entomological Bureaus, plant protection stations and agricultural experimental stations, scientific institutions established at the beginning of the 20th century, and other organizations. The establishment in 1929 of VASKhNIL, in 1969 of the Siberian Branch of VASKhNIL, and within it of the Siberian Research Institute of Agriculture and Chemicalization of Agriculture (SibNIIKhim) made it possible to significantly increase the volume of theoretical and applied research in all areas of agricultural science, including plant protection, to raise the methodological level of research due to the influx of new staff, provision of instruments and equipment, and to improve the coordination of research work. SibNIIKhim, among other things, dealt with the issues of improving chemical measures for plant protection based on increasing their cost-effectiveness, safety for beneficial organisms, and eliminating

pesticide residues in agricultural products, studying the natural resources of entomophages in grain and vegetable crops, and developing methods for their use in integrated plant protection systems. In order to fulfill the state assignment during 1971, alongside the laboratories of the agrochemical direction, herbicide laboratories, and phytopathology laboratories, SIBNIIKhim organized laboratories of biometry and agricultural entomology. The history of the study of entomophages of agricultural crop pests in Western Siberia is provided.

Keywords: brief history, plant protection, pests, biomethod, entomophages

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In the European part of the Russian Empire, the Scientific Committee established in 1837 under the Ministry of State Property, which was transformed in 1894 into the Ministry of Agriculture and State Property, was responsible for spreading agronomic knowledge among peasants and teaching methods to combat agricultural pests. To separate research and administrative tasks, various bureaus were created under the Scientific Committee: in 1894 – the Bureau of Entomology, headed by I.A. Porchinsky, and in 1907 – the Bureau of Mycology and Phytopathology (A.A. Yachevsky)[1]. By 1914, provincial entomological bureaus had been established in various regions of the European part of Russia.

As agriculture developed in Siberia, with a main focus on producing commercial grain, questions also arose about protecting crops from harmful organisms. To address these issues, the Siberian Entomological Bureau was established in Omsk in 1918–1919, and Provincial Entomological Bureaus were set up in Tomsk and Barnaul[2]. From that time, systematic work on plant protection began, which included organizing and carrying out operational activities, monitoring, and scientific research.

Primarily based on entomological bureaus, in 1922 plant protection stations (STAZR) were set up in Omsk, Tomsk, Barnaul, and Irkutsk (see footnote 2). In 1925, based on the resolutions of the Presidium of the All-Russian Central Executive Committee (VTsIK), the provincial administrative-territorial system was abolished and the Siberian Krai was established[3]. In the same year, the Siberian Regional Plant Protection Station was established in Novonikolayevsk. A little later, a plant protection station was opened in Krasnoyarsk.

On June 25, 1929, the Council of People's Commissars of the USSR issued a decree on the establishment of the All-Union Academy of Agricultural Sciences named after V.I. Lenin. This date is considered the founding day of VASKhNIL. In November 1929, on the initiative of academician N.I. Vavilov, the All-Union Scientific Research Institute of Plant Protection (VIZR) was organized as part of VASKhNIL, becoming the leading scientific institution in this field. After the division of the Siberian Territory

[1]Agricultural Scientific Committee // Runiversalis Encyclopedia. URL: https://руни.рф/Сельскохозяйственный_ учёный_комитет#Положение_Ученого_комитета_в_1894-1905_гг.

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into Western and Eastern Siberia in 1930, the regional STAZRs were disbanded and the West Siberian STAZR was organized, becoming a branch of VIZR in Novosibirsk, while instead of the Irkutsk and Krasnoyarsk STAZRs, there was the East Siberian STAZR, reorganized in 1937 into the Irkutsk support point of VIZR.

The development of plant protection in Siberia was greatly helped by the establishment of scientific institutions: in Omsk in 1918 – the Siberian Agricultural Academy (later the Omsk Agricultural Institute named after S.M. Kirov), and in 1933 – the Siberian Research Institute of Grain Farming (since 1956 – the Siberian Research Institute of Agriculture). In 1935, the Novosibirsk Agricultural Institute was established, and in 1949 in Barnaul – the Altai Zonal Research Institute of Agriculture and Animal Husbandry (since 1956 – the Altai Research Institute of Agriculture). In 1956, based on the Kamalinsk State Breeding Station, the Krasnoyarsk Research Institute of Agriculture was established. Employees of these scientific institutions, Tomsk State University, STAZR, and agricultural experimental stations (AES) worked on various areas of plant protection. Within STAZR, alongside diagnostic and forecast labs for determining residual pesticide levels in agricultural products, labs for biological pest and disease control methods were also being set up.

On November 14, 1969, the Council of Ministers of the USSR issued Resolution No. 887 "On measures to create a research complex for the development of agriculture in Siberia and the Far East"[4]; this was intended to accelerate the pace of agricultural development, enhance the role of science in the development of the productive forces in these regions, and improve the coordination of research work. In accordance with the resolution, at the suggestion of the Ministry of Agriculture of the USSR, the Council of Ministers of the RSFSR, and VASKhNIL, a decision was made to establish the Siberian Branch of VASKhNIL near Novosibirsk. As part of this branch, along with other institutes, the Siberian Research Institute for the Chemicalization of Agriculture (SibNIIKhim) was established on the basis of the Novosibirsk VIZR station. Its first director was Oleg Alexandrovich Ivanov, Candidate of Biological Sciences (1970–1975). Initially, the institute's research units were located in various places in Novosibirsk and its surroundings (the village of Ogurtsovo). In 1975, a six-story building of the SibNIIKhim, as well as a greenhouse complex, were put into operation in the urban-type settlement of Krasnoobsk. The establishment of the Siberian Branch of VASKhNIL made it possible to significantly increase the volume of theoretical and applied research in all areas of agricultural science, including plant protection, and to raise the methodological level of research thanks to the influx of new staff and the provision of instruments and equipment.

One of the first tasks of the State Committee for Science and Technology under the Council of Ministers of the USSR, assigned to SB VASKhNIL, was to develop measures for the integrated chemicalization of agriculture in the regions of Siberia and the Far East (see footnote 4).

SibNIIKhim focused on improving chemical plant protection measures by increasing their efficiency, ensuring they are safe for beneficial organisms, and eliminating pesticide residues in agricultural products. It also studied the natural resources of entomophagous organisms on grain and vegetable crops and developed methods for their use in integrated plant protection systems. To fulfill the state assignment, in 1971, SibNIIKhim established laboratories for biotechnological methods and agricultural entomology, along with laboratories specializing in agrochemical research, herbicides, and phytopathology.

In 1971, the biotechnological laboratory was headed by Vladimir Vasilyevich Guliy,

[4]Electronic Library of Historical Documents (ELHD). URL: https://docs.historyrussia.org/ru/nodes/355658#mode/ inspect/page/1/zoom/4

a researcher at the Virology Laboratory of the Biological Institute of the Siberian Branch of the USSR Academy of Sciences, and later the scientific secretary of the Presidium of the Siberian Branch of the All-Union Academy of Agricultural Sciences, Candidate of Science in Biology. In 1973, he defended his doctoral dissertation entitled "Polyhedrosis and granulosis in phytophagous insects of the Siberian fauna". Together with the staff of the former Novosibirsk VIZR station M. N.N. Aleeva, L. N.N. Spichenko, L.N. Chukanova, the biomethod laboratory included T. V. Teplyakova, M.V. Sternshis, M.C. Rakshaina, N.I. Ermakova, G.M. Ivanov, L.A. Krupko, Z.N. Alekseeva, N.G. Babushkina, N.M. Makhova, F.L. Gushchin, S.Yu. Rybina, and others. The main activity of the laboratory was the development and improvement of a microbiological control method. After V. V. Guliy, Tamara Vladimirovna Teplyakova led the work of the laboratory for some time, then Margarita Vladimirovna Sternshis (in 1987 she defended her doctoral dissertation "Principles of increasing the effectiveness of entomopathogenic drugs for plant protection"). In the 80s of the XX century, L. A. Osintseva (1981), N.G. Vlasenko (1986), I.V. Andreeva (1988), O.V. Kulagin, D. A. Shtundyuk, N.V. Lobanova and others became employees of the laboratory.

At the end of 1971, Nikolai Nikolaevich Gorbunov, Candidate of Science in Agriculture, who had previously worked as Deputy Director for Scientific Work at the Zyryanovsky Agricultural Experimental Station in the East Kazakhstan region, became head of the Laboratory of Agricultural Entomology. The laboratory staff included R. N. Fisechko, T. D. Runeva, N.N. Poskolny, T.A. Sobakar, A.F. Timokhina, V.I. Krivokhizhin, and N.N. Ivanova, who studied phytophagous insects and measures to control them. In 1984, N.N. Gorbunov defended his doctoral thesis"Scientific foundations of the construction of monitoring systems for harmful insects in the protection of field crops in Western Siberia". Victor Aleksandrovich Korobov was accepted into the laboratory in 1985, and in 1988, after N.N. Gorbunov joined the National Research Institute of Agricultural Sciences, he became the head of this laboratory (in 2006 he defended his doctoral thesis "Protection of soft spring wheat from a complex of specialized pests in Western Siberia and Northern Kazakhstan"). After completing her studies at the Institute, I. G. Krotova (Bokina) became a graduate student at the laboratory, (since 1984) she was a laboratory assistant, then E.Yu. Marmuleva (since 1986) became the graduate student of this laboratory.

In 1980, due to the expansion of the tasks assigned to the institute, SIBNIIKHIM was transformed into the Siberian Research Institute of Soil Management and Chemicalization of Agriculture (SIBNIIZKhIM), while maintaining the status of a methodological and coordinating center for research on plant protection in Siberia and the Far East. SIBNIIZKhIM was headed (1980-1989) by Doctor of Science in Biology (later academician of the VASKhNIL RAS) Valery Ivanovich Kiryushin, since 1990 - Candidate of Science in Agriculture Anatoly Nikolaevich Vlasenko (later Academician of RAAS RAS). Four departments were established at the Institute: agriculture, agro-soil science, agrochemistry, and plant protection (the first head was Doctor of Science in Agriculture Valentina Andreevna Chulkina). In the 80s and 90s, plant protection research programs were aimed at developing integrated protection systems in the context of intensive plant cultivation technologies. At the same time, special attention was paid to environmental issues.

During the 1990s, as a market economy was taking shape in the country, many staff members from the agricultural entomology and biological control laboratories moved from SibNIIZKhim to Novosibirsk Agrarian University (M.V. Shternshis, L.A. Osintseva, N.I. Ermakova, V.A. Korobov, I.V. Andreeva), to VIZR (N.G. Babushkina), and to the Novosibirsk Station for Chemicalization (T.A. Sobakar,

A.F. Timokhina). Somewhat earlier, in the 1980s, T.V. Teplyakova had transferred to the All-Russian Research Institute of Molecular Biology. Some of the remaining staff moved to other laboratories, while others left the field of science.

After V.A. Chulkina left for NSAU, the Plant Protection Department of SibNIIZKhim was headed by Lyudmila Filippovna Ashmarina (Candidate of Science in Agriculture, and Doctor of Science in Agriculture from 2005), followed by Nataliya Grigoryevna Vlasenko (Candidate of Science in Biology).

In the 1990s, based on the research conducted at SibNIIZKhim, T.V. Teplyakova (1992, "Biological aspects of the study and use of predatory hyphomycete fungi") and N.I. Ermakova (1992, "Optimization of *Baculovirus* use for harmful insect population control") successfully defended their dissertations for the degree of Doctor of Science in Biology, L.A. Osintseva (1998, "An environmentally safe system for regulating the population of leaf-eating insects in cabbage field agrocenoses"), N.G. Vlasenko (1999, "Environmentally adapted protection of spring rapeseed and other field Brassica crops in the forest-steppe of Western Siberia"). In 2010, N.G. Vlasenko was awarded the title of Corresponding Member of the Russian Academy of Agricultural Sciences (RASKhN), and in 2016, that of Academician of the Russian Academy of Sciences (RAS).

In the 1990s, despite a reduction in staff, SibNIIZKhim continued its research—including work on plant protection—and established multifactorial field experiments. Analysis of the research findings made it possible to develop plant protection systems that took into account the phytosanitary status of agrocenoses, the agro-ecological conditions of crop cultivation, and the available range of biological and chemical agents.

Biological control is one of the methods used for plant protection. One approach within this method involves the use of entomophages which, alongside other entomopathogenic organisms, regulate phytophage populations and maintain biocenotic balance in agroecosystems.

The first references to entomophages—predatory and parasitic insects—appeared in 18th-century literature in the works of the French naturalist René Réaumur, the Swedish naturalist and taxonomist Carl Linnaeus, and other scientists who recommended using ladybugs, lacewings, and parasitic hymenopterans to suppress aphid populations. In 1760, Linnaeus put forward the idea of a "balance of nature," noting that "plant-eating insects are always linked to others that destroy them if they become too numerous"[5]. The study of the predators and parasites of agricultural crop pests was initiated by the works of S.A. Mokrzhetsky[6], I.A. Porchinsky[7], N.V. Kurdyumova[8, 9], A.A. Ogloblin[10], N.A. Grossgeim[11], N.F. Meyer[12], F.G. Dobrzhansky[13], V.V. Yakhontov[14], G.Ya. Bei-

[5]*Koppel H., Mertins J.* Biological Control of Insect Pests. Moscow: Mir, 1980. 429 p.

[6]*Mokrzhetsky S.A.* Harmful animals and plants in Taurida Governorate based on observations in 1900, with an indication of control measures. Simferopol, 1901, 99 p.

[7]*Porchinsky I.A.* Our ladybirds (Coccinellidae) and their economic importance // Proceedings of the Bureau of Entomology of the Scientific Committee of the Main Administration of Land Organization and Agriculture. St. Petersburg, 1912, vol. 9, No. 11, 84 p.

[8]*Kurdyumov N.V.* The principal insects damaging cereal crops in Central and Southern Russia. Poltava, 1913, 119 p.

[9]*Kurdjumov N.V.* Notes on European species of the genus *Aphelinus* Dalm. parasitizing aphids (Hymenoptera, Chalcidoidea) // Revue Russe d'Entomologie, 1913, vol. 13, No. 2, pp. 266–270.

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Bienko[15], N.A. Telenga[16, 17], I.A. Rubtsov[18, 19], N.P. Dyadechko[20] et al. The works of I.A. Rubtsov, G.A. Viktorov[21], and other scientists have formulated the theoretical foundations for utilizing natural limiting factors to regulate the populations of harmful organisms.

Every pest species has its own entomophages. As part of the first state assignment, staff members of the Biological Control Laboratory, M.N. Aleeva and L.N. Chukanova[22] more than 20 species of entomophages targeting lepidopteran cabbage pests (cabbage moth, cabbage and large white butterflies, and diamondback moth) have been identified, and their significant role in regulating pest populations in Western Siberia has been noted. The potential of using phytoseiulus to control spider mites is demonstrated[23]. L. N. Chukanova identified entomophages of the fruit fly[24].

Among the cereal crops that occupy the bulk of the cultivated area in Western Siberia, cereal aphids host the greatest number of entomophages. Situated at the base of the trophic chains in cereal agroecosystems, aphids serve as a crucial food source, while the entomophages associated with them constitute the core of the entomofaunal species diversity within these agroecosystems. This facilitates the successful use of the biological method for controlling aphid populations and makes chemical intervention undesirable, given that the disappearance of any lower link in the food chain leads to the disappearance of all higher links [1].

Up to 70 specialized and 80 polyphagous entomophages of cereal aphids have been identified across various regions of Russia and neighboring countries[25–27]. As polyphages, the majority of them reduce the populations of many other pests in cereal crops, thereby helping to stabilize the phytosanitary situation in agroecosystems.

In Western Siberia, beneficial insects account for 31.5% of the 200 insect species found on spring wheat[28]. In wheat fields, there is high potential pressure from entomophages on herbivorous species: the ratio of the predators' daily food requirement to the average seasonal standing crop of phytophages and saprophages approaches 1:3 in the region[29]. Information on the species composition of predatory and

[15]*Bei-Bienko G. Ya.* On the zonation of agricultural crops based on pest complexes (using the wheat field as an example) // Proceedings of the Leningrad Agricultural Institute. Leningrad, 1939, Issue 3, pp. 123–134.

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[23]*Aleeva M.N., Lazareva T.A., Churkina L.G.* Experience with the use of *Phytoseiulus* for the control of spider mites in Siberia // Plant Protection: Scientific and Technical Bulletin of the Siberian Research Institute of Chemical Plant Protection (SibNIIKhim). Novosibirsk, 1972, Issue 1–2, pp. 20–21.

[24]*Chukanova L.N.* The frit fly and its entomophages in Western Siberia: abstract of a dissertation for the Degree of Candidate of Biological Sciences. Leningrad; Pushkin, 1974, 22 p.

[25]*Berest Z.L.* Entomophages regulating the abundance of cereal leaf aphids in wheat fields in the steppe zone of the Right-Bank Ukrainian SSR // Vestnik Zoologii, 1980, No. 5, pp. 84–87.

[26]*Voronin K.E., Pukinskaya G.A., Lakhidov A.I.* Entomophages of major wheat pests // Wheat Field Biocenosis, Moscow, 1986, pp. 66–80.

[27]*Kiriyak I.G.* Entomophages of aphids—pests of cereal crops in Moldavia // Entomophages of plant pests. Kishinev: Shtiintsa, 1980, pp. 21–27.

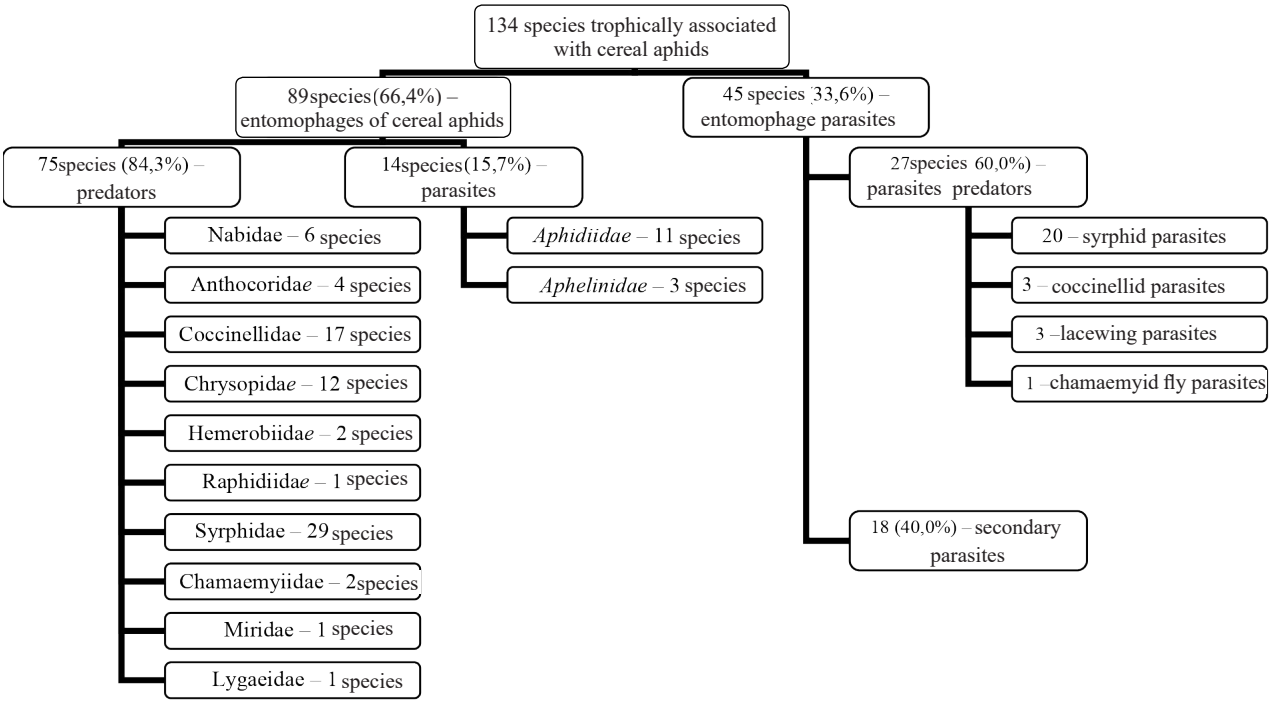
[28]*Klementieva L.B.* Entomofauna of spring crops of wheat and barley // Scientific notes of the Omsk State Pedagogical University. Omsk: Omsk book publishing house, 1961, Issue 14, pp. 33–46.

[29]*Zubkov A.F., Titova R.P.* Trophic structure of wheat field biocenoses and its alteration under the influence of chemical treatments in the Ob region forest-steppe // Entomological Review, 1976, vol. 55, No. 1, pp. 5–18.

parasitic entomofauna in the Siberian region was scarce during the initial period of their study (see footnote 28)[30–32].

In the 1970s, M.N. Aleeva and N.G. Babushkina, researchers at the biological control laboratory, initiated a broader study of entomophages in cereal crops. In the Middle Ob region, the authors identified 27 predatory and 4 parasitic species[33], the study of the biology of the cereal aphid parasite *Praon volucre* Hal.[34] has begun. At approximately the same time, 11 species of entomophages of cereal aphids were recorded in the southeastern districts of the Altai Territory, including 9 species of coccinellids and 2 species of aphidiids[35, 36].

In 1985, research on entomophages at the Agricultural Entomology Laboratory was continued by I.G. Krotova (Bokina)—initially a postgraduate student and subsequently a staff member of the SibNIIZKhim laboratory. Over a three-year period in the forest-steppe zone of Western Siberia, the species composition of predatory and parasitic insects trophically linked to cereal aphids—comprising 119 species—was studied in cereal crop agrocoenoses (spring wheat, oats, winter rye) and on bird



Структура комплекса энтомофагов, трофически связанных со злаковыми тлями
The structure of the complex of entomophages trophically associated with cereal aphids

[30] *Savoyskaya G.I.* On the study of the Coccinellidae of Western Siberia // Scientific Notes of the Tomsk Pedagogical Institute. Tomsk, 1961, vol. 19, Issue 1, pp. 101–106.

[31] *Filatova I.T.* Predatory Coccinellidae (Coleoptera, Coccinellidae) of the Southern Part of Western Siberia: abstract of a dissertation for the Degree of Candidate of Biological Sciences. Novosibirsk, 1970, 21 p.

[32] *Barannik A.P., Mirzashayekhov R.S.* Parasitoid wasps of the genus *Lysiphlebus* Förster (Hymenoptera, Aphidiidae) in the Kuznetsk Basin // Ecology and Geography of Arthropods of Siberia. Novosibirsk, 1987, pp. 165–166.

[33] *Aleeva M.N., Babushkina N.G.* Entomophages of cereal aphids // Collection of scientific works of SibNIIZKHim. Novosibirsk, 1977, No. 3, pp. 69–78.

[34] *Aleeva M.N.* On the biology of the aphidiid *Praon volucre* Hal. in the Middle Ob region // Scientific and Technical Bulletin of the Siberian Research Institute of Agriculture and Chemicalization (SibNIIZHim). 1976, Issue 16, pp. 58–65.

[35] *Semenov P.V.* Parasites of cereal aphids in the Altai Territory // Siberian Herald of Agricultural Science, 1979, No. 5, pp. 99–100.

[36] *Semenov P.V.* Ladybirds as predators of cereal aphids // Siberian Herald of Agricultural Science, 1982, No. 5, pp. 45–48.

cherry, the primary host of the bird cherry-oat aphid[37]. Subsequently, another 15 species were recorded[38] [2].

Of the 134 species of entomophages, 89 (66.4%) are entomophages of cereal aphids, and 45 (33.6%) are parasites of these entomophages. Among the entomophages, 75 species (84.3%) are predators, and 14 (15.7%) are parasites. Of the 45 species of parasites of cereal aphid entomophages, 27 (60.0%) are parasites of predators, and 18 (40.0%) are hyperparasites or secondary parasites of cereal aphids (see the figure).

Of the identified entomophages, four species were new to science: *Phaenoglyphis* sp., *Alloxysta* sp.1, *Alloxysta* sp.2, *Tetrastichus* sp.; 3 – for the fauna of the former USSR: *Nineta inpunctata*, *Woldstedtius holarcticus* and *Dendrocerus remaudierei*; 29 – recorded for the first time in the fauna of Western Siberia: *Chrysopa perplexa*, *Raphidia xanthostigma*, *Leucopis glyphinivora*, *Ephedrus nacheri*, *Parapraon necans*, *Praon flavinode*, *Aphidius rhopalosiphi*, *Trioxys auctus*, *Aphelinus transversus* и *A. asychis*, *Diplazon scutatorius*, *Sussaba cognata cognata*, *Syrphophilus tricinctorius*, *Syrphoctonus tarsatorius*, *S. nigritarsus nigritarsus*, *Woldstedtius flavolineatus*, *W. biguttatus*, *W. abdominator*, *Pachyneuron groenlandicum*, *P. formosum*, *Dendrocerus laticeps*, *D. basalis*, *D. aphidum*, *Phaenoglyphis villosa*, *Ph. fuscicornis*, *Alloxysta mullensis*, *Alloxysta* sp. *aff.* v*ictrix*, *Melanips opacus*, *Baryscapus principiae.*

Staff members of the Zoological Institute of the Russian Academy of Sciences and the All-Russian Institute of Plant Protection (St. Petersburg) provided significant theoretical and practical assistance in determining the species composition of predatory and parasitic insects, KazNIIZR, the Institute of Zoology of the Academy of Sciences of Kazakhstan (Alma-Ata), GruzNIIZR (Tbilisi), the All-Russian Research Institute of Biological Plant Protection of RAAS (Krasnodar), the Institute of Systematics and Ecology of Animals of the Siberian Branch of the Russian Academy of Sciences (Novosibirsk), Moscow Pedagogical University, Voronezh State University, and the All-Union Research Institute of Biological Plant Protection (Kishinev): Izyaslav Moiseevich Kerzhner (1936–2008), Victor Borisovich Golub – Nabidae, Anthocoridae; Galina Ivanovna Savoyskaya (1925–2017), Valentin Pavlovich Semyanov (1936–2016) – Coccinellidae; Galina Ivanovna Dorokhova – Chrysopidae, Hemerobiidae, Raphidiidae; Anatoly Vasilievich Barkalov – Syrphidae; Vitaly Nikolaevich Tanasiychuk (1928–2014) – Chamaemyiidae; Vadim Filippovich Zaitsev (1934–2012) – Phoridae; Dmitry Rafaelovich Kasparyan, Andranik Rafaelovich Manukyan – Ichneumonidae; Ivan Georgievich Kiriyak – Aphidiidae; Valentina Adamovna Yasnosh (1924 – after 2008) – Aphelinidae; Clarissa Alekseevna Dzhanokmen – Pteromalidae; Vladimir Alexandrovich Tryapitsyn (1928–2023), Viktor Vladimirovich Kostyukov – Pteromalidae, Eulophidae, Encyrtidae; Mikhail Alekseyevich Kozlov (1936–2006), Vladimir Nikolaevich Alekseev – Megaspilidae; Oleg Vasilyevich Kovalev (1937–2019) – Alloxystidae, Figitidae; Sergey Alexandrovich Belokobylsky – Heloridae. Interactions with entomologists took place either in person or through the exchange of parcels containing insects and letters that arrived after the species had been identified. I will always remember these scientists with warmth and deep gratitude.

Based on a study of the long-term and seasonal population dynamics of aphids and their entomophages—as well as their biology, synchrony with aphid development, predator voracity, and rates of aphid parasitism—the dominant aphidophagous species were

[37] *Krotova I.G.* Species composition of entomophages of cereal aphids (Homoptera, Aphididae) in Western Siberia // Entomological Review, 1989, vol. 68, N 1, pp. 51–55.

[38] *Krotova I.G.* Entomophages of cereal aphids in grain crops in the northern forest-steppe zone of the Ob region: abstract of a dissertation for the degree of Candidate of Biological Sciences. Novosibirsk, 1992, 18 p.

identified, and criteria for their effectiveness were established[39–44]. In 2000, I.G. Bokina was included in the publication *Who's Who in the World 2000* (USA) in recognition of her scientific work. In 2009, she defended her doctoral dissertation, titled "Agroecological Rationale for the Use of Entomophages in Protecting Cereal Crops from Aphids in the Forest-Steppe Zone of Western Siberia".

Subsequent research focused on the bioecological characteristics of predatory and parasitic species and their role in reducing pest population densities. Studies conducted in laboratories specializing in intensive cultivation technologies, grain crop production, and crop rotation systems examined the impact of various agronomic practices on entomophages; meanwhile, the agrocoenology laboratory investigated the effects of No-Till technology on entomophages and explored methods for maintaining high population densities of beneficial species within agrocoenoses [3–11].

In the 1990s, E.Yu. Marmuleva, under the supervision of R.N. Fisechko, obtained original data on the entomophages of the pea aphid. In 2001, she began working at NSAU, and in 2004, she defended her Candidate of Sciences dissertation[45]. The primary focus of her future research is the study of the bioecological characteristics of pests and the regulatory role of entomophages in agroecosystems, as well as the refinement of systems for optimizing phytosanitary technologies for field crop cultivation in Western Siberia, based on advances in epiphytotiology.

In 2016, the Laboratory for the Biological Control of Phytophages and Phytopathogens was established at the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences (SFSCA RAS). Under the leadership of I.V. Andreeva (Candidate of Science in Agriculture), its staff continued the traditions of the biocontrol and agricultural entomology laboratories of SibNIIZKhim. The use of entomophages and other natural mechanisms for regulating pest populations will remain a promising area of biological plant protection.

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[39]*Krotova I.G.* Lacewings (order Neuroptera) – entomophagous predators of cereal aphids in the Ob region forest-steppe // Siberian Herald of Agricultural Science, 1989, No. 3, pp. 46–50.

[40]*Krotova I.G.* Coccinellids (Coleoptera, Coccinellidae) – entomophagous predators of cereal aphids in the Ob region forest-steppe // Siberian Herald of Agricultural Science, 1990, No. 5, pp. 43–50.

[41]*Krotova I.G.* Predatory bugs of the family Nabidae (Hemiptera) that prey on aphids in the Ob region forest-steppe // Russian Journal of Zoology, 1991, vol. 70, Iss. 10, pp. 59–67.

[42]*Krotova I.G.* Hymenopteran parasitoids and their role in reducing the abundance of grain aphids in the west Siberian forest-steppe of the Ob' region// Russian Journal of Zoology, 1993, vol. 72, Iss. 12, pp. 51–57.

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[45]*Marmuleva E.Yu.* Bioecological justification of the effectiveness of entomophages of pea pests in the forest-steppe of the Ob region: Abstract of Candidate of Agricultural Sciences dissertation. Novosibirsk, 2004, 20 p.

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Эффективность применения бактерий-антагонистов фитопатогенных грибов в модельной экосистеме

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По мере развития систем контролируемого земледелия – от теплиц к полузамкнутым оранжерейным комплексам и далее к замкнутым вертикальным фермам и биорегенеративным системам жизнеобеспечения – возрастают требования к фитосанитарной безопасности и ограничиваются возможности применения химических фунгицидов. Перспективный подход к контролю возможных эпифитотий – использование бактерий-антагонистов рода *Pseudomonas*, способных подавлять фитопатогены и индуцировать системную устойчивость растения-хозяина. Применение агентов биоконтроля в замкнутых агроэкосистемах требует промежуточного этапа – испытания в модельных экосистемах, воспроизводящих ключевые параметры защищенного грунта: богатый органикой субстрат и присутствие аборигенной микрофлоры. Цель данной работы – оценка антифунгальной активности бактерий штамма *Pseudomonas extremorientalis* PhS1 в отношении возбудителя корневой гнили зерновых культур *Bipolaris sorokiniana* и его влияния на параметры развития растений пшеницы в условиях модельной экосистемы. Исследования проводили в лабораторных условиях по общепринятым методикам. Установлено, что бактерии *P. extremorientalis* PhS1 проявляли высокую антагонистическую активность по отношению к возбудителям семенных инфекций и корневых гнилей. Общая пораженность семян уменьшилась в 1,8–1,9 раза, распространенность корневых гнилей – в 1,6–2,8, индекс развития – в 1,9–7,1 раза. В экспериментах с модельными экосистемами при интродукции фитопатогена распространенность корневых гнилей у бактеризованных растений снизилась на 18%, индекс развития – на 22% по сравнению с небактеризованными. Активность гваякол-зависимой пероксидазы бактеризованных растений возросла на 12% без патогена и на 31% в присутствии *B. sorokiniana*. Полученные данные дополняют результаты лабораторных и полевых экспериментов и обосновывают перспективность применения *P. extremorientalis* как агента биоконтроля корневых гнилей пшеницы в условиях защищенного грунта и замкнутых агроэкосистем.

Ключевые слова: *Bipolaris sorokiniana, Pseudomonas extremorientalis*, биоконтроль, корневые гнили, мягкая пшеница

Effectiveness of using antagonistic bacteria against phytopathogenic fungi in a model ecosystem

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As controlled agriculture systems develop – from greenhouses to semi-closed greenhouse complexes and further to closed vertical farms and bioregenerative life support systems – requirements for phytosanitary safety increase and the possibilities of using chemical fungicides are limited. A promising approach to controlling potential epiphytotics is the use of antagonist bacteria of the genus *Pseudomonas*, capable of suppressing phytopathogens and inducing systemic resistance in the host

plant. The use of biocontrol agents in closed agroecosystems requires an intermediate stage – testing in model ecosystems that reproduce the key parameters of protected soil: organic-rich substrate and the presence of indigenous microflora. The aim of this study is to assess the antifungal activity of the bacterial strain *Pseudomonas extremorientalis* PhS1 against the causative agent of root rot in cereal crops, *Bipolaris sorokiniana*, and its effects on the growth parameters of wheat plants under model ecosystem conditions. The studies were conducted in laboratory conditions using standard methods. *P. extremorientalis* PhS1 demonstrated high antagonistic activity against seed infection and root rot pathogens: overall seed infestation reduced 1.8–1.9 times, root rot disease incidence 1.6–2.8 times, and disease severity 1.9–7.1 times. In model ecosystem experiments with pathogen introduction, disease incidence in bacterized plants decreased by 18% and root rot disease severity by 22% compared to non-bacterized plants. The activity of guaiacol-dependent peroxidase in bacterized plants increased by 12% without the pathogen and by 31% in the presence of *B. sorokiniana*. The obtained data complement the results of laboratory and field experiments and substantiate the prospects of using *P. extremorientalis* as a biocontrol agent for wheat root rots under protected soil conditions and in closed agroecosystems.

Keywords: *Bipolaris sorokiniana, Pseudomonas extremorientalis*, biocontrol, root rots, soft wheat

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INTRODUCTION

At the current stage of crop production development, there is an active shift from traditional open-field farming to using controlled agriculture technologies, including greenhouse complexes, vertical farms, and greenhouse facilities with different levels of material and energy closure [1, 2]. There's especially a high need for such technologies in regions with harsh climates, where the growing season outdoors is limited by a lack of suitable land or extreme weather conditions [2, 3]. Besides that, autonomous crop-growing systems are seen as one of the ways to ensure food security in remote locations. The experience of the mobile greenhouse project in Antarctica showed that it's possible to produce fresh crops while being isolated from the outside environment. Integrated plant protection protocols for bioregenerative life support systems (BLSS) in space missions treat these systems as a separate class of agroecosystems with a fundamentally different plant health logic [4–6]. The main focus in this system is not on using control agents, but on managing pathogens by maintaining the suppressive activity of substrates and a high level of resistance in producers.

One of the features of closed and semi-closed crop production systems is the significant limitation on the use of chemical plant protection products. In a confined space, chemical treatments carry risks of accumulating residual amounts of pesticides on surfaces and in recirculating nutrient solutions, as well as

the risk of exceeding the maximum allowable concentrations in the edible parts of plants, especially with short growing cycles, frequent harvests, and consumption of the produce without extensive processing [8]. It has been found that a number of crops grown in greenhouses can accumulate pesticide concentrations exceeding the allowable limits if the waiting periods after treatment are not observed, which is practically inevitable under the conditions of an intensive greenhouse conveyor[1]. In addition, broad-spectrum fungicides have a negative impact on beneficial microbial communities, disrupting the basis of biological balance [9]. All the factors mentioned above point to the need for using biological protection methods as the foundation of plant health management in controlled farming systems.

In closed ecosystems, the risk of widespread plant diseases can increase due to high plant density, limited substrate volume, and the specific dynamics of microbial load. It has been shown that frequent plant care treatments, which are typical for standalone systems, can lead to a decrease in beneficial microflora diversity and a subsequent dominance of certain microorganisms, including potentially pathogenic ones [7].

A promising approach to controlling plant disease pathogens is using the antagonist bacteria, primarily representatives of the genus *Pseudomonas*. Plant-associated pseudomonads (*P. fluorescens*, *P. chlororaphis*, *P. protegens*, *P. extremorientalis*, etc.) have a wide range of useful mechanisms for controlling plant pathogens: producing antimicrobial metabolites, cyclic lipopeptides, siderophores, volatile organic compounds, lytic enzymes, and more [10–12]. Besides direct antagonism, pseudomonads induce systemic plant resistance and stimulate plant defense responses, including the production of reactive oxygen species, phytoalexins, phenolic compounds, pathogenesis-related proteins (PR proteins), and they can also help optimize their endogenous hormone balance [10, 13, 14].

To improve the phytosanitary condition of model ecosystems, it seems advisable to introduce bacteria that have high antifungal activity against the most harmful phytopathogenic fungi.

The goal of this work is to assess the antifungal activity of the *P. extremorientalis* PhS1 bacterial strain against the root rot pathogen *Bipolaris sorokiniana* and its effect on wheat plant development parameters in a model ecosystem.

MATERIAL AND METHODS

The subject of the study is *P. extremorientalis* PhS1 bacteria, isolated from earthworm coprolites[2, 3]. Liquid batch bacterial culture was obtained using periodic cultivation in flasks on GRM broth (fish meal hydrolysate) on a LOIP LS 110 shaker (JSC "Laboratory Equipment and Instruments", Russia) at 180 rpm and 28.0 ± 0.5 °C. Population and purity control were carried out using standard plating methods on solid nutrient media.

The experiments were carried out in laboratory conditions on wheat seeds of the "Iren" variety (*Triticum aestivum* L., milturum variety). The effectiveness of using the strain against wheat seed pathogens was assessed using a phytotesting method on filter paper rolls (GOST 12044–93). Antifungal activity was judged by the reduction in the number of seeds showing signs of infection, and growth-stimulating effects on the embryo were evaluated based on the germination rate, seedling length, and the number of primary roots.

The effect of seed bacterization on the development and infection of plants by root

[1]*Park D.W., Kim K.G., Choi E.A., Kang G.R., Kim T.S., Yang Y.S., Moon S.J., Ha D.R, Kim E.S., Cho B.S.* Pesticide residues in leafy vegetables, stalk and stem vegetables from South Korea: a long-term study on safety and health risk assessment // Food Additives & Contaminants: Part A. 2016, vol. 33, N 1, pp. 105–118. DOI: 10.1080/19440049.2015.1108524.

[2]*Tereshchenko N.N., Kravets A.V., Akimova E.E., Minaeva O.M., Zotikova A.P.* Efficacy of using microorganisms isolated from earthworm casts to increase grain crop yields // Siberian Herald of Agricultural Science, 2013, No. 5, pp. 10–17.

[3]*Minaeva O.M., Akimova E.E., Tereshchenko N.N., Kravets A.V., Zyubanova T.I., Apenysheva M.V.* Prospects for using pseudomonads associated with soil-dwelling lumbricids against pathogens causing root rot in spring cereals // Agricultural Biology, 2019, vol. 54, No. 1, pp. 91–100. DOI: 10.15389/agrobiology.2019.1.rus.

rot pathogens under controlled conditions of a growth experiment was studied using sterile coarse river sand as a substrate and adding extra infectious pressure in the form of a phytopathogenic fungus. Wheat seeds, which were preliminarily treated for 3 minutes with 70% ethanol to remove surface infections, were rinsed with sterile water and germinated in a moist chamber at 18–20 °C.

After the embryo appeared (1 mm), the seeds were soaked for 20 minutes in a 0.85% sodium chloride solution (control plants), which is used for preparing bacterial dilutions, or in a bacterial suspension diluted to a concentration of 2–5 × 10^7 cells/ml. After treatment, the seeds (45 each) were placed in containers (1200 ml) filled with sand (800 ml), evenly moistened with Knop's sterile solution for hydroponic and sand cultures, g/l: Ca $(NO_3)_2$ – 1,0, KH_2PO_4 – 0,25, $MgSO_4 \cdot 7H_2O$ – 0,125, KNO_3 – 0,25, $FeCl_3$ – 0,012[4].

As a phytopathogenic load, agar plates with six-day-old mycelium of the fungus *B. orokiniana* (Sacc.) Shoemaker, grown on potato-glucose agar at 22–24 °C was used. This microfungus is a widespread cause of root rot in cereals in Siberia [15]. Agar strips with the fungus mycelium were placed in rows with plant seeds and then covered with sand. In the system without additional infection pressure, the seeds were laid out on sterile agar strips.

The plants were grown in a climate chamber (GH-300TLH, Jeio Tech, Korea) under fluorescent light at 12,000 lux with a 16/8-hour photoperiod, at 18–20 °C during the day and 14–16 °C at night, with 75% humidity. The experiment lasted for 14 days.

To assess the biological effectiveness of using bacteria as agents for controlling phytopathogens in an artificial agroecosystem, a model consisting of four components was used: substrate – plant (wheat) – agent (bacterial strain) – phytopathogen (*B. sorokiniana*). The substrate was prepared by mixing de-acidified moistened highbog peat (90% by weight) and fresh cattle manure (10%). Seed bacterization and pathogen introduction were done according to the method described above. During the experiments, the plants were watered with settled tap water (by weight).

The model ecosystems were maintained under conditions as close to natural as possible, without keeping them sterile, in a phytotron under controlled settings: LED light intensity at 30 klx with a 16/8-hour photoperiod at 20–22 °C/15–17 °C (day/night temperatures) and 60% humidity. The experiments lasted for 35 days.

Upon completion of the experiments, germination was recorded and the length of each plant was measured. The severity of root rot infection was assessed by rating the degree of browning at the stem base and root system of each plant on a five-point scale, and the prevalence and disease development index were calculated[5]. Also, in the experiments with model systems, the total activity of guaiacol-dependent peroxidase in the aerial parts of the plants was also assessed spectrophotometrically (λ = 470 nm) according to the method of Chance and Maehly[6].

The experiments were conducted with four replicates, using 45 plants per treatment. The data were processed using analysis of variance and are presented as arithmetic means with confidence intervals calculated using Student's *t*-test at the 95% significance level. The statistical significance of differences between the results was assessed using Student's *t*-test ($p < 0,05$).

RESULTS AND DISCUSSION

Earthworm-associated *P. extremorientalis* PhS1 bacteria were selected during a screening

[4]*Baslavskaya S.S., Trubetskaya O.M.* Practical course in plant Pphysiology. Moscow: Moscow State University Press, 1964, 327 p.
[5]*Chulkina V.A., Konyaeva N.M., Kuznetsova T.T.* Combating crop diseases in Siberia. Moscow, 1987, 252 p. [6]*Chance B., Maehly A.C.* Assays of catalases and peroxidases. In: S.P. Colowick, N.O. Kaplan (Eds.), Methods in enzymology (Vol. II, pp. 764–775). Academic Press., 1955, pp. 764–775.

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for fungistatic activity against pathogens causing root rot in cereal crops. In the *in vitro* experiments, these bacteria reduced the growth rate of the fungi *Alternaria* spp., *Bipolaris sorokiniana*, and *Fusarium oxysporum* by half on artificial nutrient media (see footnote 3).

Standard phytopathological analysis of the grain revealed that bacterization contributed to a significant improvement in the phytosanitary condition of the seeds and the quality of the wheat seedlings (see Table 1).

Bacterization reduced the overall incidence of seed-borne pathogens by a factor of 1.8–1.9. A trend toward increased seed germination and wheat seedling length was observed (up to 12% higher than in non-bacterized controls). The use of bacteria for seed treatment also facilitated the fuller expression of the caryopsis's potential, manifested as a significant increase in the number of primary roots (by 14–15%).

In the *in planta* experiments (without complete seed sterilization), it was found that introducing bacteria into the substrate during the cultivation of wheat plants in sand culture promotes the manifestation of their antagonistic activity, both in variants with the additional introduction of the phytopathogen *B. sorokiniana* and in those without it (see Table 2).

A statistically significant reduction in the prevalence of root rot was observed in bacterized wheat plants: 2.6–2.8-fold in variants without the introduction of a phytopathogen into the substrate (relying on the natural seed-borne inoculum) and 1.6–1.7-fold when *B. sorokiniana* was introduced into the substrate. The disease severity index in the bacterized variants decreased statistically significantly by 6.9–7.1-fold and 1.9–2.0-fold, respectively.

The ability of bacteria to successfully compete with native soil and rhizosphere microflora and occupy the specific ecological niche associated with wheat roots can be indirectly assessed by their ability to retain antifungal properties following seed bacterization in field experiments (2011–2023). It has previously been shown that pre-sowing treatment of wheat seeds reduces the prevalence and development index of root rots by a factor of 1.3 to 3.4, depending on weather and soil conditions during the growing season as well as the cultivation technology (see footnotes 3, 4) [16]. The data obtained regarding the reduced incidence of leaf pathogens suggest that *P. extremorientalis* is capable of inducing systemic resistance in wheat plants. Field experiments showed a reduction in the prevalence of dark brown spot by 6.0–18.8% and a 1.5- to 5.5-fold decrease in the disease severity index, depending on the study year; for powdery mildew, the corresponding reductions were 1.6–2.8-fold and 1.9–6.8-fold [17].

Field experiments also revealed growth-promoting activity in the bacterial strain used—an effect that had appeared merely as a trend in laboratory tests. Increases of up to 10% in height, up to 70% in wheat plant biomass, and up to 60% in yield were observed [16, 17].

In vitro, *in planta*, and field studies demonstrate that the use of a bacterial strain to

Табл. 1. Общая пораженность фитопатогенами и всхожесть семян, морфометрические параметры проростка пшеницы при бактеризации

Table 1. General infection by phytopathogens and seed germination, morphometric parameters of wheat seedlings during bacterization

Experiment option	Overall prevalence, %	Germination, %	Length of seedlings, cm	Number of roots, pcs.
Control	85,0 ± 3,7	85,0 ± 3,6	10,1 ± 1,1	3,5 ± 0,2
Pseudomonas extremorientalis	46,0 ± 5,6*	90,0 ± 3,0	11,3 ± 1,1	4,0 ± 0,3*

Note. Here and in Table 2, Figs. 1 and 2: * – statistically significant difference from the control, based on the Student's t-test ($p < 0,05$).

Табл. 2. Пораженность растений пшеницы возбудителями корневых гнилей, выращенных в стерильном песке, %

Table 2. Infection of wheat plants by root rot pathogens, grown in sterile sand, %

Option	Without introduction of a phytopathogen		In the presence of *B. sorokiniana*	
	Prevalence	Development index	Prevalence	Development index
Control	28,3 ± 7,4	11,9 ± 4,3	50,2 ± 10,1	22,9 ± 5,0
Pseudomonas extremorientalis	10,4 ± 5,0*	1,7 ± 0,5*	30,9 ± 9,2*	11,5 ± 2,3*

control phytopathogens in model ecosystems (microcosms) and enhance their productivity is of practical value. The results obtained in microcosms may confirm the feasibility of its application in semi-closed and closed agroecosystems—such as greenhouses, conservatories, and bioregenerative systems—where the requirements for environmental safety and biocontrol stability are particularly high. Introducing the phytopathogen *B. sorokiniana* into the system makes it possible to assess whether the strain retains its antifungal activity in an organic-rich substrate and in the presence of indigenous microflora—factors that are crucial for its application in protected cultivation.

Bacterization of wheat seeds had practically no effect on plant morphometric parameters: plant height showed a tendency to increase by 3%, while fresh and dry mass increased by 17% and 20%, respectively, compared to the control (see Table 3).

A similar trend was observed upon the introduction of the phytopathogen into the system: plant height and fresh and dry biomass did not differ significantly from the control. As in previous experiments, the application of bacteria in model ecosystems under conditions approximating natural ones had a positive effect on the phytosanitary status of the wheat plants (see Fig. 1).

In the system without the introduction of a phytopathogen, the prevalence of root rot in bacterized plants was 6% lower than in the control; this reflects a trend toward increased ecosystem suppressiveness against the natural background of infection, which is primarily associated with the presence of seed-borne pathogens in the spermosphere. Upon the introduction of a phytopathogen into the system, a reduction was observed in both the prevalence of root rot (by 18%) and the disease severity index (by 22%) in bacterized plants compared to non-bacterized plants.

More pronounced changes in wheat plants resulting from bacterial inoculation were observed during the analysis of guaiacol-dependent peroxidase activity in the leaves (see Fig. 2).

In the absence of a pathogen, bacterization with *P. extremorientalis* PhS1 significantly increased the activity of the enzyme under study by 12% compared to the control, indicating the activation of antioxidant systems even in the absence of an overt stress factor. The increase in guaiacol-dependent peroxidase activity in response to inoculation indicates the activation of plant defense mechanisms; this can be linked to the development of induced systemic resistance and the reduced susceptibility of bacterized plants to foliar pathogens observed in field experiments.

In the presence of *B. sorokiniana*, peroxidase activity in the control group increased by a statistically significant 16% compared to non-bacterized plants in systems without additional phytopathogen application; in the variant with seed inoculation by *P. extremorientalis*, the increase was 31%. This rise was accompanied by reduced disease severity, consistent with the mechanisms of induced resistance in cereals described for pseudomonads.

An increase in the activity of class III

Табл. 3. Морфометрические параметры развития растений пшеницы в модельных экосистемах, выращенных на органическом субстрате и аборигенной микрофлорой

Table 3. Morphometric parameters of wheat plant development in model ecosystems grown on organic substrate and indigenous microflora

Indicator	A version of a model system			
	without introduction of a phytopathogen		in the presence of *B. sorokiniana*	
	control	*P. extremorientalis*	control	*P. extremorientalis*
Plant height, cm	28,9 ± 0,9	29,8 ± 0,9	30,2 ± 1,0	28,8 ± 0,9^
Plant wet weight, g	0,25 ± 0,01	0,30 ± 0,06	0,26 ± 0,05	0,25 ± 0,04
Plant dry weight, g	0,06 ± 0,01	0,07 ± 0,01	0,06 ± 0,01	0,06 ± 0,01

Note. Here and in Fig. 2: ^ – statistically significant difference from the variant without the phytopathogen, based on the Student's t-test ($p < 0,05$).

peroxidases—which are responsible for lignification and the detoxification of reactive oxygen species—is directly linked to reduced susceptibility of plants to phytopathogens[7]. The observed increase in guaiacol-dependent peroxidase activity and the reduction in the prevalence and development index of root rots indicate the induction of systemic plant resistance by *P. extremorientalis*.

The experimental data obtained indicate that *P. extremorientalis* PhS1 bacteria retain their antifungal properties in a nature-like system—one with characteristics similar to protected-ground conditions—and help reduce the prevalence of wheat root rot in the presence of pathogen pressure, without adversely affecting plant growth processes. At the same time, the increased activity of guaiacol-dependent peroxidase in the leaves points to mechanisms of induced resistance as a key element of the beneficial effect of pseudomonads under conditions of limited chemical fungicide use.

CONCLUSION

The results of the study are consistent with published data indicating that members

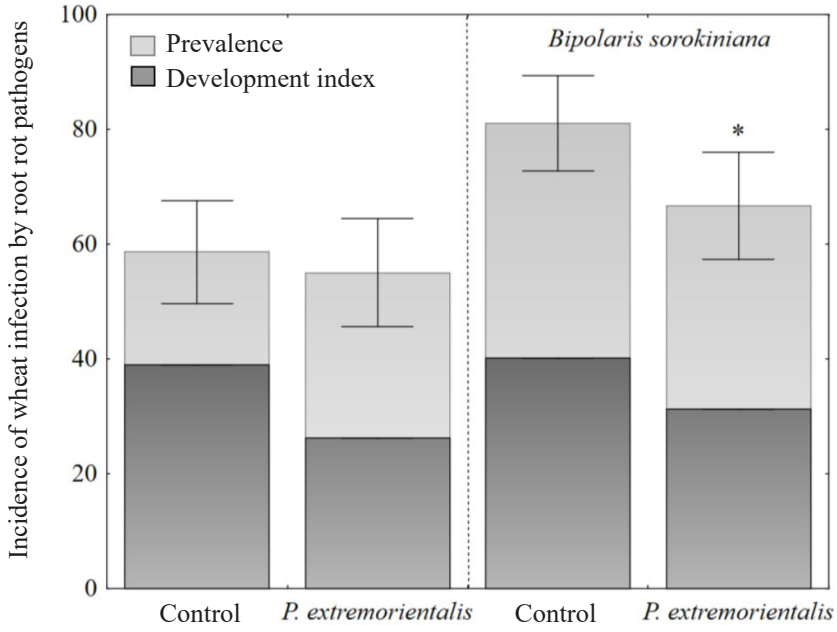


Рис. 1. Распространенность и индекс развития корневых гнилей растений пшеницы в модельных системах

Fig. 1. Root rot disease incidence and severity of wheat plants in model systems

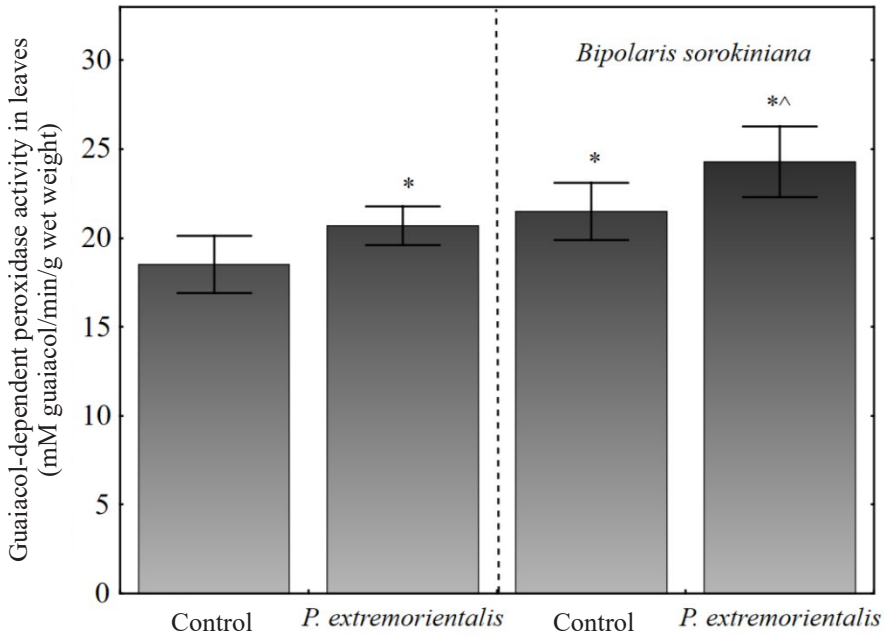


Рис. 2. Активность гваякол-зависимой пероксидазы в листьях пшеницы в модельных системах
Fig. 2. Activity of guaiacol-dependent peroxidase in wheat leaves in model systems

of the genus *Pseudomonas*, upon successful colonization of the root system, are capable of suppressing the development of phytopathogens and activating the host plant's defense mechanisms. Introducing the bacterium *P. extremorientalis* PhS1 into greenhouse complexes and strictly controlled closed ecosystems as a biological control agent—settings where phytosanitary standards are particularly stringent—shows promise.

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Особенности биологии клопа *Arma custos* в лабораторных условиях

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В современном сельском хозяйстве отмечен рост численности вредных членистоногих. Возрастает интерес к использованию энтомофагов как экологически безопасных агентов биологического контроля. Хищный клоп *Arma custos* (Fabricius, 1794) (Hemiptera: Pentatomidae: Asopinae) – полифаг, способный эффективно подавлять популяции ряда сельскохозяйственных и лесных вредителей. Изучены биологические особенности развития *A. custos* для оптимизации его массового культивирования. Исследование проводили на базе лаборатории биологического контроля фитофагов и фитопатогенов в Новосибирской области. Лабораторную популяцию клопов содержали в климатических камерах при температуре 24 ± 1 °C, относительной влажности 70–80% и фотопериоде 20 : 4 (день : ночь). Кормление осуществляли личинками и куколками *Tenebrio molitor*. Определяли продолжительность развития на разных стадиях онтогенеза, биометрические показатели имаго, репродуктивные характеристики и суточную прожорливость на четырех видах жертв (*Tenebrio molitor*, *Leptinotarsa decemlineata*, *Loxostege sticticalis*, *Mamestra brassicae*). Статистическую обработку данных выполняли с использованием U-критерия Манна-Уитни. Полный цикл развития от яйца до имаго составляет в среднем 34,3 ± 2,9 сут. Наиболее продолжительная стадия – имаго (49,8 ± 5,03 сут), максимальная зарегистрированная продолжительность жизни – 91 сут. Самки достоверно крупнее самцов (81 ± 2 мг против 59,0 ± 1,5 мг). Половой индекс ♀ : ♂ = 1,0 : 0,7. Среднее количество яиц в кладке – 27,4 ± 2,5 шт. (от 11 до 92). Максимальная суточная прожорливость имаго зафиксирована на гусеницах *L. sticticalis* (1,8 ± 0,37 особи/сутки), минимальная – на *M. brassicae* (0,6 ± 0,2). Личинки первого возраста не питаются, держатся колонией и только восполняют водный баланс. Начиная со второго возраста нимфы переходят к индивидуальному питанию. Полученные данные могут быть использованы при разработке технологий массовой наработки *A. custos* для биологической защиты растений.

Ключевые слова: *Arma custos,* Hemiptera, биологическая защита растений, энтомофаг, фитофаг, сельское хозяйство, клоп, полужесткокрылые

Biological features of the *Arma custos* bug in laboratory conditions

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In modern agriculture, there has been an increase in the number of harmful arthropods. There is growing interest in the use of entomophages as environmentally safe biological control agents. The predatory bug *Arma custos* (Fabricius, 1794) (Hemiptera: Pentatomidae: Asopinae) is a polyphagous species capable of effectively suppressing populations of a number of agricultural and forest pests. The biological characteristics of *A. custos* development have been studied to optimize its mass cultivation. The study was conducted at the laboratory of biological control of phytophages and phytopathogens in the Novosibirsk region. The laboratory population of bugs was kept in climate chambers at a temperature of 24 ± 1 °C, relative humidity of 70–80%, and a photoperiod of 20 : 4 (day : night). Feeding was carried out with larvae and pupae of *Tenebrio molitor*. The duration of development at different stages of ontogenesis, biometric indicators of the imago, reproductive characteristics and daily voracity were determined on four types of prey (*Tenebrio molitor*, *Leptinotarsa decemlineata*, *Loxostege sticticalis*, *Mamestra brassicae*). Statistical analysis was performed using the Mann–Whitney U test. The full development cycle from egg to adult averages 34,3±2,9 days. The longest stage is the adult stage (49,8 ± 5,03 days), with a maximum recorded lifespan of 91 days. Females are significantly larg-

er than males (81 ± 2 mg vs. 59 ± 1,5 mg). The sex ratio ♀ : ♂ = 1 : 0,7. The average number of eggs per clutch is 27,4 ± 2,5 (ranging from 11 to 92). The maximum daily voracity of adults was recorded on *L. sticticalis* caterpillars (1,8 ± 0,37 individuals/day), and the minimum on *M. brassicae* (0,6 ± 0,2). First-instar larvae do not feed, stay in a colony, and only replenish their water balance. Starting from the second instar, nymphs switch to individual feeding. The obtained data can be used in the development of mass rearing technologies for *A. custos* for plant protection purposes.

Keywords: *Arma custos,* Hemiptera, biological plant protection, entomophage, phytophage, agriculture, bug, hemipterans

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Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

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INTRODUCTION

In modern agriculture, pest control is mainly carried out using a mix of pesticides, which negatively affects beneficial invertebrates [1]. The increase in the number of harmful organisms that damage crops is due to a number of factors, including the rise in pest species and the development of resistance to the chemicals used. Because of this, special attention is given to finding new entomophages and maintaining the existing diversity of these, as they play a key role in biological pest control and help produce environmentally friendly agricultural products.

The suborder of hemipterans, also known as true bugs (Hemiptera: Heteroptera), constitutes one of the most extensive groups of insects. Among the representatives of this suborder, there are species classified as zoophages and zoophytophages that are capable of effectively controlling populations of harmful arthropods and positively influencing the ecological balance of agroecosystems.

One of these species is *Arma custos*, a polyphage capable of effectively controlling the spread of a number of agricultural and forest pests.

Arma custos (Fabricius, 1794) belongs to the order Hemiptera (hemipterans or true bugs), the family Pentatomidae (stink bugs), and the subfamily Asopinae. The species was described by the Danish entomologist Johann Fabricius in 1794. Following its initial description, this species underwent several changes in its taxonomic placement: in 1804, it was transferred to the genus *Pentatoma* Latreille, and in 1835, to *Asopus* Burmeister. In 1832, the German zoologist Carl Wilhelm Hahn—known for his detailed, illustrated works on the fauna of Germany—designated the genus *Arma* as a separate taxon, and *Arma custos* became the type species of this genus.

Due to repeated changes in its taxonomic position and the duplication of its description, this species has a number of synonyms: *Cimex custos* Fablicius, 1794, *Pentatoma custos* Latreille, 1804, *Asopus custos* Burmeister, 1835, *Stiretrus custos* Blanchard, 1840, *Asopus (Arma) custos* Blanchard, 1840, *Auriga custos* Flor, 1860, *Arma custos* f. *scutellaris* Stichel, 1961, *Arma neocustos* Ahmad & Onder, 1990, *Arma neoinspemta* Ahmad & Onder, 1990, *Arma chinensis*. The name of the genus *Arma*

derives from the Latin word “arma”, meaning "weapons," "armor," or "armament," as well as—in a figurative sense—"war" or "military operations"[1–4].

An important aspect of systematics is the clarification of the species status of individual species. For instance, in 2018, Zhao et al. [2] established the synonymy of *Arma chinensis* and *Arma custos* based on morphological, molecular-genetic, and geographic data—a finding of significant importance for the practical application of this species in biological control.

A. custos is a widely distributed species found throughout the Palaearctic; in Europe, it occurs everywhere from the Atlantic coast to the Urals. It inhabits central and southern regions (France, Germany, Poland, Ukraine, Belarus). In Scandinavia, it is less common, occurring primarily in the southern parts. In Russia, the species is widely distributed across the European part of the country, the Caucasus, southern Siberia, and the Far East (including Primorye and Sakhalin). In Asia, its range extends through Kazakhstan, Central Asia, Mongolia, and China to the Korean Peninsula and Japan. In Asia Minor and the Middle East, the species has been recorded in Turkey and the northern mountainous regions of Iran[5, 6] [3].

A. custos exhibits a broad prey spectrum, comprising predominantly representatives of the order Lepidoptera (lepidopterans), Coleoptera (coleopterans), as well as certain other insects. *A. custos* is a zoophytophage. The primary groups of prey in agroecosystems are owlet moth caterpillars (Noctuidae), cankerworms (Geometridae), white butterflies (Pieridae), leaf-roller moth (Tortricidae), as well as leaf beetle larvae (Chrysomelidae), weevils (Curculionidae).

The predatory behavior of *A. custos* relies on the use of a specialized venomous secretion produced by the salivary glands. Light microscopy studies have revealed that the venom apparatus of *A. custos* consists of a paired main gland and a tubular accessory gland. The main gland consists of two lobes: an anterior main lobe and a posterior main lobe. Between the lobes of the main gland lies a distinct constriction forming a hilum, into which two separate ducts empty: the venom duct of the main gland and the duct connecting the accessory gland to the main gland. The venom duct extends toward the head and connects to the venom delivery apparatus (venom pump), whereas the accessory gland duct runs toward the thorax and connects to the accessory gland. Venom synthesis and accumulation occur in the anterior main, posterior main, and accessory glands, while their ducts are responsible for transporting the secretion [4].

A study published by Qu et al. presents a detailed analysis of the composition of the venomous secretion of *A. custos*. The researchers identified over 100 proteins in the secretion, 47 of which were classified as potential toxins. The main functional groups include oxidoreductases, transferases, hydrolases, ligases, and protease inhibitors, as well as recognition, transport, and binding proteins. Alongside uncharacterized proteins, the most abundant protein families are hydrolases, such as serine proteases, cathepsins, phospholipase A2, phosphatases, nucleases, alpha-amylases, and chitinases [5].

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The mechanism of the venom's action involves several stages: proteolytic enzymes cause the destruction of the victim's tissues and internal organs; neurotoxic components block the victim's nervous system, causing paralysis; and hemolytic factors destroy the insect's hemolymph.

The combined action of these components ensures the rapid immobilization of the victim [6].

Many research groups have noted the potential of predatory bug toxins as promising sources of selective insecticides[7, 8] [7, 8].

In addition, *A. custos* eggs are parasitized under laboratory conditions by egg parasitoids of the genus *Trissolcus*. Consequently, this species could serve as a laboratory host for the mass rearing of biological control agents [9–11].

In plant protection practice, the bug *A. custos* itself can be used directly to control pest populations, while its eggs can serve as a substrate for rearing parasites used in plant protection; furthermore, in research, various metabolites derived from the insect can provide a basis for the development of selective insecticides.

The purpose of the study is to investigate the biological developmental characteristics of the Siberian population of *A. custos* under laboratory conditions in order to optimize its mass cultivation.

MATERIAL AND METHODS

Since 2023, a colony of *A. custos*—derived from individuals collected in Western Siberia—has been maintained at the Laboratory of Biological Control of Phytophages and Phytopathogens of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences (SFSCA RAS). Individuals collected from agro- and phytocenoses are introduced into the population annually. The laboratory population of *A. custos* adults and nymphs was maintained in Biotron-8 climate chambers (manufactured by the Siberian Physical and Engineering Institute of Agrarian Issues SFSCA RAS) with controlled environmental parameters. The insects were reared in plastic containers (30 × 40 × 25 cm) covered with fine mesh, at a temperature of 24 ± 1°C, a relative humidity of 70–80%, and a 20:4 light-dark photoperiod. Spurflower plants (*Coleus amboinicus*) and kalanchoe (*Kalanchoe blossfeldiana*) were kept continuously in the containers housing adults and late-instar nymphs (third to fifth instars). Feeding was carried out 2–3 times a week using *Tenebrio molitor* larvae and pupae.

The sex ratio was calculated and expressed as ♀ : ♂ = 1 : x depending on the proportion of females to males among the total number of adult individuals counted in the entire lab population of adults[9].

Daily prey consumption was measured by placing a single *A. custos* adult in a 9 cm Petri dish with three larvae of one prey species (*Tenebrio molitor, Leptinotarsa decemlineata, Loxostege sticticalis, Mamestra brassicae*). All the predators used in the study were starved for 24 hours before the experiment started and were given only water. The number of dead prey insects was counted after one day.

To compare the groups, the non-parametric Mann-Whitney U test was used (results were considered statistically significant at $p \leq 0.05$). The data are presented as the mean ± standard error of the mean (Mean ± SE).

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RESULTS AND DISCUSSION

To develop an effective and economically viable technology for the mass rearing of the predatory bug *A. custos*, a detailed study of its biological characteristics under controlled laboratory conditions is essential. Understanding developmental timing across ontogenetic stages, biometric parameters, reproductive potential, and trophic activity is critical for optimizing rearing processes, planning production cycles, and evaluating the efficacy of this entomophage as a biological control agent.

Under laboratory conditions, female *A. custos* deposited egg batches in sheltered locations—primarily on the undersides of spurflower leaves, and less frequently on tulle fabric or the walls of the plastic container (see Fig. 1). Each batch contains between 11 and 92 eggs, with a mean of 27.4 ± 2.5. Fresh eggs laid by fertilized females are milky white but acquire an orange hue as the embryo develops. Females do not exhibit parental instincts after oviposition. First-instar *A. custos* larvae hatching from a single egg batch remain together in a colony for an extended period. Under laboratory conditions, they do not feed prior to molting into the second instar, instead merely replenishing their water balance from a moist cotton swab. From the second instar onwards, the colony disperses, and the nymphs begin to hunt and feed individually. Laboratory observations have also shown that both nymphs and adults may share a single prey item.



Рис. 1. Яйцекладки *Arma custos* на листьях *Coleus amboinicus* (фото Е.И. Шаталовой)

Fig. 1. Egg clutches of *Arma custos* on the leaves of *Coleus amboinicus* (photo by E.I. Shatalova)

Under laboratory rearing conditions, the developmental time parameters for *A. custos* at each stage of ontogenesis were determined (see Table 1).

Under laboratory conditions, the egg stage lasted an average of 4.2 ± 0.54 days. During the larval stage, the transitions between successive instars—from the first to the fifth—were roughly equal in duration, taking 5–6 days; the mean development time from egg to adult was 34.3 ± 2.9 days (see Fig. 2). The adult stage was the longest, with a mean lifespan of 49.80 ± 5.03 days. The maximum recorded lifespan of *A. custos* adults was 91 days. Several research groups abroad have also studied the biological characteristics of *A. custos* within similar temperature ranges, and their results show developmental periods that deviate in one direction or the other. For instance, Zou et al.[10]

Табл. 1. Жизненный цикл *A. custos* при температуре 24 ± 1 °C

Table 1. Life cycle of *A. custos* at a temperature of 24 ± 1 °C

Insect development stage	Duration of development, days		
	min	max	mean ± SE
Egg	2	9	4,20 ± 0,54
Nymphs of the age: first	3	9	5,48 ± 0,35
second	2	9	6,00 ± 0,10
third	2	12	6,50 ± 0,67
fourth	4	10	6,40 ± 0,57
fifth	3	9	5,75 ± 0,70
Imago	5	91	49,80 ± 5,03

[10]*Zou D.Y., Wang M.Q., Zhang L.S., Zhang Y., Zhang X.J., Chen H.Y.* Taxonomic and bionomic notes on *Arma chinensis* (Fallou) (Hemiptera: Pentatomidae: Asopinae) // Zootaxa. 2012. Vol. 3382. N 1. P. 41–52. DOI: 10.11646/zootaxa.3382.1.4



Рис. 2. Нимфы *Arma custos* первого возраста на листе *Coleus amboinicus* (фото А.В. Воронковой)

Fig. 2. Nymphs of *Arma custos* of the first instar on the leaf of *Coleus amboinicus* (photo by A.V. Voronkova)

studied the developmental rate of *A. custos* (the synonym *A. chinensis* is cited in the paper) at 27 ± 1°C. The resulting mean developmental durations (in days) from the egg stage to the fifth-instar nymph stage were 6.43 ± 0.08, 3.25 ± 0.07, 4.11 ± 0.1, 3.41 ± 0.07, 4.00 ± 0.11, and 5.89 ± 0.09, respectively. The lifespan was 44.18 ± 1.08 for males and 37.25 ± 1.14 for females. Wang et al. [12] studied the developmental rate ranges of *A. custos* under various temperature regimes. Thus, at 22 ± 1°C, the average developmental duration (in days) from egg to adult was, respectively, 8,76 ± 0,04; 6,74 ± 0,18; 6,19 ± 0,21; 5,20 ± 0,15; 6,28 ± 0,22;11,09 ± 0,19; 112,94 ± 6,06. When bed bugs were reared at 26 ± 1°C, the mean developmental duration (in days) from egg to adult was, respectively, 6,39 ± 0,04; 4,12 ± 0,80; 4,50 ± 0,09; 3,48 ± 0,10; 4,17 ± 0,10; 7,08 ± 0,09 и 99,91 ± 4,52. The observed differences may be attributed to specific aspects of laboratory rearing, including variations in biotic factors (e.g., food sources, the temperature sensitivity of *A. custos* populations from different regions, and the presence or absence of plants in the rearing containers) as well as the maintenance of abiotic factors (such as the characteristics of climate-control equipment and the provision of optimal humidity).

Biometric parameters of the adults and reproductive characteristics are crucial for assessing the quality of the laboratory culture and its capacity for sustainable reproduction (see Table 2). It was found that females are significantly larger than males: their average mass was 81 ± 2.0 mg, whereas that of males was 59 ± 1.5 mg.

Reproductive parameters of *A. custos* varied widely: the mean number of eggs per clutch was 27.4 ± 2.5, ranging from a minimum of 11 to a maximum of 92. The high variability of this parameter may be attributed to both rearing conditions and individual characteristics of the specimens.

The trophic activity of *A. custos* is of great importance for assessing its effectiveness as a biological control agent. Table 3 presents data on the daily consumption rate of adult *A. custos* when feeding on various species of prey insects.

Adult *A. custos* exhibited the highest daily voracity when feeding on meadow moth (*L. sticticalis*) caterpillars (1.80 ± 0.37 individuals per day) and mealworm (*T. molitor*) larvae (1.6 ± 0.4 individuals per day). *L. decemlineata* (0.83 ± 1.60 individuals per day) and *M. brassicae* (0.6 ± 0.2 individuals per day) proved to be less attractive prey for *A. custos*. It is worth noting the high variability in the consumption of Colorado potato beetle larvae by the bugs, as in many replicates the prey remained alive and

Табл. 2. Биометрические показатели *A. custos*
Table 2. Biometric parameters of *A. custos*

Indicator	♂	♀
Weight, mg ± SE	59,0 ± 1,5[a]	81 ± 2[b]
Sex ratio, ♀:♂	1 : 0,7	
Average number of eggs, pcs. ± SE	27,4 ± 2,5	
Number of eggs in a clutch: minimal	11	
maximum	92	

Note. The letters "a" and "b" denote values of the indicator that differ significantly ($p > 0,05$). Pairwise comparisons were performed using the Mann-Whitney U test.

Табл. 3. Суточная прожорливость имаго *A. custos* на личинках третьего – пятого возраста представителей отряда Lepidoptera и Coleoptera

Table 3. Daily feeding rate of *A. custos* adults on 3rd–4th instar larvae of Lepidoptera and Coleoptera

Вид кормового насекомого	Среднее количество жертв ± SE
Tenebrio molitor	1,6 ± 0,4[a]
Leptinotarsa decemlineata	0,83 ± 1,6[b]
Loxostege sticticalis	1,8 ± 0,37[a]
Mamestra brassicae	0,6 ± 0,2[b]

Note. The letters "a" and "b" denote values of the indicator that do not differ significantly ($p > 0,05$). Pairwise comparisons were performed using the Mann-Whitney U test.

the predator did not feed throughout the entire experiment.

CONCLUSIONS

1. Under laboratory conditions (temperature 24 ± 1°C, relative humidity 70–80%, photoperiod 20:4), the complete developmental cycle of *A. custos* from egg to adult averaged 34.3 ± 2.9 days. The adult stage was the longest, lasting 49.80 ± 5.03 days, with a maximum recorded lifespan of 91 days.

2. Sexual dimorphism in body mass was observed: *A. custos* females are significantly larger than males (mean mass 81 ± 2 mg vs. 59.0 ± 1.5 mg; $p < 0.05$). Females predominate in the population; the sex ratio in the laboratory population is ♀ : ♂ = 1,0 : 0,7.

3. Reproductive parameters are characterized by high variability: the mean clutch size is 27.4 ± 2.5, ranging from 11 to 92. No parental behavior was observed in females after egg-laying.

4. The maximum daily consumption rate of *A. custos* adults was recorded when feeding on larvae of the meadow moth (*L. sticticalis*)—1.8 ± 0.37 individuals/day—while the minimum was observed with larvae of the cabbage moth (*M. brassicae*)—0.6 ± 0.2 individuals/day. Consumption rates for larvae of the yellow mealworm (*T. molitor*) and the Colorado potato beetle (*L. decemlineata*) were 1.6 ± 0.4 and 0.83 ± 1.6 individuals, respectively.

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Скрининг почвенно-ризосферных микроорганизмов, перспективных для контроля фитопатогенов и стимуляции роста растений

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В условиях экологизации земледелия возрастает значение поиска микроорганизмов, обладающих антагонистической активностью в отношении фитопатогенов и свойствами, связанными со стимулированием роста растений. Цель данной работы – отбор перспективных микробных изолятов для дальнейшего использования в составе биопрепаратов сельскохозяйственного назначения. В работе изучали 24 бактериальных изолята, выделенных из образцов почвы и ризосферы, отобранных в луговых экосистемах и сельскохозяйственных агроценозах различных регионов Российской Федерации. Таксономическую принадлежность бактериальных изолятов устанавливали по последовательностям гена 16S рРНК. Антифунгальную активность оценивали в отношении *Fusarium oxysporum*, *Rhizoctonia solani*, *Alternaria alternata* и *Bipolaris sorokiniana*. Дополнительно определяли амилолитическую, протеолитическую и фосфатмобилизирующую активность как показатель гидролитического потенциала и отдельных признаков, связанных с ростостимулирующим действием. В результате молекулярно-генетической идентификации установлено, что исследованные изоляты относятся преимущественно к представителям родов *Bacillus*, *Pseudomonas*, *Priestia*, *Achromobacter*, *Enterobacter*, *Serratia*, *Enterococcus* и к семейству Bacillaceae. Наиболее высокую совокупную антифунгальную активность продемонстрировал изолят 26, отнесенный к *Bacillus* sp. (*subtilis* species complex), который ингибировал все изучаемые фитопатогенные грибы. Максимальная протеолитическая активность отмечена у изолята 35 (*Pseudomonas* sp., *P. fluorescens* group) – 2,45 см, амилолитическая – у изолята 42 (семейство Bacillaceae) – 3,56 см, фосфатмобилизирующая – у изолята 39 (*Bacillus* sp., *subtilis* species complex) – 1,4 см. Установлено, что наиболее перспективные по комплексу изученных признаков изоляты относились преимущественно к представителям рода *Bacillus* и *Pseudomonas*. Полученные результаты указывают на целесообразность дальнейшего изучения данных изолятов как потенциальных компонентов микробных консорциумов и биопрепаратов с биоконтрольным и ростстимулирующим потенциалом.

Ключевые слова: *Bacillus*, *Pseudomonas*, антифунгальная активность, гидролитические ферменты, фосфатмобилизирующая активность

Screening of soil-rhizosphere microorganisms promising for the control of phytopathogens and stimulation of plant growth

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In the context of agriculture ecologization, the importance of searching for microorganisms with antagonistic activity against phytopathogens and properties related to the stimulation of plant growth is increasing. The purpose of this work is the selection of promising microbial isolates for further use as part of agricultural biopreparations. The study examined 24 bacterial isolates obtained from soil and rhizosphere samples collected in meadow ecosystems and agricultural agrocenoses of various regions of the Russian Federation. The taxonomic affiliation of the bacterial isolates was determined using 16S rRNA gene sequences. Antifungal activity was evaluated against *Fusarium oxysporum*, *Rhizoctonia solani*, *Alternaria alternata*, and *Bipolaris sorokiniana.* Additionally, amylolytic, proteolytic, and phosphate-mobilizing activities were determined as an indicator of hydrolytic potential and specific

traits associated with growth-stimulating effects. As a result of molecular-genetic identification, it has been established that the studied isolates primarily belong to the genera *Bacillus*, *Pseudomonas*, *Priestia*, *Achromobacter*, *Enterobacter*, *Serratia*, *Enterococcus*, and the *Bacillaceae* family. The highest overall antifungal activity was demonstrated by isolate 26, classified as *Bacillus* sp. (*subtilis* species complex), which inhibited all the studied phytopathogenic fungi. The maximum proteolytic activity was observed in isolate 35 (*Pseudomonas* sp., *P. fluorescens* group) and amounted to 2.45 cm, amylolytic activity in isolate 42 (*Bacillaceae* family) was 3.56 cm, and phosphate-mobilizing activity in isolate 39 (*Bacillus* sp., *subtilis* species complex) was 1.4 cm. It has been found that the isolates most promising in terms of the set of studied traits belonged predominantly to the genera *Bacillus* and *Pseudomonas*. The results obtained indicate the feasibility of further investigating these isolates as potential components of microbial consortia and biological preparations with biocontrol and growth-stimulating potential.

Keywords: *Bacillus, Pseudomonas*, antifungal activity, hydrolytic enzymes, phosphate-mobilizing activity

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INTRODUCTION

Soil and rhizosphere microorganisms play a key role in keeping agroecosystems productive, taking part in breaking down organic matter, mobilizing nutrients, and helping plants resist harmful biotic and abiotic factors. In this regard, there is particular interest in finding microbial isolates that can both suppress the growth of plant pathogens and have properties that promote plant growth. Such microorganisms are seen as a promising basis for creating next-generation bioproducts aimed at reducing chemical use in crop production [1].

Among the most important groups of microorganisms for agricultural biotechnology, *Bacillus* and *Pseudomonas* are traditionally highlighted, as they are known for their ability to produce a wide range of biologically active compounds, including antibiotic metabolites, siderophores, organic acids, and extracellular hydrolytic enzymes. Because of this, such microorganisms can act both as biocontrol agents against phytopathogens and as components of plant-microbe systems that improve nutrient availability and the competitiveness of plants in the rhizosphere [1–3]. Important traits when selecting promising isolates include antagonistic activity against pathogenic fungi, hydrolytic potential, and the ability to mobilize poorly soluble phosphates [4, 5].

Antifungal activity is of primary interest when searching for microorganisms for biological plant protection, while amylolytic and proteolytic activity can be considered as an indicator of strong hydrolytic potential, important for the transformation of organic matter and interactions between microbes. The ability to mobilize phosphate is one of the most sought-after traits in microbes that promote

growth, as it is linked to increasing phosphorus availability for plants [1, 4]. A comprehensive assessment of these properties allows for a more informed selection of strains suitable for creating effective microbial consortia.

The relevance of searching for new isolates is due to the fact that even closely related microorganisms can differ significantly in the expression of economically valuable traits. Cultures isolated from soil and the rhizosphere of various ecosystems are especially promising, as they are adapted to living in complex natural communities and can potentially combine properties important for biocontrol and plant growth stimulation.

The purpose of the study is to select promising microbial isolates with a set of traits important for controlling plant pathogens and promoting plant growth, and to determine their taxonomic identity for later use in microbial consortia and agricultural bioproducts.

MATERIAL AND METHODS

The research was conducted at the Laboratory of Plant Biological Protection and Biotechnology at the Siberian State University of Engineering and Biotechnology (Novosibirsk) in 2025. During the work, 24 isolates were selected and studied from the laboratory collections and the industrial partner OOO "EM-Biotech," which had previously been characterized by their morphocultural properties (growth rate on ANM, colony shape, motility, Gram staining). The microbial isolates were obtained from soil and rhizosphere samples collected in meadow ecosystems and agricultural agrocenoses in various regions of the Russian Federation.

Proteolytic activity was determined by detecting gelatinase activity on a gelatin medium[1].

The medium of the following composition: gelatin – 50 g/l, K_2HPO_4 – 0.5 g/l – was poured in 6 ml portions into test tubes, after which inoculation was done by stabbing 3.5 cm deep. Cultivation was carried out at 26 °C for 10 days, which ensured that the gelatin medium remained firm throughout the entire observation period. After incubation, the test tubes were kept in the fridge for 1 hour, then the depth of the gelatin liquefaction zone along the stab line was measured. The result was expressed in centimeters. The experiment was done five times.

The ability of isolates to mobilize insoluble phosphates was evaluated on the standard Pikovskaya medium[2]. The sowing was done by stabbing the center of the Petri dish. Cultivation was carried out at 30 °C, and results were recorded on the 7th day. Activity was assessed by the diameter of the clearing zone around the colony, with results expressed in centimeters. The experiment was performed in triplicate.

Amylolytic activity was determined by the ability of isolates to hydrolyze starch on starch-ammonium agar (SAA); the hydrolysis zones were detected after treating the plates with Lugol's solution[3]. The inoculation was done with a stab, and the cultivation was carried out at 30 °C for 7 days. After incubation, the plates were treated with Lugol's solution, and then the diameter of the starch hydrolysis zone was measured in centimeters. Measurements were taken in the dark with backlighting. The experiment was done in five replicates.

The antagonistic activity of the isolates against phytopathogenic fungi was determined on Czapek-Dox medium[4]. A block of actively growing culture of the phytopathogenic fungus

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[3] *Allen P.W.* A Simple Method for the Classification of Bacteria as to Diastase Production // Journal of Bacteriology, 1918, vol. 3, N 1, pp. 15–17. DOI: 10.1128/jb.3.1.15-17.1918.

[4] *Dox A.W.* The intracellular enzymes of *Penicillium* and *Aspergillus*: with special reference to those of *Penicillium camemberti* // U.S. Department of Agriculture, Bureau of Animal Industry Bulletin. 1910. N 120. P. 1–70.

was placed on the surface of the medium (*Fusarium oxysporum, Rhizoctonia solani, Alternaria alternata* and *Bipolaris sorokiniana*). Three blocks of the two isolates being studied were placed on each Petri dish. So, one dish was treated as one biological replicate, and the three blocks of a single isolate on one dish were considered technical replicates. For each test fungus, the experiment was done in five independent Petri dishes. The results were recorded after 7–10 days, when the control fungus had completely covered the Petri dish. Antifungal activity was evaluated based on the size of the fungal growth inhibition zone, measured in centimeters.

The taxonomic affiliation of the bacterial isolates was determined based on the 16S rRNA gene sequences[5, 6] to the Shared Use Center "Genomics" of the SB RAS (Institute of Chemical Biology and Fundamental Medicine SB RAS, Novosibirsk, Russia).

The identification of bacterial isolates was carried out using the 16S rRNA gene fragment by Sanger sequencing with primers 27F/1492R. AB1 chromatogram files were analyzed using the UGENE program[7]. Low-quality regions at the 5' and 3' ends of the reads were manually removed based on the chromatograms; for the sequence obtained with the 1492R primer, a reverse-complement sequence was generated. Then the forward and reverse reads were combined, and a local pairwise alignment was performed to find overlapping regions. If a correct overlap was present, a consensus sequence was formed.

Ambiguous positions were marked with IUPAC codes and, when aligned with an unambiguous position from a second reading, clarified with the corresponding nucleotide. The resulting sequences were identified using BLASTn (Megablast) against the NCBI database "16S ribosomal RNA sequences (Bacteria and Archaea)" while excluding "uncultured/environmental sample sequences"; the closest BLAST hits, query length, percentage identity, and coverage were taken into account[8]. In cases where it wasn't possible to form a consensus sequence, a single read was used to search for the closest BLAST hits. The RC notation in the table indicates that the analysis was done on the reverse complement sequence.

The taxonomic affiliation was interpreted taking into account the limited resolution of the 16S rRNA marker for closely related taxa[9]. By default, isolates were assigned to a certain genus. If there were several closely related species with comparable identity and coverage values and no consistently dominant taxon, the identification level was indicated as a group or complex of closely related species. The species level was only used in the cases of stable dominance of one species among the closest BLAST hits. If the closest hits belonged to several genera, the taxonomic affiliation was indicated at the family level (see Table 1).

The results were processed using StatSoft STATISTICA 12.0. The results are presented as the mean and standard deviation ($M \pm SD$). For antifungal activity, one Petri dish was considered as one biological replicate, with three blocks of one isolate on a single dish counted as technical replicates ($n = 15$). For proteolytic and amylolytic activities, the experiments were done in five replicates ($n = 5$), and for phosphate-mobilizing activity – in triplicate ($n = 3$).

[5]*White T.J., Bruns T., Lee S., Taylor J.W.* Amplification and Direct Sequencing of Fungal Ribosomal RNA Genes for Phylogenetics // In: PCR Protocols: A Guide to Methods and Applications / ed. by M.A. Innis, D.H. Gelfand, J.J. Sninsky, T.J. White. San Diego: Academic Press, 1990. P. 315–322. DOI: 10.1016/B978-0-12-372180-8.50042-1.

[6]*Schoch C.L., Seifert K.A., Huhndorf S. et al.* Nuclear ribosomal internal transcribed spacer (ITS) region as a universal DNA barcode marker for Fungi // Proceedings of the National Academy of Sciences of the United States of America. 2012. Vol. 109. N 16. P. 6241–6246. DOI: 10.1073/pnas.1117018109.

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[9]*Janda J.M., Abbott S.L.* 16S rRNA gene sequencing for bacterial identification in the diagnostic laboratory: pluses, perils, and pitfalls // Journal of Clinical Microbiology. 2007. Vol. 45. N 9. P. 2761–2764. DOI: 10.1128/JCM.01228-07.

Табл. 1. Таксономическое обозначение исследованных микробных изолятов и результаты их молекулярной идентификации

Table 1. Taxonomic designation of the studied microbial isolates and the results of their molecular identification

Isolate number	Accepted taxonomic designation	Level of identification	Upcoming BLAST hits	Request length, bp	Identity, %	Coverage, %
6	*Bacillus* sp. (*B. cereus* group)	Group	*B. thuringiensis; B. paramobilis; B. mobilis*	1421	99,9	100
9	*Bacillus* sp. (*subtilis* species complex)	Complex	*B. subtilis; B. stercoris; B. inaquosorum; B. cabrialesii*	1431	99,9	100
16	*Bacillus* sp. (*B. cereus* group)	Group	*B. thuringiensis; B. paramobilis; B. mobilis*	1416	99,4	100
17	*Bacillus* sp. (*B. cereus* group)	Group	*B. thuringiensis; B. paranthracis; B. proteolyticus*	1428	99,8	100
20	*Bacillus* sp. (*subtilis* species complex)	Complex	*B. subtilis;B. stercoris; B. cabrialesi*i	1469	99,0	100
23	Bacillaceae	Family	*Priestia aryabhattai; P. flexa; Bacillus zanthoxyli; Peribacillus simplex*	1183	100,0	100
24	*Bacillus* sp. (*subtilis* species complex)	Complex	*B. velezensis; B. amyloliquefaciens; B. subtilis*	1412	99,7	100
29	*Bacillus* sp. (*subtilis* species complex)	Complex	*B. subtilis; B. stercoris; B. cabrialesii*	1402	99,8	100
26	*Bacillus* sp. (*subtilis* species complex)	Complex	*B. velezensis; B. subtilis; B. amyloliquefaciens*	1405	97,7	100
31	*Achromobacter* sp.	Genus	*Achromobacter deleyi; A. spanius; A. piechaudii*	683 (RC)	98,7	100
34	*Bacillus* sp. (*B. cereus* group)	Group	*B. mycoides;B. hominis; B. wiedmannii*	1430	98,5	100
35	*Pseudomonas* sp. (*P. fluorescens* group)	Group	*Pseudomonas koreensis; P. reinekei; P. glycinae*	1428	99,4	100
39	*Bacillus* sp. (*subtilis* species complex)	Complex	*B. velezensis; B. subtilis; B. amyloliquefaciens*	1438	99,7	100
40	*Bacillus* sp. (*subtilis* species complex)	Complex	*B. subtilis; B. cabrialesii; B. inaquosorum*	1371	99,7	100
42	Bacillaceae	Family	*B. velezensis; Calidifontibacillus erzurumensis; B. amyloliquefaciens*	1327	96,0	100
44	*Pseudomonas chlororaphis*	Genus	*P. chlororaphis* subsp. *aurantiaca; P. chlororaphis* subsp. *aureofaciens*	1423	99,5	100
45	*Priestia* sp.	Genus	*Priestia aryabhattai; P. flexa; Bacillus zanthoxyli*	1284	97,9	95
52	*Enterococcus* sp.	Genus	*Enterococcus faecium; E. durans; E. hirae*	1470	94,0	100
51*	*Enterococcus*-like isolate	–	*Enterococcus lactis; E. faecium; E. durans*	687 (RC)	87,0	80
58	*Serratia* sp.	Genus	*Serratia plymuthica; S. inhibens; S. liquefaciens*	1426	99,1	100
78	*Bacillus* sp. (*B. pumilus* group)	Group	*B. aerius; B. stratosphericus; B. altitudini*s	1417	99,8	100
100	*Enterobacter* sp.	Genus	*Enterobacter quasihormaechei; E. hormaechei; E. bugandensis*	1352	97,4	97
122	*Bacillus* sp. (*B. cereus* group)	Group	*B. proteolyticus; B. sanguinis; B. cereus; B. wiedmannii*	1418	99,9	100
134	*Bacillus* sp. (*B. cereus* group)	Group	*B. cereus; B. proteolyticus; B. albus*	1414	99,4	100

*For isolate 51, identification based on 16S rRNA is preliminary: the closest BLASTn hits belong to the genus *Enterococcus*; however, the identity and coverage values (87.0% identity and 80% coverage; query length 687 bp, RC) are insufficient for reliable taxonomic identification.

RESULTS AND DISCUSSION

As a result of the experiments conducted, it was found that isolate 26, classified as *Bacillus* sp. (*subtilis species* complex), showed the highest overall antifungal activity against *Rhizoctonia solani*, *Fusarium oxysporum*, *Alternaria alternata*, and *Bipolaris sorokiniana* (see Table 2). Next in terms of overall antifungal effect were isolates 44 (*Pseudomonas chlororaphis*), 42 (family Bacillaceae), 35 (*Pseudomonas* sp., *P. fluorescens* group), and 23 (family Bacillaceae). So, the highest antagonistic potential in the collection studied was mainly characteristic of members of the genus *Bacillus*, family Bacillaceae, and genus Pseudomonas.

When analyzing activity against specific phytopathogens, it was found that isolate 26 had the most pronounced inhibitory effect against *R. solani* (2.80 cm), followed by isolates 17 (2.19 cm) and 45 (1.97 cm). For *F. oxysporum*, isolate 26 also led the way (3.41 cm), followed by isolates 44 (1.72 cm) and 23 (1.53 cm) (see Fig. 1). For *A. alternata*, the largest inhibition zones were formed by isolates 26 (2.47 cm), 44 (1.82 cm), and 23 (1.57 cm). For *B. sorokiniana*, the most active were isolates 26 and 29 (both 1.87 cm), as well as isolate 20 (1.83 cm). So, isolate 26 showed the highest antifungal activity against all four test fungi.

It is known that one possible mechanism of bacteria's antagonistic action is the production of

Табл. 2. Антифунгальная активность изолятов *in vitro* ($n = 15$, $M \pm SD$)
Table 2. Antifungal activity of isolates *in vitro*, ($n = 15$, $M \pm SD$)

Isolate number	Diameter of the growth inhibition zone for the test culture (halo, cm)				Taxonomic designation
	R. solani	*F. oxysporum*	*A. alternata*	*B. sorokiniana*	
6	1,75 ± 0,22	0,96 ± 0,66	0,68 ± 0,58	0,09 ± 0,15	*Bacillus* sp. (*B. cereus* group)
44	1,79 ± 0,21	1,72 ± 0,24	1,82 ± 0,25	1,58 ± 0,41	*Pseudomonas chlororaphis*
35	1,57 ± 0,26	1,34 ± 0,27	1,53 ± 0,37	1,11 ± 0,65	*Pseudomonas* sp. (*P. fluorescens* group)
26	2,80 ± 0,24	3,41 ± 0,49	2,47 ± 0,63	1,87 ± 0,45	*Bacillus* sp. (*subtilis* species complex)
16	1,65 ± 0,21	0,43 ± 0,56	0,32 ± 0,58	0,09 ± 0,15	*Bacillus* sp. (*B. cereus* group)
45	1,97 ± 0,12	1,26 ± 0,20	1,29 ± 0,18	0,07 ± 0,18	*Priestia* sp.
58	0,00 ± 0,00	0,00 ± 0,00	0,00 ± 0,00	0,86 ± 0,64	*Serratia* sp.
39	0,65 ± 0,28	0,41 ± 0,12	0,84 ± 0,24	1,37 ± 0,35	*Bacillus* sp. (*subtilis* species complex)
17	2,19 ± 0,29	1,37 ± 0,46	1,06 ± 0,74	0,09 ± 0,15	*Bacillus* sp. (*B. cereus* group)
34	1,38 ± 0,18	0,39 ± 0,58	0,21 ± 0,44	0,00 ± 0,00	*Bacillus* sp. (*B. cereus* group)
42	1,73 ± 0,43	1,25 ± 0,19	1,34 ± 0,19	1,71 ± 0,38	Bacillaceae
23	1,71 ± 0,24	1,53 ± 0,39	1,57 ± 0,18	0,63 ± 0,87	Bacillaceae
122	0,00 ± 0,00	0,00 ± 0,00	0,00 ± 0,00	0,44 ± 0,51	*Bacillus* sp. (*B. cereus* group)
24	0,65 ± 0,20	1,13 ± 0,21	1,13 ± 0,21	1,60 ± 0,29	*Bacillus* sp. (*subtilis* species complex)
9	0,71 ± 0,28	0,05 ± 0,11	0,05 ± 0,11	1,64 ± 0,26	*Bacillus* sp. (*subtilis* species complex)
31	1,33 ± 0,33	0,01 ± 0,05	0,01 ± 0,05	0,59 ± 0,59	*Achromobacter* sp.
100	0,32 ± 0,44	0,06 ± 0,13	0,06 ± 0,13	0,00 ± 0,00	*Enterobacter* sp.
20	0,79 ± 0,34	0,45 ± 0,41	0,45 ± 0,41	1,83 ± 0,40	*Bacillus* sp. (*subtilis* species complex)
29	0,35 ± 0,29	0,67 ± 0,44	0,67 ± 0,44	1,87 ± 0,39	*Bacillus* sp. (*subtilis* species complex)
51	0,00 ± 0,00	0,00 ± 0,00	0,11 ± 0,25	1,08 ± 0,57	*Enterococcus*-like isolate
52	0,00 ± 0,00	0,00 ± 0,00	0,23 ± 0,35	0,95 ± 0,39	*Enterococcus* sp.
78	0,69 ± 0,27	0,03 ± 0,05	0,16 ± 0,15	0,43 ± 0,22	*Bacillus* sp. (*B. pumilus* group)
134	0,06 ± 0,12	0,18 ± 0,26	0,47 ± 0,33	0,60 ± 0,44	*Bacillus* sp. (*B. cereus* group)
40	0,40 ± 0,37	0,34 ± 0,28	0,33 ± 0,41	1,69 ± 0,35	*Bacillus* sp. (*subtilis* species complex)

proteolytic enzymes, like proteases, which can break down the cellular structures of pathogens [6]. However, some isolates, like 78 and 134, showed only moderate antagonistic activity despite high protease activity, suggesting that there are additional factors that affect antagonism. The maximum depth of gelatin liquefaction was recorded for isolate 35 (*Pseudomonas* sp., *P. fluorescens* group) and was 2.45 cm (see Table 3, Fig. 2). Next was isolate 134 (*Bacillus* sp., *B. cereus* group) – 1.60 cm. This indicates a strong proteolytic potential in certain representatives of *Pseudomonas* and *Bacillus*.

The best amylolytic activity was shown by isolates 42, 29, and 26. The largest starch hydrolysis zone was observed in isolate 42 (family Bacillaceae) – 3.56 cm, slightly lower in isolates 29 (*Bacillus* sp., *subtilis* species complex) – 3.14 cm, and 26 (*Bacillus* sp., *subtilis* species complex) – 3.06 cm (see Fig. 3). Overall, it was the bacillus isolates that made up the main group of the most active amylolytic strains in the collection we studied.

Phosphate-mobilizing activity was most pronounced in isolates 39, 35, and 34. The largest clear zone was formed by isolate 39 (*Bacillus* sp., *subtilis* species complex) – 1.4 cm. This was followed by isolate 35 (*Pseudomonas* sp., *P. fluorescens* group) – 1.3 cm, and isolate 34 (*Bacillus* sp., *B. cereus* group) – 1.2 cm. So, the most active phosphate-mobilizing isolates mostly belonged to bacillus and pseudomonad taxa.

The data show that the highest levels of antifungal, amylolytic, proteolytic, and phosphate-mobilizing activity in the studied collection were mainly characteristic of members of the genus *Bacillus*, the family Bacillaceae, and

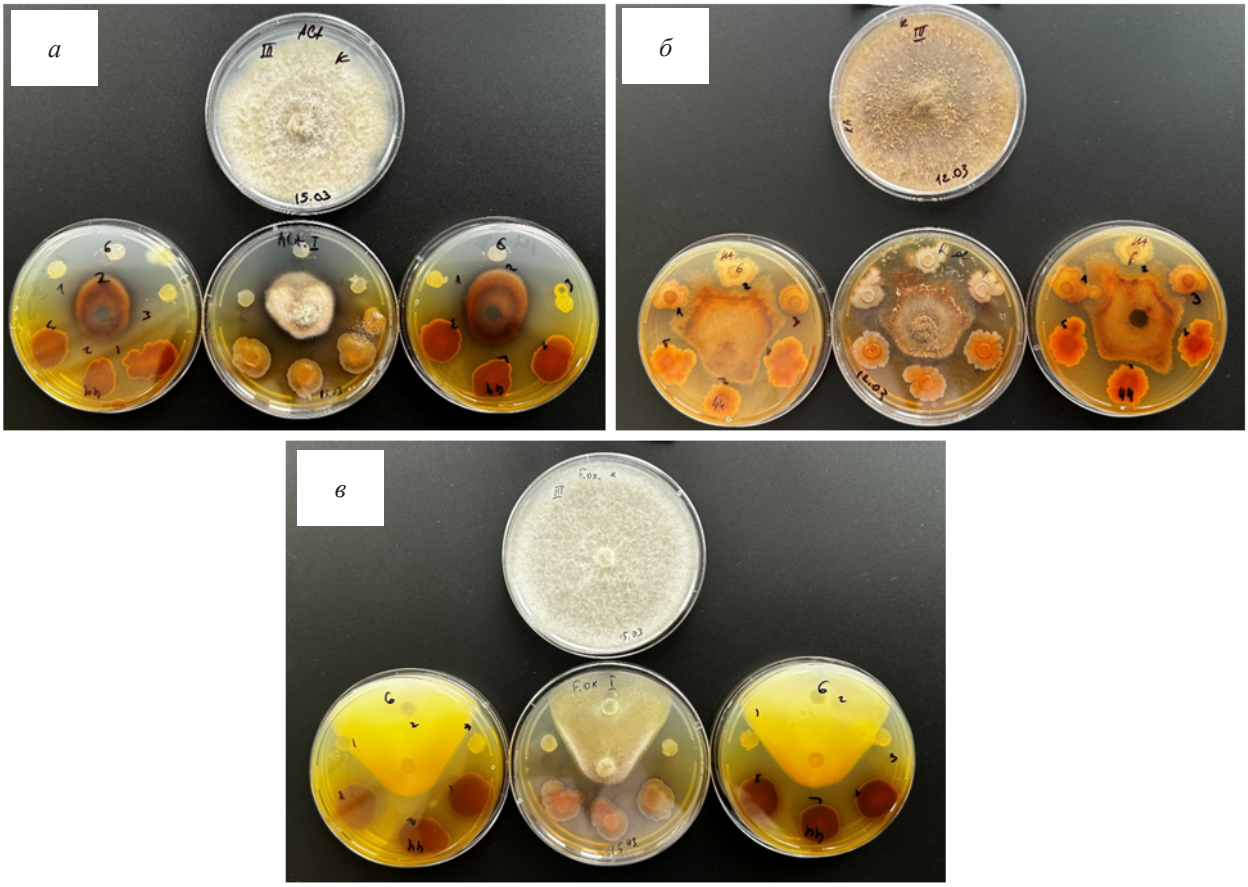


Рис. 1. Фунгицидная активность изолятов 6 и 44 в отношении:
а – A. alternata; *б – R. solani*; *в – F. oxysporum*
Fig. 1. Fungicidal activity of isolates 6 and 44 against:
а – A. alternata; *б – R. solani*; *в – F. oxysporum*

Табл. 3. Амилолитическая, протеолитическая и фосфатмобилизирующая активность изолятов *in vitro* (*M* ± *SD*)

Table 3. Amylolytic, proteolytic and phosphate-mobilizing activity of isolates *in vitro* (*M* ± *SD*)

Isolate number	Proteolytic activity	Amylolytic activity	Phosphate-mobilizing activity	Taxonomic designation
	см			
6	0,00 ± 0,00	1,98 ± 0,22	0,80 ± 0,06	*Bacillus* sp. (*B. cereus* group)
44	0,00 ± 0,00	0,82 ± 0,15	1,00 ± 0,26	*Pseudomonas chlororaphis*
35	2,45 ± 0,32	0,00 ± 0,00	1,30 ± 1,04	*Pseudomonas* sp. (*P. fluorescens* group)
26	0,88 ± 0,34	3,06 ± 0,11	0,80 ± 0,20	*Bacillus* sp. (*subtilis* species complex)
16	0,00 ± 0,00	2,58 ± 0,33	0,00 ± 0,00	*Bacillus* sp. (*B. cereus* group)
45	0,00 ± 0,00	0,88 ± 0,13	0,00 ± 0,00	*Priestia* sp.
58	0,00 ± 0,00	0,86 ± 0,05	0,50 ± 0,00	*Serratia* sp.
39	0,00 ± 0,00	2,96 ± 0,31	1,40 ± 0,21	*Bacillus* sp. (*subtilis* species complex)
17	0,38 ± 0,46	1,02 ± 0,43	1,10 ± 0,17	*Bacillus* sp. (*B. cereus* group)
34	1,38 ± 0,77	1,88 ± 0,21	1,20 ± 0,29	*Bacillus* sp. (*B. cereus* group)
42	0,68 ± 0,77	3,56 ± 0,11	0,00 ± 0,00	*Bacillaceae*
23	0,00 ± 0,00	1,14 ± 0,21	0,60 ± 0,12	*Bacillaceae*
122	0,00 ± 0,00	2,14 ± 0,09	0,00 ± 0,00	*Bacillus* sp. (*B. cereus* group)
24	0,00 ± 0,00	2,34 ± 0,14	0,80 ± 0,15	*Bacillus* sp. (*subtilis* species complex)
9	1,06 ± 0,56	2,72 ± 0,15	0,00 ± 0,00	*Bacillus* sp. (*subtilis* species complex)
31	1,02 ± 0,30	0,50 ± 0,07	0,00 ± 0,00	*Achromobacter* sp.
100	0,88 ± 1,03	1,26 ± 0,29	0,70 ± 0,21	*Enterobacter* sp.
20	0,38 ± 0,25	2,90 ± 0,12	0,00 ± 0,00	*Bacillus* sp. (*subtilis* species complex)
29	1,06 ± 0,51	3,14 ± 0,25	0,00 ± 0,00	*Bacillus* sp. (*subtilis* species complex)
51	0,00 ± 0,00	0,00 ± 0,00	0,90 ± 0,25	*Enterococcus*-like isolate
52	0,00 ± 0,00	0,00 ± 0,00	0,60 ± 0,06	*Enterococcus* sp.
78	1,42 ± 0,20	0,22 ± 0,04	0,50 ± 0,00	*Bacillus* sp. (*B. pumilus* group)
134	1,60 ± 0,83	1,92 ± 0,08	0,30 ± 0,58	*Bacillus* sp. (*B. cereus* group)
40	0,52 ± 0,34	2,40 ± 0,13	0,00 ± 0,00	*Bacillus* sp. (*subtilis* species complex)

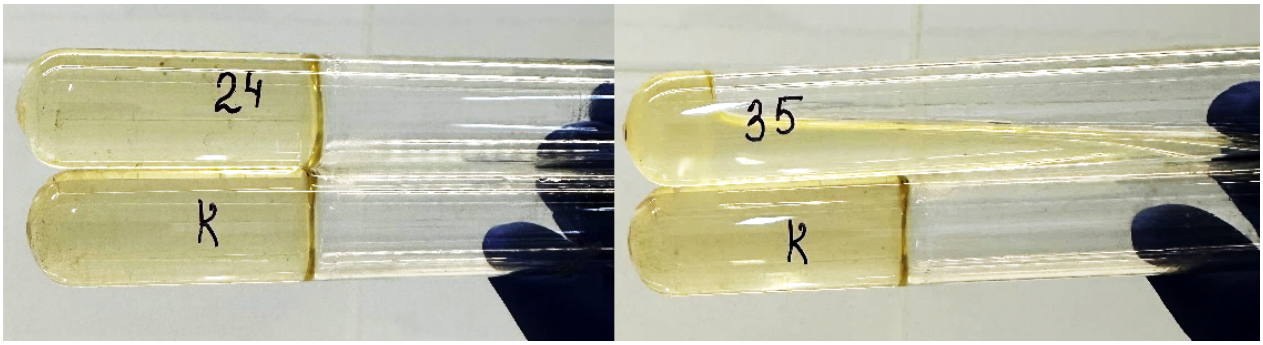


Рис. 2. Отсутствие протеолитической активности у изолята 24, высокая активность у изолята 35

Fig. 2. Proteolytic activity was absent in isolate 24, whereas high activity was observed in isolate 35



Рис. 3. Отсутствие амилазной активности у изолята 51 (*а*), высокая активность у изолята 42 (*б*) и 26 (*в*)
Fig. 3. Amylolytic activity was absent in isolate 51 (*а*), whereas high activity was observed in isolates 42 (*б*) and 26 (*в*)

the genus *Pseudomonas*. These results are in line with current understanding of how rhizosphere microorganisms work, including producing antibiotics and other secondary metabolites, like lipopeptides, as well as extracellular hydrolases, organic acids, and siderophores [7, 8]. The high antifungal activity of isolate 26, classified as *Bacillus* sp. (*subtilis* species complex), as well as the strong results seen with isolates 39 and 42, belonging to related bacillary taxa, fits well with the literature on the high fungicidal and metabolic activity of members of this group [2, 9].

The pronounced antifungal and proteolytic activity of isolate 35 (*Pseudomonas* sp., *P. fluorescens* group), as well as the high overall antifungal activity of isolate 44 (*Pseudomonas chlororaphis*), match literature data on the significant biotechnological potential of *Pseudomonas* species, which combine antagonism towards plant pathogens with growth-promoting properties [10, 11]. The presence of an active isolate 45 (*Priestia* sp.) in the collection, which showed a pronounced inhibitory effect on certain test fungi, is also interesting, since members of the genus *Priestia* are considered promising agents for biocontrol and plant growth promotion [12–14].

Isolates that showed selectively expressed traits deserve special attention. For example, isolate 100 (*Enterobacter* sp.) was noted for moderate phosphate-mobilizing activity, which aligns with data on this genus's ability to dissolve insoluble phosphates and help increase phosphorus availability for plants [15, 16].

CONCLUSION

The most promising for further research based on the set of studied traits should be considered isolates 26 (*Bacillus* sp., *subtilis* species complex), 35 (*Pseudomonas* sp., *P. fluorescens* group), 39 (*Bacillus* sp., *subtilis* species complex), 42 (Bacillaceae family) and 44 (*Pseudomonas chlororaphis*). Isolate 26 had the highest overall antifungal activity, 35 had the maximum proteolytic activity, 42 had the maximum amylolytic activity, and 39 had the greatest phosphate-mobilizing activity. The results suggest that it makes sense to continue studying these isolates in both model and vegetation experiments, as well as to evaluate them as potential components of microbial consortia and bio-preparations with fungicidal and growth-promoting potential.

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Управление природными энтомокомплексами в агроландшафтах: мировой опыт исследований

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В статье рассматриваются вопросы разработки эффективных методов защиты сельскохозяйственных культур на основе экологичных принципов. Цель исследования – анализ существующего отечественного и мирового опыта в управлении энтомокомплексами агроландшафтов. Основная проблема современных методов биологической защиты растений состоит в том, что они ориентированы на устранение последствий заселения растений вредными организмами, а не причин. Поэтому большинство применяемых методов не позволяют обеспечить стабильный долговременный положительный эффект и, как следствие, недостаточны для сохранения и восстановления естественной среды обитания диких видов растений, насекомых и сохранения их биоразнообразия. В связи с этим вопрос разработки эффективных методов защиты сельскохозяйственных культур на основе экологичных принципов достаточно актуален. Одним из таких методов, по мнению мирового научного сообщества, является создание в пределах агроландшафтов управляемых природных энтомокомплексов, которые смогут обеспечить достаточную защиту возделываемых культур от вредителей в течение всего вегетационного сезона. В условиях обнищания агроценозов современные методы биозащиты должны быть направлены на устранение дисбаланса между экосистемами культурного выращивания и естественной средой. Несмотря на достаточное количество подтвержденных данных об эффективности рассматриваемого метода защиты растений, вопросы оптимизации экологического и экономического управления природными энтомокомплексами остаются открытыми. Требуются масштабные междисциплинарные исследования количественной и качественной динамики популяций фито- и энтомофагов, их временной изменчивости, влияния флористического состава агроландшафта и стрессовых факторов. Необходимы изучение вопроса управления энтомокомплексами в агроландшафте с учетом интересов сельхозпроизводителей и местных властей, разработка оптимизированного подхода к биозащите растений без ущерба объему валового продукта.

Ключевые слова: агроландшафт, биозащита, сельское хозяйство, энтомофаги, энтомокомплекс, биоразнообразие

Management of natural entomocomplexes in the agrolandscape: global research experience

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The article discusses the development of effective methods of crop protection based on environmentally friendly principles. The purpose of the study is to analyze the existing domestic and global experience in the management of agrolandscape entomocomplexes. The main problem with modern methods of biological plant protection is that they are aimed at eliminating the consequences of plant colonization by harmful organisms, rather than the causes. Therefore, most of the methods used do not allow for a stable long-term positive effect and, as a result, are insufficient to preserve and restore the natural habitat of wild plant species, insects, and their biodiversity. In this regard, the issue of developing effective methods of protecting agricultural crops based on environmentally friendly principles remains important. One of these methods, according to the global scientific community, is the creation within agrolandscapes of managed natural entomocomplexes that can provide sufficient protection of

cultivated crops from pests throughout the entire growing season. In conditions of impoverishment of agrocenoses, modern methods of biological protection should be aimed at eliminating the imbalance between the ecosystems of cultural cultivation and natural environment. Despite the sufficient amount of confirmed data on the effectiveness of the plant protection method under consideration, questions of optimizing the ecological and economic management of natural entomocomplexes remain open. Large-scale interdisciplinary studies of the quantitative and qualitative dynamics of phytophagous and entomophagous populations, their temporal variability, the influence of the floral composition of the agricultural landscape and stress factors are required. The study of the issue of management of entomocomplexes in the agrolandscape should be carried out taking into account the interests of agricultural producers and local authorities, and an optimized approach to plant biosecurity should be developed without prejudice to the volume of gross product.

Keywords: agrolandscape, biological protection, agriculture, entomophages, entomocomplex, biodiversity

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INTRODUCTION

A key factor behind the global food crisis is agriculture that relies on chemical methods of plant protection, which are more economically beneficial for producers compared to biological methods. Despite positive experiences using entomophages for plant protection in Russia, China, the USA, India, Brazil, Japan, Korea, and Turkmenistan, over the past decade, European countries like France, Italy, Germany, Poland, Romania, and the Czech Republic have preferred biopreparations as an alternative to chemical plant pest control within the framework of sustainable farming. The widespread use of entomoacariphages, which are an effective means of biological plant protection, is limited by several factors: legal restrictions on the use of insects, insufficient industrial-scale production, difficulties with transporting biological material, lack of educational programs for training specialists in this area, specifics of carrying out protective measures, and insufficient funding[1].

The concept of agro-landscape ecology remained theoretical for many years. A technocratic approach, the drive to increase production by expanding farmland, and the widespread use of pesticides over the past 100 years have led to a loss of 75% of agricultural biodiversity[2] [1].

The main problem with modern methods of biological plant protection is that they focus on eliminating the effects of harmful organisms on plants, rather than the causes. Because of this,

[1]An agrolandscape-based farming system for the Krasnodar Territory: a textbook / A.N. Korobka, S.Yu. Orlenko, E.V. Alekseenko, et al. Krasnodar, 2015, 352 p.

[2]May 22 – International Day for Biological Diversity // Organic Farming Union: website. URL: https://soz. bio/22-maya-mezhdunarodnyy-den-bioraznoobra-2.

they can't provide a stable long-term effect and, as a result, are insufficient for preserving and restoring the natural habitats of wild plant and insect species, as well as their biodiversity. In this context, the development of effective crop protection methods based on ecological principles has become a pressing issue. One such method involves the creation of managed natural insect complexes within agricultural landscapes; these have the potential to provide adequate pest protection for crops throughout the entire growing season.

The purpose of the study is to analyze existing domestic and international experience in the management of entomocomplexes in agricultural landscapes.

MAIN BODY

The scientific community has divided into proponents of creating semi-natural habitats and preserving natural ones for insect fauna within agricultural landscapes, and skeptics who base their views on economic considerations and call for a more detailed, systemic, selective, and interdisciplinary approach to studying the issue.

In 2013, the European Commission reformed the Common Agricultural Policy (CAP). Measures were introduced to restore natural and semi-natural insect habitats, and incentives were developed to maintain permanent grasslands; additionally, agricultural producers were required to designate at least 5% of their land as Ecological Focus Areas (EFAs). For instance, in Switzerland, 13% of the land is allocated to so-called biodiversity promotion areas [2].

Current widespread methods of agricultural intensification are altering the structure of insect communities at the systemic level. Monoculture cultivation leads to a significant increase in the abundance of specialized phytophagous insects. Combined with the large-scale use of pesticides, this agricultural practice alters food webs, reduces the stability of agroecosystems, and causes a sharp rise in pest populations. For example, in the crop cultivation systems used in the Mediterranean region and due to the fact that the proportion of monoculture fields to natural landscapes is strongly skewed in favor of the former, generalist predators are unable to effectively control pest populations, even though in nature the share of polyphagous predators is much higher than that of specialists [3].

Spatially explicit models of predator and prey metapopulations show the importance of collecting data on population sizes, their temporal variability, and resource diversity to understand how landscape heterogeneity affects the ecosystem services provided by entomophages [4–6]. The complexity and diversity of the habitat in the agrocenosis help it stay resilient to climate change, providing redundancy and species diversity among taxa and guilds, and preventing phenotypic shifts and major changes in the habitats of pests [7].

Natural and semi-natural communities are characterized by a more complex structure of entomocomplexes and functional diversity [8]. In addition, in monoculture landscapes, entomophage species show a narrow range of productivity, whereas in natural and semi-natural biocenoses, broad polyphages prevail [9, 10]. In the scientific community, there is a growing understanding of the importance of research aimed at studying the spatiotemporal dynamics of insect biodiversity in agricultural crop production [11].

Natural and semi-natural habitats of entomofauna, integrated into the agricultural landscape, can become perfect targets for solving the challenges of sustainable pest biocontrol in crops [12, 13]. For example, studies on the effectiveness of aphidophages in the southern regions of the Krasnodar Territory showed high effectiveness (up to 95%) against aphids under natural conditions [14]. A symbiotic relationship has been confirmed between crop productivity and the diversity of natural insect fauna in North Africa [15]. Studies conducted in EU agricultural landscapes show that pest control by natural predators reduces the yield gap by 4%, which

increases agricultural profitability by the corresponding amount [16].

Some researchers note that reducing habitat areas by 30% leads to a decrease in species richness [17].

Creating sustainable, self-reproducing populations on various types of crops through farming methods that increase plant cover in spring and early summer has allowed natural enemies in intensive farming areas in the Netherlands to maintain an effective predator-to-prey ratio [18]. In the Black Sea subtropical areas of Russia, scientists have shown that ladybugs have a high (up to 97.02%) regulatory effect on fig pests that feed on a single type of plant, even in polyculture farming within a heavily fragmented agroecosystem. Under these conditions, the optimal predator-to-prey ratio of 1 to 36–38 individuals is maintained [19].

Setting up semi-natural habitats for insect communities in agroecosystems helps boost a wide range of ecosystem services provided by insects, across multiple spatial and temporal scales. Managed natural insect complexes create spatial diversity and species interactions, which are key for effective and sustainable biocontrol [20]. The plant diversity of natural communities in the agricultural landscape provides natural predators with shelters for hibernation and reproduction, as well as alternative food, which ensures they continuously deliver ecosystem services in protecting crops from pests [21].

Environmentalists are pushing for a change in the strategy for shaping agro-landscapes. They suggest replacing tree planting with a system for restoring local vegetation [22]. A mix of different crops along with changing the balance between farmed areas and natural habitats reduces the overall number of pests by providing more resources for beneficial insects[3] [23]. Researchers emphasize that setting up semi-natural habitats in agroecosystems and filling them with a wide variety of insect fauna doesn't guarantee results. At the same time, these same scientists have shown that giving entomophages the chance to successfully survive the winter in natural surroundings close to farmland, and providing alternative prey, especially at the beginning of the growing season, significantly improves natural pest control. The presence of alternative prey for entomophages in crops alone can reduce phytophage numbers by 10–70% [24].

The practice of managing orchards by creating and maintaining semi-natural habitats for insect fauna has a positive effect on the effectiveness of biocontrol. For example, in apple orchards, there are high rates of egg predation by natural predators of *Halyomorpha halys* Stal. – up to 40% compared to the usual 10% [25]. Research conducted in the Samara and Volgograd regions shows that agroecosystems surrounded by multifunctional plantings have 1.6–3.5 times fewer pests and 2.3–6.1 times more beneficial organisms [26]. Organizing these kinds of semi-natural habitats helps align the population peaks of plants and insects, which in turn affects how effectively they provide ecosystem services [27].

It's important to create and manage micro-reserves for insect fauna in agroecosystems to boost the regulatory potential of entomophages and increase the potential of pollinators [28]. One vivid example of successfully using technology to manage natural insect communities is the pest control system at Woodleaf Farm in the USA. The plants grow wild and serve as a habitat for natural predators and parasites. Thanks to this strategy, over the past 30 years the farm has seen a steady decrease in both the number and harmfulness of phytophagous insects [29]. In several wineries in the US and New Zealand, insectaries have been set up, as well as semi-natural patches of local vegetation that attract natural predators and serve as habitats for native insect fauna. This kind of monoculture diversification system increases the share of ecosystem

[3]*Root R.B.* Organization of a plant arthropod association in simple and diverse habitats: the fauna of collards (*Brassica oleracea*) // Ecological monographs, 1973, vol. 43, N 1, pp. 95–124.

services provided by local predators and, as a result, reduces the pesticide load on the agrobiocenosis [30]. An example of the positive impact of natural and semi-natural habitats of entomofauna on agriculture is the traditional agroforestry systems in Switzerland, Wytweiden and Selven. These systems provide a suitable habitat for many species, thereby supporting landscape biodiversity [31].

Despite broad support for the idea of expanding the management of insect habitats in agricultural landscapes, this area requires systematic study. Some studies note that current approaches to managing insect communities in agricultural landscapes lack sufficient spatial and temporal specificity [32]. Some authors point out that the impact of landscape and climate factors on the number and density of entomofauna is not well studied [33]. Monoculture agro-landscapes are currently better researched than the surrounding landscape, which skews the assessment of relevance and leads to systematic bias in evaluations [34].

A high degree of instability and vulnerability in natural-anthropogenic landscapes, according to researchers, requires determining the ecological potential of natural landscapes and taking into account the intensity and type of human impact on the ecosystem [35]. An integrated plant protection system that includes a high share of ecosystem services provided by natural predators is beneficial in the long run. However, according to H. Parry, because this issue hasn't been studied enough, the widespread use of pesticides is still economically advantageous for farmers [36].

Researchers note the need for a better understanding of how the composition of plant species and the spatial scaling of vegetation affect natural enemies [37, 38]. Forecasting the effects obtained shouldn't be based on general principles; it's necessary to take into account the specifics of each individual agroecosystem [39]. It's important to take into account a large set of both general and local data, including risk management for farmers and benefits for government entities. A shift in perspective toward long-term dynamic studies is crucial, considering the interdisciplinary connections of various social, economic, and behavioral sciences in these matters [40].

The relevance of using biogeography data in managing fragmented and semi-natural natural communities is noted in Russian studies [41]. The potential of agroecological modeling for effectively predicting pest population control by natural enemies is best based on applying context-sensitive ecological mechanisms [42]. The effect of predicting configuration effects will depend on understanding the relationship between trophic levels, insects' ability to disperse, and the spatial scale of landscape structure [43]. The challenge of managing habitats is to integrate resources for the development of natural insect populations while considering the spatial and temporal support for natural enemies [44]. There is an urgent need to carry out a large number of fundamental, multi-species, and multifunctional studies of various agricultural landscape gradients, involving not only scientists but also farmers. These studies should help bridge the gap between science and practice [45].

Russian researchers studying the issue of identifying key agro-landscape ecosystems have developed mapping models, proposed adaptive approaches to forming the ecological framework of landscapes, and created low-cost methods for preserving biodiversity in agro-landscapes [46, 47]. As part of creating a system to minimize the negative impact of agriculture on the environment, an agro-landscape ecological zoning of 11 natural-economic regions of Russia has been developed, along with scientific foundations for optimizing, increasing productivity, and managing agricultural landscapes [48]. A new approach to farming should be based on agro-ecological methods for assessing the natural conditions of a specific region.

CONCLUSION

So, it can be said that nowadays, solving the issues of creating and managing natural entomo-

complexes in the agricultural landscape is one of the key tasks for optimizing farming production. With the depletion of agrocenoses, modern bioprotection methods should focus on fixing the imbalance between crop ecosystems and the surrounding natural environment.

Despite having quite a bit of confirmed data on how effective natural insect complexes are in providing ecosystem services in agricultural landscapes, questions about optimizing the ecological and economic management of these natural insect complexes still remain open. There is a need for large-scale interdisciplinary research aimed at assessing the quantitative and qualitative dynamics of phytophagous and entomophagous populations, their temporal variability, and determining the influence of the floristic composition of agro-landscapes and various stress factors. Studying the management of insect complexes in agro-landscapes should be carried out with consideration for the interests of farmers and local authorities, within an optimized approach.

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Использование гуминового препарата из торфа в композиции с бактериями для контроля возбудителей семенных инфекций яровой пшеницы

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Цель статьи – изучение возможности использования композиции на основе гуминового препарата из торфа Гумостим и бактерий *Pseudomonas extremorientalis,* выделенных из копролитов дождевых червей, для контроля возбудителей семенных инфекций яровой пшеницы. Объектами исследования стали семена пшеницы яровой мягкой (*Triticum aestivum* L.) сортов Ликамеро и Каликсо, гуминовый препарат Гумостим, бактерии-антагонисты возбудителей корневых гнилей *Pseudomonas extremorientalis*. Использовали метод фитоэкспертизы в рулонах фильтровальной бумаги. Обработка семян пшеницы сорта Ликамеро бактериями статистически значимо увеличила длину проростка от 12 см в контроле до 14 см в варианте. Совместное использование бактерий и гуминового препарата при двух концентрациях 0,001 и 0,0001% статистически значимо увеличило длину проростка до 13,1 и 13,0 см. В вариантах обработки гуминовым препаратом в двух концентрациях число корней на растение увеличилось от 3 шт. в контроле до 4 шт. В варианте совместной обработки с меньшей концентрацией Гумостима присутствует тенденция увеличения данного показателя. Препарат проявляет антифунгальный эффект в концентрации 0,001%, снижая общую зараженность семян фитопатогенами от 23% в контроле до 16% в варианте; в концентрации 0,0001% – от 23% в контроле до 9% в варианте. Бактеризация уменьшает общую зараженность до 12%. Совместное влияние бактерий и Гумостима в двух концентрациях статистически значимо снижает общую зараженность до 7 и 11%. Для сорта Каликсо длина проростка в варианте обработки Гумостимом в меньшей концентрации статистически значимо меньше контроля (контроль – 11,9 см, Гумостим 0,0001% – 9,5 см). Общая зараженность фитопатогенами в вариантах опыта меньше контроля на 4–8%, но статистически значимый результат отмечен только в варианте совместного применения бактерий и Гумостима в меньшей концентрации: снижение от 20% в контроле до 9% в варианте.

Ключевые слова: бактерии, *Pseudomonas extremorientalis*, Гумостим, яровая пшеница, семенные инфекции

The use of a peat-based humic preparation in a composition with bacteria to control seed infection pathogens of spring wheat

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The purpose of the article is to study the possibility of using a composition based on a humic preparation from Humostim peat and *Pseudomonas extremorientalis* bacteria isolated from earthworm coprolites to control the pathogens of seed infections of spring wheat. The objects of the study were seeds of spring wheat (*Triticum aestivum* L.) of the Licamero and Calixo varieties, the humic preparation Humostim, and the bacteria antagonists of the root rot pathogens *Pseudomonas extremorientalis*. The phytoexpertize method was used in filter paper rolls. Treatment of the Licamero wheat seeds with

bacteria significantly increases the length of the seedling from 12 cm in the control to 14 cm in the experiment. The combined use of bacteria and a humic preparation at two concentrations of 0.001% and 0.0001% significantly increased the length of the seedling to 13.1 and 13.0 cm. In the variants of treatment with a humic preparation in two concentrations, the number of roots per plant increased from 3 pcs. in the control to 4 pcs. In the variant of joint treatment with a lower concentration of Humostim, there is a tendency to increase this indicator. The preparation exhibits an antifungal effect at a concentration of 0.001%, reducing the total infection of seeds with phytopathogens from 23% in the control to 16%; at a concentration of 0.0001% – from 23% in the control to 9%. Bacterization reduces the overall infection rate by up to 12%. The combined effect of bacteria and Humostim in two concentrations significantly reduces the overall infection rate to 7 and 11%. For the Calixo variety, the length of the seedling in the variant of treatment with Humostim in a lower concentration is statistically significantly less than the control (in the control – 11.9 cm, Humostim 0.0001% – 9.5 cm). The total infection with phytopathogens in the experimental variants is 4-8% less than the control, but a statistically significant result was noted only in the variant of the combined use of bacteria and Humostim in a lower concentration.: reduction from 20% in control to 9%.

Keywords: bacteria, *Pseudomonas extremorientalis*, Humostim, spring wheat, seed infections

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INTRODUCTION

The damage to cereal grains by root rots is a reality for modern farmers. In particular, in the Tomsk region, diseases like fusariosis and helminthosporiosis are common. Because the autumn cold sets in quickly, the period from harvest until temperatures drop below 10 °C is short, lasting from 18 to 30 days. During this time, soil microbial activity drops, crop residues don't break down, and as a result, they become a reservoir for infection agents in the spring[1]. The occurrence and development of diseases lead not only to a significant decrease in crop yields but also to a deterioration in quality. During their life processes, lower fungi release toxic metabolites – mycotoxins, which make the grain unsuitable for food and livestock feed [1].

Pseudomonas spp. bacteria are widespread in nature. This is a diverse genus found in various environments – from soil and water to plant surfaces and animal tissues. They are an everywhere biocontrol agent that protects plants from pathogens by suppressing them, directly killing them, or boosting the plant's own defense mechanisms. Different species of *Pseudomonas* spp. can be ideal bioinoculants for a wide range of hosts, especially for cereal crops. These bacteria are known for producing a wide range of bioactive antimicrobial metabolites, which give them an advantage by inhibiting competing microorganisms and serve as the main mechanism for biocontrol of plant diseases [2–4]. The scientific community has recognized pseudomonads as biopesticides that reduce agriculture's reliance on chemical pesticides [5–8].

The main source of isolated strains of *Pseudomonas* bacteria is the rhizosphere of various plant species. However, bioactive strains can also be isolated from other environments, such as the coprolites of manure worms. Quite of-

[1]Overview of the phytosanitary condition of agricultural crops in the Tomsk Region in 2025 and a forecast for the development of harmful organisms in 2026. Tomsk, 2026, 118 p.

ten, the model species *Eisenia fetida* is used to obtain coprolites, extract them, and use these products to positively affect plant growth and resistance to pathogens (Haplotaxida: Lumbricidae) [9, 10]. Researchers at the Biotechnology Laboratory of the Siberian Research Institute of Agriculture and Peat (Tomsk) isolated a strain of *Pseudomonas extremorientalis* from the coprolites of earthworms *Eisenia fetida* Andrei, which showed high antifungal activity. Treating wheat seeds with this strain reduced their overall infection rates by 53–76%[2].

To stimulate plant growth and increase resistance to various stress factors, seeds are often treated with humic preparations from different organic sources before sowing [11–13]. Their combined use with bacteria from different taxa is also discussed in studies: spraying spring wheat during vegetation [14], using humate +7 "Healthy Harvest" and pseudobacterin-2Zh on oil flax [15], creating the Agrophit-humate preparation [16], and others. Since the early growth stage of cereal crops is most vulnerable to root rot due to weather conditions (low or high temperatures, insufficient moisture), it was decided to combine the humic peat-based product Humostim with bacteria isolated from coprolites into a single composition for pre-sowing treatment of wheat seeds.

The aim of the work is to explore the possibility of using a composition based on the humic preparation Humostim and the bacteria *Pseudomonas extremorientalis* to control the pathogens of seed infections in spring wheat.

MATERIAL AND METHODS

Two medium-maturing spring soft wheat (*Triticum aestivum* L.) varieties with a growing season of 72–97 days were taken as the objects of study. The Licamero variety is included in the State Register of Breeding Achievements of the Russian Federation for the Northwest, Central, and Central Black Earth regions. It is resistant to powdery mildew, septoriose, and Fusarium head blight, but has low resistance to brown rust. The Calixo variety is included in the State Register for the Northwestern and West Siberian regions. It exhibits high resistance to fusariosis, yellow rust, and powdery mildew, moderate resistance to Septoria, and low resistance to brown rust[3].

The bacterial culture consists of *Ps. extremorientalis* bacteria isolated from the coprolites of the composting earthworm *Eisenia fetida* Andrei. The working concentration of the bacterial suspension is a titer of 1–5 × 10^6 CFU/ml.

The experiments utilized Humostim (ammonium humate)—a product of the Siberian Research Institute of Agriculture and Peat obtained through the peroxide-ammonia hydrolysis of low-moor peat[4]. Humostim is produced in liquid form. It contains carboxylic and essential amino acids, nitrogen, phosphorus, calcium, iron, and trace elements (copper, zinc, manganese). The recommended concentration for pre-sowing seed treatment is 0.001% based on humic acids. In our experiments, a concentration of 0.0001% based on humic acids was also used. In the control, wheat seeds were treated with distilled water.

Laboratory experiments to assess the effect of treatments on seed infection by pathogens and germination were carried out according to GOST 12044–93[5]. After accounting for signs of seed infection, they determined the biometric traits of the seedlings: air-dry mass, length, and the number of embryonic roots.

The information obtained during the experiments was processed using the StatSoft STATIS-

[2]*Minaeva O.M., Akimova E.E., Tereshchenko N.N., Kravets A.V., Zyubanova T.I., Apenysheva M.V.* Prospects for using pseudomonads associated with soil-dwelling lumbricids against pathogens causing root rot in spring cereals // Agricultural Biology, 2019, vol. 54, No. 1, pp. 91–100. DOI: 10.15389/agrobiology.2019.1.91rus.

[3]State Register of Breeding Achievements Approved for Use. Vol. 1. Plant Varieties (official publication), Moscow, 2024, 620 p.

[4]Patent No. 2213452, Russian Federation, IPC A 01N 65/00, C05F 11/02. The method for producing a plant growth stimulant: No. 2001115641/13; / L. V. Kasimova; filed June 6, 2001; published October 10, 2003; applicant: SibNIIT.

[5]GOST 12044–93. Seeds of agricultural crops. Methods for determining infection with diseases: interstate standard: effective date 1995-01-01. Minsk: Interstate Council for Standardization, Metrology and Certification, 1995, 57 p.

TICA 10.0 package. Data on seedling length and the number of roots are presented as medians. Statistical significance of differences in seedling length and root number between the variants was determined using the non-parametric Mann-Whitney U test ($p < 0.05$). Data on seed germination and infection by seed-borne pathogens are presented as probabilities with a confidence interval ($p < 0.05$), calculated using the Student's *t*-test for probabilities between 25% and 75%, and using the Fisher's angular transformation for other probability values ($p < 0,05$)[6].

RESULTS AND DISCUSSION

In the testing, the drug Humostim was used at the manufacturer's recommended concentration of 0.001% based on humic acids, and additionally diluted 10 times down to a concentration of 0.0001%. In the testing, the drug Humostim was used at the manufacturer-recommended concentration of 0.001% based on humic acids, and additionally diluted 10 times to a concentration of 0.0001%. This dilution was prompted by the previously observed retention of its properties at a reduced recommended concentration[7] and economic considerations (lowering the cost per hectare).

Figure 1 shows the length of the wheat seedling, where treatment with bacteria significantly increased this parameter from 12 cm in the control to 14 cm in the treated group. Treatment with Humostim at two concentrations did not affect this measure, but combining bacteria with the humic product at 0.001% and 0.0001% concentrations significantly increased the seedling length to 13.1 and 13.0 cm.

The graphic representation of the number of primary seedling roots per plant shows a posi-

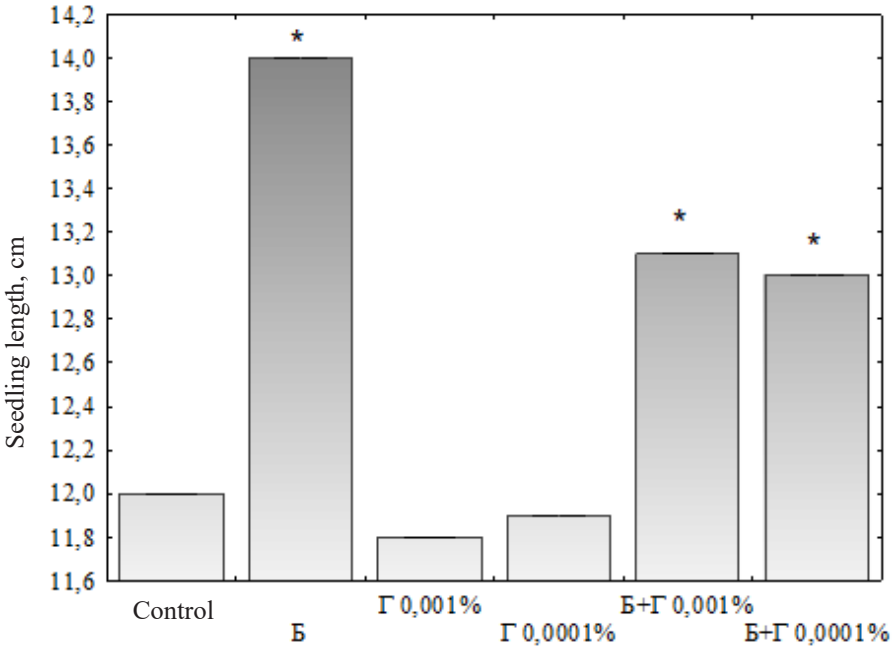


Рис. 1. Длина проростка пшеницы сорта Ликамеро в эксперименте с обработкой семян Гумостимом и бактериями; здесь и на рис. 2–4, в табл. 1, 2: Б – бактерии; Г – Гумостим.
*Статистически значимое различие с контролем ($p < 0,05$).

Fig. 1. Length of a Licamero wheat germ in an experiment with seed treatment with Humostim and bacteria; here and in Fig. 2–4, in Tables 1, 2: Б – bacteria; Г – Humostim.
* Statistically significant difference from the control ($p < 0.05$).

[6]*Lakin G.F.* Biometry: a textbook for biology majors at higher education institutions. 4th ed., revised and expanded. Moscow: Vysshaya Shkola, 1990. 342 p.

[7]*Titova E.V., Udintsev S.N., Kravets A.V., Glagolev V.P., Zhilyakova T.P., Kasimova L.V., Karnachuk R.A.* Mechanism of action of low doses of peat-derived preparations on plants // Plodorodie, 2005, No. 3 (24), pp. 23–25.

tive trend of increase in the treatments with the humic acid preparation at two concentrations (from 3 in the control to 4 in the treatment) (see Fig. 2). In the treatment with the lower concentration of Humostim, there is also a trend of increase in this indicator, but all the presented data were not statistically significantly different from the control.

Germination in all variants was 82–99% and didn't differ much between the experiment versions, same with the seedling weight.

The key factors are the antifungal activity indicators of the declared solutions and their compositions (see table 1).

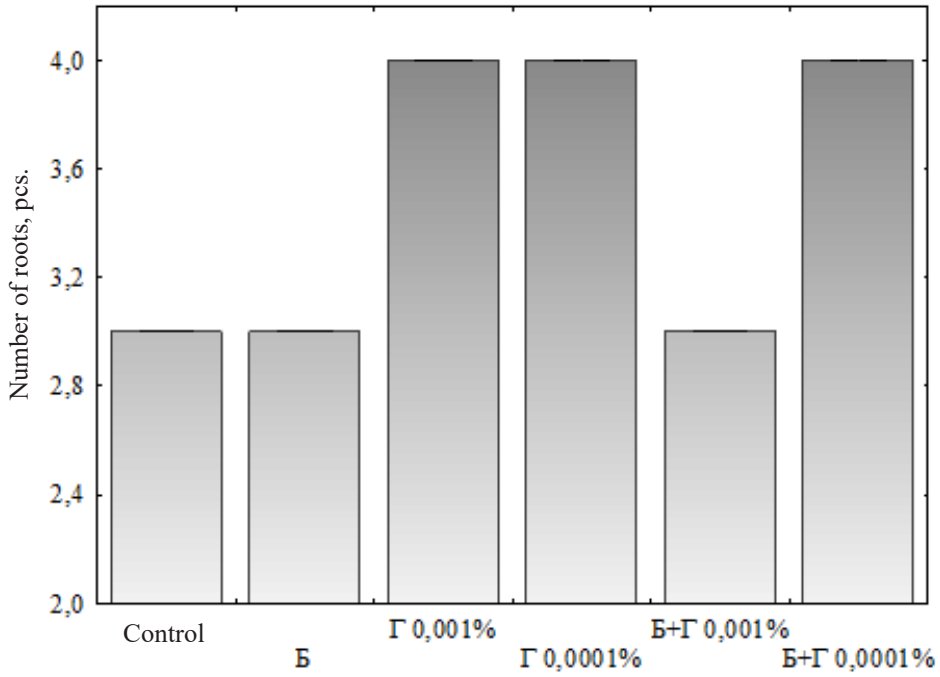


Рис. 2. Число корней на растение пшеницы сорта Ликамеро в эксперименте с обработкой семян Гумостимом и бактериями

Fig. 2. Number of roots per Licamero wheat plant in an experiment with seed treatment with Humostim and bacteria

Табл. 1. Зараженность семян пшеницы сорта Ликамеро возбудителями семенных инфекций в эксперименте с обработкой семян Гумостимом и бактериями, %

Table 1. Infection of wheat seeds of the Licamero variety with seed infection pathogens in an experiment with seed treatment with Humostim and bacteria, %

Experiment option	Overall prevalence	Helminthosporiose	Fusariosis	Alternaria leaf spot	Bacteriosis	Molds
Control	$23^{+8,7}_{-7,7}$	0	1,0	8,0	0,5	13,5
Б	$12^{+7,0*}_{-5,6}$	0	0,0	3,0	0,0	9,0
Г 0,001%	$16^{+7,8}_{-6,5}$	0	0,5	4,5	2,0	9,0
Г 0,0001%	$9^{+6,4*}_{-4,8}$	0	0,5	2,0	0,5	6,0
Б+Г 0,001%	$7^{+5,8*}_{-4,1}$	0	0,5	0,5	1,0	5,0
Б+Г 0,0001%	$11^{+6,8*}_{-5,3}$	0	2,5	1,5	0,0	7,0

*Statistically significant difference compared to the control ($p < 0,05$).

The Humostim drug shows an antifungal effect at the recommended concentration of 0.001%, reducing the overall infection rate of seed-borne pathogens from 23% in the control to 16% in the tested version. At a reduced concentration (0.0001%), Humostim significantly lowers the total infection rate from 23% in the control group to 9% in the test group. The bacteria reduce the overall infection rate to 12%. Combinations of bacteria and Humostim at concentrations of 0.001% and 0.0001% significantly reduce the total infection rate to 7% and 11%, respectively.

It can be concluded that using bacteria together with Humostim at both concentrations has a positive effect on some biometric indicators of spring wheat of the Licamero variety, and also significantly reduces the overall seed infection rates by seed pathogens.

Further experiments were carried out with seeds of the Calixo variety. Figure 3 shows the length of the wheat seedling in the experiment with bacteria and Humostim at two concentrations. The sprout length in the Humostim option at a lower concentration is statistically significantly less than the control (in the control, the length is 11.9 cm, while in the Humostim 0.0001% option it's 9.5 cm). The sprout length is also less than the control when bacteria and Humostim are used together at the recommended concentration (10.1 cm).

The number of roots per plant varies across experiment options in a statistically insignificant way and ranges from 4 to 5 (see Fig. 4).

Germination in the experimental variants didn't differ much from the control and ranged from 71 to 95%. Just like with the seeds of the Licamero variety, no statistically significant change in seedling weight was observed.

The results of the seed infection analysis in different experimental setups are shown in Table 2. Overall, seed infection by pathogens in the experimental setups is 4–8% lower than in the control, but it is only statistically significantly lower in the setup where bacteria and Humostim are used together at a lower concentration: drop-

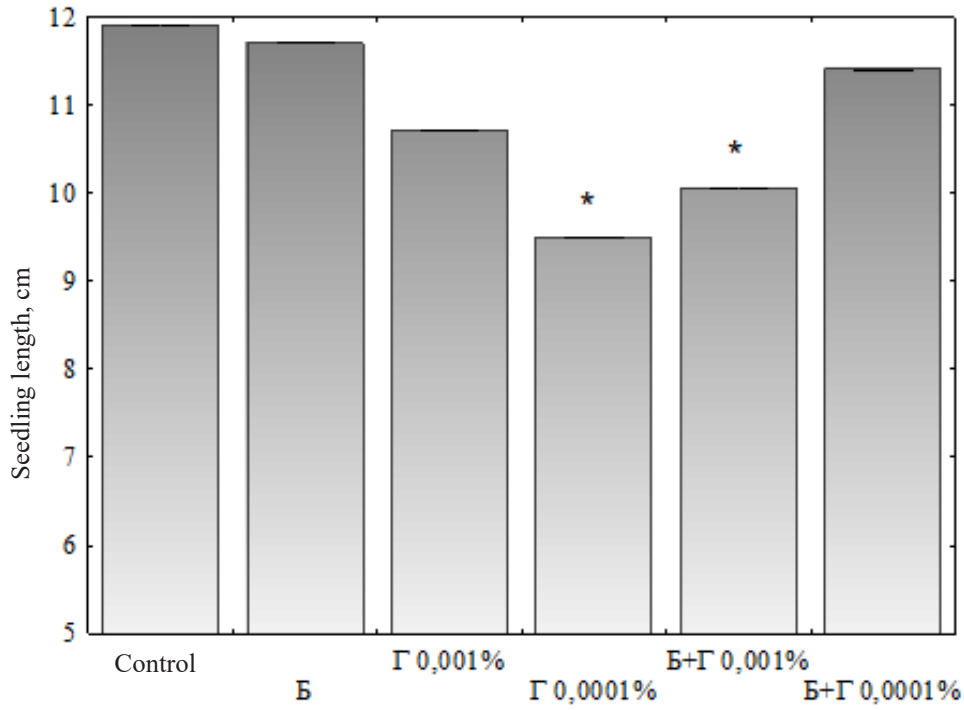


Рис. 3. Длина проростка пшеницы сорта Каликсо в эксперименте с обработкой семян Гумостимом и бактериями

Fig. 3. The length of a wheat germ of the Calixo variety in an experiment with seed treatment with Humostim and bacteria

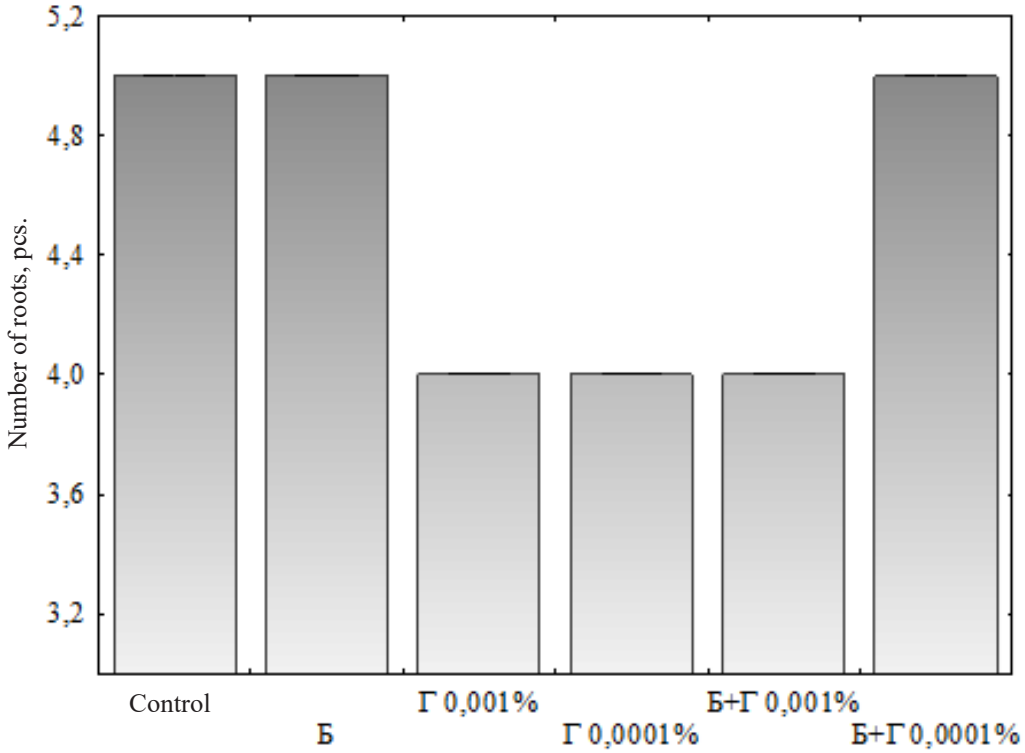


Рис. 4. Число корней на растение пшеницы сорта Каликсо в эксперименте с обработкой семян Гумостимом и бактериями

Fig. 4. The number of roots per wheat plant of the Calixo variety in an experiment with seed treatment with Humostim and bacteria

Табл. 2. Зараженность семян пшеницы сорта Каликсо возбудителями семенных инфекций в эксперименте с обработкой семян Гумостимом и бактериями, %

Table 2. Infection of wheat seeds of the Calixo variety with seed infection pathogens in an experiment with seed treatment with Humostim and bacteria, %

Experiment option	Overall prevalence	Helminthosporiose	Fusariosis	Alternaria leaf spot	Bacteriosis	Molds
Control	$20^{+8,3}_{-7,2}$	0	2	0	0	18
Б	$14^{+7,4}_{-6,1}$	0	0	1	1	12
Г 0,001 %	$14^{+7,4}_{-6,1}$	0	2	0	0	12
Г 0,0001 %	$16^{+7,8}_{-6,5}$	0	3	0	0	13
Б+Г 0,001 %	$12^{+7,0}_{-5,6}$	0	3	0	0	9
Б+Г 0,0001 %	$9^{+6,4*}_{-4,8}$	0	0	0	0	9

*Statistically significant difference compared to the control ($p < 0,05$)

ping from 20% in the control to 9% in that setup.

The presented data confirm previous results obtained for Licamero seeds: fluctuations in morphometric indicators and a statistically significant decrease in overall infection in the variants with combined application of bacteria and Humostim at two concentrations were observed. Since we looked at the effect of humic preparations both on their own and in combination with bacteria, it's worth noting that when humic

preparations are used on plants of different varieties, there's a clear variety-specific response[8, 9], which we also noted for some morphometric parameters.

One should pay attention to the option of using a humic product at a concentration reduced by 10 times. In some cases, using a lower dosage shows better results compared to the recommended concentration. A study by V.N. Pishchik et al.[10] concluded that the working concentration of a humic preparation can be reduced when it is combined with a bacterial preparation, compared to the concentration recommended for the humic preparation alone. Apparently, a reduced dose of the humic preparation is sufficient for the combined effect on plants in the presence of the bioagent.

CONCLUSION

Laboratory testing has demonstrated the potential of using a composition comprising a humic preparation and *Ps. extremorientalis* bacteria to control seed-borne infections during the pre-sowing treatment of spring wheat seeds. The peat-derived humic preparation Humostim can be used in combination with the bacteria at both recommended and reduced concentrations. The composition investigated shows promise for application in agricultural production.

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Эффективность *Macrotyphula phacorrhiza* против снежной плесени на газонах

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На территории Московской области в 2023–2025 гг. на основе проведенного фитосанитарного мониторинга выявлено доминирование в патокомплексе травостоя гольф-полей патогенных грибов *Typhula ishikariensis* S. Imai и *Microdochium nivale* (Fr.) Samuels & I.C. Hallett, являющихся возбудителями розовой и серой крапчатой снежных плесеней. В лабораторных условиях в Главном ботаническом саду им. Н.В. Цицина РАН и на кафедре защиты растений Российского государственного аграрного университета – МСХА им. К.А. Тимирязева были получены чистые культуры данных патогенов, которые использовали в дальнейшем для создания искусственного инфекционного фона в мелкоделяночном полевом опыте по оценке эффективности гриба-антагониста *Macrotyphula phacorrhiza* (Reichard) Olariaga, Huhtinen, Lessóe, J.H. Petersen & K. Hansen. Предварительно из четырех изолятов данного биоагента, выделенных из зараженных газонных злаковых трав, в культуре *in vitro* максимальную эффективность против *T. ishikariensis* и *M. nivale* продемонстрировал изолят ГБС-1. Этот же изолят в мелкоделяночном опыте показал максимальную биологическую эффективность (2024 г. – 31,1%, 2025 г. – 40,6%), снижая по сравнению с контролем развитие болезни на 26,3 (весна 2024 г.) и 25,6 п.п. (весна 2025 г.), а ее распространенность – на 25,0 п.п. в оба сезона. В результате оценки качества травостоя после применения *M. phacorrhiza* выявлено, что изолят ГБС-1 улучшал побегообразовательную способность и общую декоративность газонных трав, что в совокупности дало 20 баллов и перевело категорию качества покрытия в «хорошее», в отличие от других вариантов, где сохранялось «удовлетворительное» состояние газона.

Ключевые слова: газонные травы, снежная плесень, грибы-патогены *Microdochium nivale* и *Typhula ishikariensis*, биоагенты *Macrotyphula phacorrhiza*, биологическая эффективность

Effectiveness of *Macrotyphula phacorrhiza* against snow mold on lawns

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In the territory of the Moscow region in 2023–2025, based on the conducted phytosanitary monitoring, the dominance of pathogenic fungi *Typhula ishikariensis* S. Imai and *Microdochium nivale* (Fr.) Samuels & I.C. Hallett in the turf complex of golf courses was identified, which are the causative agents of pink and gray mottled snow molds. In the laboratory conditions at the N.V. Tsitsin Main Botanical Garden RAS and at the Department of Plant Protection at the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, pure cultures of these pathogens were obtained, which were later used to create an artificial infectious background in a small-plot field experiment to assess the effectiveness of the antagonist fungus *Macrotyphula phacorrhiza* Reichard Olariaga, Huhtinen, Lessóe, J.H. Petersen & K. Hansen. As a preliminarily, among the four isolates of this bioagent, obtained from infected lawn cereal grasses, in *in vitro* culture, the MBG-1 isolate showed the highest effectiveness against *T. ishikariensis* and *M. nivale*. In a small-scale experiment, this same isolate showed maximum biological efficacy (2024 – 31.1%, in 2025 – 40.6%) reducing compared with the control the development of the disease by 26.3 percentage points (spring 2024) and 25.6 percentage points (spring 2025), and its prevalence increased by 25.0 percentage points in both seasons. As a result of the assessment of the quality of the herbage after the use of *M. phacorrhiza* bioagents, it was found that the MBG-1 isolate improved the shoot-forming ability and over-

all decorative effect of the herbage, which together gave a score of 20 points and transferred the quality category of the coating to "good", unlike other options where the "satisfactory" condition of the lawn was maintained.

Keywords: lawn grasses, snow mold, pathogenic fungi *Microdochium nivale* and *Typhula ishikariensis*, bioagents *Macrotyphula phacorrhiza*, biological efficiency

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INTRODUCTION

Infectious turfgrass diseases pose a serious threat to golf courses, leading to significant economic losses and a decline in turf quality. Leaf spots and root rots cause the appearance of patches, discoloration, thinning of the turf, and an overall deterioration in aesthetic appeal.

Among turfgrass diseases, the following diseases are characterized by significant prevalence and harmfulness: dollar spot (pathogen – *Sclerotinia homoeocarpa* F.T. Benn.), anthracnoses (pathogen – species of the genus *Colletotrichum*) [1], rust diseases (pathogen – *Puccinia* sp.) [2], red thread disease (pathogen – *Laetisaria fuciformis* (Berk.) Burds.), powdery mildew (pathogen – *Blumeria graminis* (DC.) Speer) [3], Rhizoctonia rot (pathogen – species of the genus *Rhizoctonia*), foot rot (main pathogen – *Gaeumannomyces graminis* (Sacc.) Arx & D.L. Olivier), greasy spot (pathogen – species of the genus *Pythium*) [4], Fusarium blight (pathogen – species of the genus *Fusarium*) [5], as well as snow molds of fungal origin, previously called diseases of infectious dieback [6].

In some years, damage from snow molds caused by cold-temperature fungi can significantly reduce the look and quality of lawns [7]. When these diseases develop heavily, they affect the tillering nodes of grasses, leading not only to weakening but also to the death of the plants. The most common in Russia are: pink snow mold (pathogen – psychrotolerant *Microdochium nivale* (Fr.) Samuels & I.C. Hallett), speckled snow mold (pathogen – psychrophile-biotroph *Typhula ishikariensis* S. Imai) [8].

It's known that using chemical treatments against snow mold is quite effective, but it also brings a number of problems: pathogen resistance, high treatment costs, and toxicological impact on the ecosystem. In this regard, finding and using not only new fungicides but also alternative protective methods is important for ensuring the sustainable development of the golf industry. As of February 9, 2026, the State Catalog of Pesticides and Agrochemicals permitted for use in the Russian Federation lists only one chemical product intended for lawn grass treatment (Brapix, SC based on 100 g/l picoxystrobin + 500 g/l chlorothalonil), which is clearly not enough.

Protecting lawn grasses should be based on integrating different methods and tools, with bioproducts playing an important role. Using them to protect sports lawns is a relevant approach, allowing to reduce pesticide load and increase grass stand resilience.

According to the International Biocontrol Manufacturers Association, of all the companies producing biopesticides and other bioagents, 40% are in the USA, 35% in Europe, and 25% in other countries. Russia isn't on this list, since it doesn't have that kind of industry. The use of

foreign bioprotection agents not registered in Russia is prohibited, so it's necessary to screen domestic microorganisms that are effective against infectious diseases for possible future registration. For example, sufficient biological effectiveness against pythium, rhizoctonia, and fusarium rots, as well as helminthosporium leaf spot, anthracnose, and rust diseases, has been proven for bioproducts based on: 1) selected for aggressiveness species and strains of fungi of the genus *Trichoderma* – Trichoderma Veride, WP, Trichocin, WP, Gliocladin, WP [9]; 2) bacteria of the genus *Pseudomonas* – Pseudobacterin-3 (Liquid), Biocomposit-Pro (Liquid); 3) strains of *Bacillus subtilis* – Alirin-B, SP [1]. Research on the use of *Macrotyphula phacorrhiza* (Reichard) Olariaga, Huhtinen, Lessóe, J.H. Petersen & K. Hansen as a biological agent against gray snow mold (pathogen – *Typhula* spp.) were held in Japan on cocksfoot grass (*Dactylis glomerata* L.) and Italian ryegrass (*Lolium multiflorum* Lam.). Various isolates of this fungus were effective as bioagents on *Lolium perenne* against different isolates *T. ishikariensis* (biotypes A and B) with a snow cover lasting more than 140 days [10]. In Canada, an *M. phacorrhiza* isolate was successfully used to suppress the development of *T. ishikariensis* var. *ishikariensis* on marsh bent grass (*Agrostis palustris* Huds.) [6–8].

The purpose of the study is to clarify the biological effectiveness of experimental samples of the antagonist fungus *M. phacorrhiza* isolates against the plant pathogens *M. nivale* and *T. ishikariensis*, which cause snow mold in lawn grasses.

MATERIAL AND METHODS

Monitoring of turfgrass diseases was conducted at the following golf clubs in the Moscow region: Skolkovo, Forest Hills, Pirogovo, Moscow Country Club, and Raevo. The pathogens were identified using moist chambers, microscopy, and the isolation of fungi on artificial culture media (potato dextrose agar (Potato Dextrose Agar, PDA) and wort agar (Wort agar)) at the plant protection laboratory of the Main Botanical Garden (MBG) named after N.V. Tsitsin of the Russian Academy of Sciences and at the Department of Plant Protection of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy.

The small-plot field experiment was conducted during the winter seasons of 2023/24 and 2024/25 in the arboretum of the MBG RAS. The species composition of the grass stand, which was established in 2018, is mostly made up of meadow fescue (*Poa pratensis* L.), common ryegrass (*Lolium perenne* L.) and red fescue (*Festuca rubra* L.). To keep it healthy and looking good, the experimental plot was regularly given a set of care tasks, including raking and aerating the turf (twice a season), overseeding in the spring, fertilizing with minerals, and mowing.

To obtain a pure culture of the antagonist fungus *M. phacorrhiza*, sclerotia were used; after surface sterilization with alcohol, their outer shells were breached, and the sclerotia were plated onto a nutrient medium in Petri dishes. The dishes were incubated in a refrigerated incubator (Sankyo Medicool, Japan) at 10°C for 3–4 weeks to allow the fungus to grow. Subsequently, the cultures were used to produce biomass on non-viable barley grains.

Pure cultures of *T. ishikariensis* and *M. nivale* isolates were obtained using the same method. Subsequently, stock cultures of these pathogen isolates were used to inoculate sterile barley grains in flasks to prepare the inoculum for establishing infection plots [11].

Five treatments were tested—comprising four isolates of the bioagent (Nakhabino [NAKh], Pirogovo [PIR], MBG-1, and MBG-2) and a control—with four replicates each. The application rate was 30 g/m². Plot size was 1 × 1 m, with a grid spacing of 10 × 10 cm. Over a two-year period, each plot was artificially inoculated once during the second ten-day period of November—simultaneously with the application of the bioagent—with the pathogens causing pink snow mold (*M. nivale*) and gray snow mold (*T.*

ishikariensis) at a rate of 15 g/m² for each phytopathogen. The application of the inoculum, as well as the combined application of the inoculum and the antagonist fungus, was carried out in a randomized manner.

The development of snow mold was assessed in the spring, immediately after the snow cover melted, using a 4-point scale:

0 – there are no signs of damage;

1 – sparse spots on lower and upper leaves (1–3 spots), with a total affected area of up to 10% of the leaf surface;

2 – the lower leaves are completely affected, while the upper ones show 2–3 spots, with a total affected area of up to 30% of the leaf surface;

3 – both lower and upper leaves are affected, with up to 70% of the total leaf surface area damaged, and lateral shoots are dying off;

4 – all leaves and shoots are affected (100%), the plants have died.

The development of snow mold (R, %), its prevalence (P, %), and the biological efficacy of the bioagent (C, %) were determined using the standard formulas [12].

To comprehensively assess the quality of the experimental plot, the generally accepted methodology of A.A. Laptev [13] was used. First, shoot formation productivity (turf density) was evaluated using a 6-point scale. To do this, a 10 × 10 cm frame was used to determine the number of shoots per 100 cm², followed by a calculation of the number per 1 m². Overall ornamental quality was assessed based on the density (closure) of the turf and the percentage of ground cover, using a 5-point scale. In addition, a comprehensive evaluation of the turf quality was conducted using a 30-point scale [14].

The data were analyzed using one-way ANOVA: the significance of differences between experimental conditions was assessed with Fisher's F test at a significance level of $p < 0.05$. If significant differences were found, the least significant difference (LSD_{05}) was calculated for pairwise comparisons. The analysis was carried out in Microsoft Excel using the “Data Analysis” add-in.

RESULTS AND DISCUSSION

Significant development of snow molds on cereal grasses occurs in the fall, winter, and early spring only under favorable conditions, when the ground is covered with snow and doesn't freeze for more than 120 days, and also when the snow stays for a long time [15]. In 2023/24 and 2024/25, the winter weather conditions in the Moscow region were very different. In 2023/24, a stable snow cover formed, lasting for about 130 days and reaching a maximum height of 62 cm. These conditions were favorable for the development of snow mold and the bioagent. In contrast, the winter of 2024/25 was abnormally low on snow: the snow cover did not exceed 26 cm, there were three instances of complete snowmelt, and the maximum duration of the snow period did not exceed 50 days (see the figure). The conditions of the winter season 2024/25 negatively affected the development of snow molds, but artificial inoculation allowed the pathogens to develop.

The tested isolates of the antagonist fungus *M. phacorrhiza* (NAKh, PIR, MBG-1, MBG-2) differed significantly in their ability to suppress the mycelium of *M. nivale* and *T. ishikariensis*. The studies were carried out *in vitro*, with preliminary screening of the isolates using the dual culture method. The GBS-1 isolate showed the highest effectiveness.

It also showed the best result in the small-plot experiment, demonstrating the highest biological effectiveness in both winter seasons: 2024 – 31.1%, 2025 – 40.6%. At the same time, the development and spread of snow molds significantly decreased (see table 1).

Compared to the control, the application of isolate MBG-1 reduced the development of snow molds by 26.3 percentage points (spring 2024) and 25.6 percentage points (spring 2025), and disease prevalence by 25.0 percentage points in both seasons. The other isolates did not provide a protective effect, as they failed to reach the threshold of statistical significance, indicating insufficient fungicidal activity against the studied pathogens under the given conditions.



Высота снежного покрова в зимний период 2023/24 и 2024/25 гг.
Snow depth in winter 2023/24 and 2024/25

Табл. 1. Развитие, распространенность снежных плесеней в вариантах опыта и биологическая эффективность изолятов биоагента (дендропарк Главного ботанического сада РАН)
Table 1. Development, prevalence of snow molds in experimental variants and biological efficiency of bioagent isolates (arboretum of the Main Botanical Garden of the Russian Academy of Sciences)

Option	2024 (II ten-day period of March)			2025 (II ten-day period of March)		
	R, %	P, %	C, %	R, %	P, %	C, %
Control	84,4 ± 2,4	100,0 ± 0,0	–	63,1 ± 1,3	92,5 ± 5,0	–
NAKh	85,0 ± 2,0	100,0 ± 0,0	–0,8 ± 4,4	64,4 ± 2,4	90,0 ± 0,0	–2,0 ± 2,3
PIR	85,0 ± 3,5	100,0 ± 0,0	–0,7 ± 2,8	60,6 ± 3,1	90,0 ± 8,2	4,0 ± 3,3
MBG-1	58,1 ± 4,3*	75,0 ± 5,8*	31,1 ± 4,1*	37,5 ± 3,5*	67,5 ± 9,6*	40,6 ± 5,8*
MBG-2	83,8 ± 1,4	100,0 ± 0,0	0,7 ± 2,8	64,4 ± 3,8	92,5 ± 5,0	–1,9 ± 3,8
LSD_{05}	4,3	4,0	5,9	3,3	10,2	5,4

*Values that differ from the control in a statistically significant manner ($p < 0,05$).

The methodology developed by A.A. Laptev, used to evaluate turf quality, includes an assessment of stand density on a 6-point scale, an assessment of overall aesthetic appeal on a 5-point scale, and a general assessment on a 30-point scale (based on criteria established for the forest zone). The obtained data are presented in Table 2.

An assessment of turf quality following the application of the bioagent *M. phacorrhiza* revealed that isolate MBG-1 improved turf density and uniformity; this yielded a combined score of 20 points, characterizing the cover quality as "good," in contrast to other treatments where the turf cover remained in "satisfactory" condition.

The NAKh, PIR, and MBG-2 isolates showed no advantages over the control variant; the condition of the herbage—specifically regarding stand density and projective cover—did not improve. Therefore, it was decided to use the MBG-1 isolate for further field studies.

Unstable weather and climatic conditions, combined with improper establishment techniques for sports turf, will foster the proliferation of low-temperature fungi that compromise the turf's aesthetic appeal and viability. Consequently, methods for regular phytosanitary monitoring and for evaluating the efficacy of various biocontrol agents—including both novel agents and those originally developed for cereal crops—could also be applied to golf courses.

Табл. 2. Результаты оценки качества газонного покрытия (2023/24 и 2024/25 гг., дендропарк Главного ботанического сада РАН), балл

Table 2. Results of the lawn cover quality assessment (2023/24 and 2024/25, arboretum of the Main Botanical Garden of the Russian Academy of Sciences), points

Option	Herbage density	Overall decorative quality	Comprehensive quality assessment	Quality category	Herbage density	Overall decorative quality	Comprehensive quality assessment	Quality category
Autumn 2023					*Spring 2024.*			
Control	5	5	25	Exc.	3	3	9	Mod.
PIR	5	5	25	Exc.	3	3	9	Mod.
NAKh	5	5	25	Exc..	3	3	9	Mod.
MBG-1	5	5	25	Exc.	4	4	16	Satisf..
MBG-2	5	5	25	Exc.	3	3	9	Mod.
Autumn 2024					*Spring 2025*			
Control	5	5	25	Exc.	4	4	16	Satisf..
PIR	5	5	25	Exc.	4	4	16	Satisf..
HAX	5	5	25	Exc.	4	4	16	Satisf..
MBG-1	5	5	25	Exc.	4	5	20	Good
MBG-2	5	5	25	Exc.	4	4	16	Satisf..

Note. Exc. – excellent; good – good; satisf. – satisfactory; mod. – moderate.

CONCLUSION

Despite differences in climatic conditions between the 2023/24 and 2024/25 winter seasons, the fungi *M. nivale* and *T. ishikariensis*—causative agents of pink and gray (speckled) snow mold—were consistently found in the pathogen complexes affecting golf course turf in the Moscow region.

In a small-plot experiment using artificial inoculation with *M. nivale* and *T. ishikariensis*, the *M. phacorrhiza* isolate MBG-1 demonstrated a statistically significant ($p < 0.05$) inhibitory effect on snow mold development during both winter seasons. Its application resulted in a 25.6 percentage point reduction in disease development and a 25.0 percentage point reduction in prevalence during the spring of 2025 compared to the control (biological efficacy of 40.6%).

According to the results of a comprehensive assessment of turfgrass quality, in the springs of 2024 and 2025, the use of the MBG-1 isolate resulted in higher shoot-forming capacity, overall turf aesthetic appeal, and quality category—surpassing the control and other experimental isolates by 7 and 4 points, respectively.

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Полевая оценка применения микосимбионта на яровой пшенице

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Работу проводили с целью определения эффективности инфицирования семян яровой пшеницы спорами микосимбионта. Полевые эксперименты проходили в южной лесостепи Курганской области (55°15′09″ с. ш., 65°07′48″ в. д.). Севооборот трехпольный зернопаровой, опыты закладывали на яровой пшенице по пару. Почва опытного участка – выщелоченный малогумусный тяжелосуглинистый чернозем. В ходе исследования сравнивали варианты обработки семян яровой пшеницы препаратом Ризомакс (споровомицелиальный комплекс микоризного гриба *Glomus* spp.), а также его сочетаниями с комплексом агрономически ценных бактерий (*Bacillus subtilis* + *Bacillus megatherium* + *Azotobacter chroococcum* + *Metarhizium anisopliae* + *Beauveria bassiana*), аминокислотным препаратом Амицид и комплексом микроэлементов Аквамикс. Выяснили, что благодаря действию микосимбионта растения сформировали большую массу корней к фазе начала кущения в вариантах Ризомакс, 2 л/т и Ризомакс, 2 л/т + Аквамикс, 100 г/т (соответственно +44 и 88% к контролю). Отрицательно на массу корней повлияла совместная обработка семян препаратом Ризомакс и Амицидом (–17% к контролю). Изучаемые препараты оказали положительное влияние на надземную часть пшеницы – ее масса была больше контрольного варианта на 8–42%. Результативнее повышалась полновесность растений в варианте Ризомакс, 2 л/т + Аквамикс, 100 г/т (+42% к контролю). Кроме того, корневая система растений в этом варианте была развита лучше. В фазу кущения поражение яровой пшеницы корневыми гнилями (гельминтоспориозной и фузариозной) не выходило за рамки порога вредоносности. В вариантах с обработкой препаратами интенсивность поражения составила от 5,8 до 6,4%, несколько меньше – в варианте с Биокомплексом (биологическая эффективность 26,5% по показателю развития болезни, 40% – по распространенности гнилей). В целом микоризный препарат обеспечил получение достоверных прибавок урожая (+2,0–2,7 ц/га). При этом его совместное применение с аминокислотным препаратом не позволило достоверно повысить урожайность пшеницы.

Ключевые слова: микориза, яровая пшеница, урожайность, препарат Ризомакс, симбиоз

Field evaluation of mycobiont application on spring wheat

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The work was carried out in order to determine the effectiveness of infecting spring wheat seeds with mycosymbiont spores. Field experiments were conducted in the Kurgan region: southern forest-steppe (55°15′09″ N, 65°07′48″ E). The crop rotation was a three-field grain-fallow system, experiments were set up on spring wheat in a fallow field. The soil of the experimental plot was leached, low-humus, heavy loamy chernozem. During the study, variants of treating spring wheat seeds with the Rizomax preparation (spore-mycelial complex of the mycorrhizal fungus *Glomus* spp.) were compared, as well as its combinations with a complex of agronomically valuable bacteria (*Bacillus subtilis* + *Bacillus megatherium* + *Azotobacter chroococcum* + *Metarhizium anisopliae* + *Beauveria bassiana*), with an amino acid preparation (Amicid) and a complex of trace elements (Aquamix). It was found that due to the action of the mycosymbiont, the plants developed a larger root mass by the tillering phase in the Rhizomax variants, 2 l/t and Rhizomax, 2 l/t + Aquamix, 100 g/t (respectively +44 and 88% compared to the control). The combined treatment of seeds with the preparations

Rizomax and Amicid negatively affected the root mass (–17% compared to the control). The studied preparations had a positive effect on the above-ground part of the wheat – its mass was 8–42% higher than the control variant. Full seed development of the plants increased more effectively in the Rizomax variant, 2 l/t + Aquamix, 100 g/t (+42% compared to the control). In addition, the root system of the plants in this variant was better developed. The infestation of spring wheat at the tillering stage by root rots (helminthosporium and fusarium) did not exceed the threshold of harmfulness. In the versions with treatment using the preparations, the intensity of damage ranged from 5.8 to 6.4%, slightly less in the version with Biocomplex (biological effectiveness 26.5% according to the disease development indicator, 40% – according to the prevalence of rot). Overall, the mycorrhizal preparation resulted in significant yield increases (+2.0–2.7 c/ha). However, its combined use with the amino acid preparation did not significantly increase wheat yield.

Keywords: mycorrhiza, spring wheat, yield, Rizomax preparation, symbiosis

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INTRODUCTION

Mycorrhiza is a symbiotic association of a fungus's mycelium with the roots of a higher plant. It's an evolutionarily developed, structurally formed symbiosis between a fungus adapted to life in the soil and inside a plant, and the root of a living plant, necessary for one or both partners. The symbiotic nutrition system is quite promising for crop production and is vital for plants, especially in conditions of low temperatures, high acidity, the presence of insoluble forms of phosphates in the soil, a short growing season, and other unfavorable factors[1] [1, 2].

It is known that among higher plants, all gymnosperms, about 70% of monocots, and 80–90% of dicots participate in symbiosis. At the same time, around 80% of all plants form symbiosis with Glomeromycota fungi, which create arbuscular mycorrhiza [2, 3].

Arbuscular mycorrhiza is found in all natural zones of Russia – from the polar desert to subtropical forests. Despite this, the biodiversity of arbuscular mycorrhizal fungi is not very high. Only a little over 300 species are known, belonging to the Glomeromycota phylum[2] [3].

The use of arbuscular mycorrhizal fungi in agricultural practice helps increase the uptake of nutrients from the soil, which usually leads to enhanced photosynthetic activity in plants and increased nitrogen-fixing activity [4, 5]. A root system colonized by mycorrhizal fungi can absorb more water. Studies have shown that water molecules with isotopic labels, accessible only to the mycorrhizal fungi's hyphae, can make their way into host plants [6–8]. With symbiosis,

[1] *Geltzer F.Yu.* Symbiosis with microorganisms – the basis of plant life. Moscow: MSKhA Publishing House, 1990, 136 p.

[2] *Spatafora J.W., Chang Y., Benny G.L., Lazarus K, Smith M.E., Berbee M.L., Bonito G., Corradi N., Grigoriev I., Gryganskyi A., James T.Y., O'Donnell K., Roberson R.W., Taylor T.N., Uehling J., Vilgalys R., White M.M., Stajich J.E.* A phylum-level phylogenetic classification of zygomycete fungi based on genome-scale data // Mycologia, 2016, vol. 108, Iss. 5, pp. 1028–1046.

plants have better root nutrition, soil resources are used more effectively, and crops become more resistant to phytopathogens [9–13].

Experiments conducted at the Bashkir State Agrarian University investigated the effect of the bio-fertilizer "Kormilitsa Mycorrhiza" on the growth and formation of arbuscular mycorrhiza in cultivated plants (soft wheat, field pea, and onion). It was demonstrated that the biological product—based on mycorrhizal fungi and consisting of mycelium and spores of the genus *Glomus*—enhanced plant growth and endomycorrhiza formation. Wheat proved to be the most responsive to the application of the product to the growing medium [14].

The use of arbuscular mycorrhiza is a promising approach that helps optimize the nutrition of agricultural crops and enhances their resistance to stress factors. However, there are reports of limitations regarding effective root colonization and the establishment of the plant-fungus symbiosis.

In the Trans-Urals, the mycotrophic status of herbaceous plants across a wide variety of ecological habitats was studied by I.A. Selivanov et al. According to the available data, the prevalence of vesicular-arbuscular mycorrhiza across different landscape-geographic zones is as follows: tundra – 42.2% of plants are mycorrhizal; forests – 77.9%; steppe – 85.4%; and desert – 60.9%. The researchers concluded that 78% of the plants studied were mycotrophic and that "mycosymbiotrophy in higher plants is the rule rather than the exception"[3].

In subsequent years, research most closely approximating the conditions of the Trans-Urals was conducted in Bashkiria and the dry steppe of the Cis-Urals (Republic of Kazakhstan)[4] [15].

It's known that in the Kurgan region over the past 25 years, the share of growing seasons with droughts of various intensities was 52%, including eight seasons that were moderately dry (HTC_{05-08} = 0,7–0,9), five – hyperarid (HTC = 0,3–0,6). More than half of the arable land has low levels of available phosphorus.

It is possible to reduce risks when growing crops in such conditions by using the process of mycorrhization. Scientific study of this issue for the main regional crop – spring wheat – has hardly been conducted in recent decades. However, there are prospects for this method to reduce dependence on abiotic environmental factors.

The goal of the study was to determine how effective it is to infect spring wheat seeds with mycosymbiont spores in the dry conditions of Trans-Urals.

MATERIAL AND METHODS

The study was carried out in the experimental field of the Kurgan Research Institute of Agriculture – a branch of the Ural Federal Agricultural Research Center of the Ural Branch of the Russian Academy of Sciences in 2018 and 2019. The study focused on spring soft wheat (*Triticum aestivum* L.) of the Omsk 36 variety (elite seed material) and the biological product Rizomax, which is a spore-mycelial complex of mycorrhizal fungi (with at least 2.0×10^9 CFU/ml of viable *Glomus* spp. cells).

The establishment of field trials and statistical data processing were carried out according to B.A. Dospekhov[5]. The study was conducted within a three-field grain-fallow crop rotation. There were four repetitions, and the size of the experimental plots was 20–22 m².

The soil of the experimental plot is a leached, low-power, low-humus heavy loamy chernozem. The humus content in the arable layer (0–20 cm) is 4.3–4.6%, available P_2O_5 (according to Chirikov) is 108–118 mg/kg of soil, exchangeable K_2O is 177–210 mg/kg, and the water pH is

[3]*Selivanov I.A., Gavrilyuk S.L.* On the mycotrophy of halophytes in the forest-steppe Trans-Urals // Selected Issues in Plant Biology, Physiology, and Ecology: A Collection of Articles. Perm, 1966. pp. 23–31.

[4]*Kuramshina Z.M., Khayrullin R.M.* Impact of extreme drought on mycorrhization of roots *Triticum aestivum* L. in the Southern Urals // Reports of the Russian Academy of Agricultural Sciences, 2015, N 1-2, pp. 13–15.

[5]*Dospekhov B.A.* Methodology of Field Experiment (with fundamentals of statistical analysis of research results): a textbook. Moscow: Alliance, 2011, 350 p.

5.6–5.7. The nitrate N-NO_3– content in the 0–20 cm layer before sowing was 13.2–19.5 mg/kg.

Weather conditions during the 2018 growing season were characterized by a lack of heat in May and June, a hot and dry July, and abundant precipitation during the second and third ten-day periods of August. The hydrothermal coefficient (HTC) for the growing season was 1.25, indicating favorable growing conditions; however, the uneven distribution of precipitation reduced spring wheat productivity.

In 2019, hydrothermal conditions were characterized by sharp temperature fluctuations at the beginning of the growing season and drought during the second half. The Hydrothermal Coefficient (HTC) for May–August was 0.85, indicating moderately dry conditions.

Primary surface tillage was carried out in the autumn using a BDM-2.4 disc harrow to a depth of 8–10 cm. In the spring, harrowing was performed once the soil reached physical maturity. As weeds emerged and the soil warmed to the optimal temperature, cultivation was carried out to a depth of 6–8 cm (using a KPS-4.2 stubble cultivator). Subsequently, row sowing was performed using an SSFK-6 mounted disc-type breeding seed drill, with a row spacing of 21 cm and a seeding rate of 5.0 million viable seeds per hectare. Immediately after sowing, the soil was compacted using a 3-KKSH-6 ring-spur roller. Harvesting was carried out in a single-phase operation using a Sampo-130 breeding combine, with each plot harvested individually.

Crop maintenance during the growing season involved chemical weeding at the tillering stage (Drotik, 0.4 l/ha + Zinger, 5 g/ha + ARGO, 0.6 l/ha) and a foliar application of fungicide and insecticide (Titul Duo, 0.32 l/ha + Eforia, 0.15 l/ha)—performed as needed between the end of stem elongation and flag leaf emergence (BBCH 34–37).

One day before sowing, the seed material was treated with a biological preparation (manual method; working solution application rate: 10 l/t).

The experimental design included the following variants:

1) Rizomax, 2 l/t;

2) Rizomax, 3 l/t;

3) Rizomax, 2 l/t + Amicid, 10 g/t (composition of amino acids and polypeptides);

4) Rizomax, 2 l/t + Aquamix, 100 g/t (concentrated micro-fertilizer);

5) Rizomax, 2 l/t + Biocomplex (*Bacillus subtilis* + *Bacillus megatherium* + *Azotobacter chroococcum* + *Metarhizium anisopliae* + *Beauveria bassiana*, by 1 l/t);

6) control (without seed treatment).

RESULTS AND DISCUSSION

The effectiveness of applying a mycosymbiont to spring wheat was evaluated using a fallow predecessor, which ensured a high level of macronutrient availability. Seed material with a low level of phytopathogen infection was used, as the combined application of a fungicidal seed treatment and a fungal-based mycorrhizal inoculant is not permissible.

Across the trial, the average field emergence of wheat ranged from 88% to 91%. It was slightly higher in the treatment involving Rizomax (2 l/t) plus Biocomplex; evidently, the bacteria (such as *Bacillus subtilis* and phosphate-solubilizing bacteria) introduced into the wheat rhizosphere successfully colonized the relevant ecological niches and positively influenced seedling development (through mechanisms such as antagonism toward phytopathogens, the production of enzymes and vitamins, and the conversion of certain mineral nutrients into plant-available forms).

To evaluate the effect of the preparations on wheat growth and development during the tillering stage, plants were sampled and their parameters determined. The obtained data are presented in Tables 1 and 2.

A positive effect of the preparations on the number and mass of the roots was observed with seed treatment using Rizomax at a dosage of 2 L/t (7.0 roots; +44% compared to the control), as

Табл. 1. Влияние инокуляции семян изучаемыми препаратами на параметры корневой системы и длину ростка (начало фазы кущения, 2018 и 2019 гг.)

Table 1. The effect of seed inoculation with the studied preparations on root system parameters and shoot length (beginning of the tillering phase, 2018 and 2019)

Option	Root length, cm	Number of roots, pcs..	Root mass from 10 plants	
			g	% to the control
Rizomax, 2 l/t	7,9	7,0	0,92	+44
Rizomax, 3 l/t	8,6	5,2	0,81	+27
Rizomax, 2 l/t + Amicid, 10 g/t	7,6	5,4	0,53	–17
Rizomax, 2 l/t + Aquamix, 100 g/t	7,9	8,5	1,20	+88
Rizomax, 2 l/t + Biocomplex	8,0	5,5	0,78	+22
Control	8,1	5,5	0,64	–
LSD_{05}	0,55	1,08	0,17	

Табл. 2. Влияние обработки семян изучаемыми препаратами на параметры надземной части растений (фаза кущения, 2018 и 2019 гг.)

Table 2. The effect of seed treatment with the studied preparations on the parameters of the aboveground part of plants (tillering phase, 2018 and 2019)

Option	Average leaf length, cm	Average leaf width, cm	Mass of the above-ground part of the plant	
			g	% to the control
Rizomax, 2 l/t	20,5	0,6	1,227	+19
Rizomax, 3 l/t	20,1	0,5	1,203	+16
Rizomax, 2 l/t + Amicid, 10 g/t	21,0	0,6	1,120	+8
Rizomax, 2 l/t + Aquamix, 100 g/t	19,5	0,6	1,467	+42
Rizomax, 2 l/t + Biocomplex	20,1	0,5	1,207	+17
Control	19,1	0,5	1,034	–
LSD_{05}	0,97	0,05	0,105	

well as with its combination with Aquamix (8.5 roots; +88%). The Rizomax (3 L/t) (+27%) and Rizomax (2 L/t) + Biocomplex (+22%) treatments had a slightly less pronounced positive effect on root system mass. Combined seed treatment with Rizomax and Amicid had a negative effect on the root mass (–17%).

When evaluating the effect of the tested preparations on the growth and development of the above-ground part of the plants, it should be noted that all of them had a beneficial effect on the wheat; its biomass exceeded that of the control variant by 8–42%. The treatment with Rizomax (2 L/t) + Aquamix (100 g/t) demonstrated the highest efficacy (+42%).

In the control group, the incidence of root rots (Helminthosporium and Fusarium) in spring wheat at the tillering stage was 7.9%, with symptoms observed in 58% of the plants. In the variants treated with the test preparations, the severity of infection ranged from 5.8% to 6.4%, with a prevalence of 36–40%; these figures remained below the critical level (economic damage threshold of 10%). Plant infection levels were somewhat lower in the treatment with Rizomax (2 L/t) + Biocomplex (biological efficacy of 26.5% regarding disease development and 40% regarding rot prevalence). Research on this matter will continue.

Analysis of the spring wheat yield structure showed that plant density and productive tillering were higher in the treatments involving the mycorrhizal preparation. The number of productive stems was 366 per m² in the control, compared to 375–387 per m² (+6%) in the Rizomax treatments. The treatment with microelements proved to be the most effective.

Plant height reached 91–96 cm. In the Rizomax (2 L/t) + Aquamix (100 g/t) treatment, plants were 2 cm taller and exhibited superior spike-bearing characteristics compared to the control.

Treating spring wheat seeds with the mycosymbiont resulted in statistically significant yield increases (+2.0–2.7 c/ha). When the Rizomax preparation was used alone, the yield increase was 2.3 c/ha; when used in combination with microelements, it was 2.9 c/ha. The application of the mycosymbiont with an amino acid preparation did not result in a statistically significant increase in crop yield (see Table 3). It

Табл. 3. Влияние изучаемых препаратов на урожайность и качество зерна (среднее за 2018 и 2019 гг.)

Table 3. The effect of the studied preparations on yield and grain quality (average for 2018 and 2019)

Option	Actual yield		Wet gluten content, %
	c/ha	+/– to the control	
Rizomax, 2 l/t	29,1	+2,3	26,2
Rizomax, 3 l/t	29,2	+2,4	26,6
Rizomax, 2 l/t + Amicid, 10 g/t	28,1	+1,3	25,8
Rizomax, 2 l/t + Aquamix, 100 g/t	29,5	+2,7	25,2
Rizomax, 2 l/t + Biocomplex	28,8	+2,0	26,4
Control	26,8	–	26,4
LSD_{05}	1,45		2,08

should be noted that this plant protection method can only be applied to seed material with a low level of infection by phytopathogenic fungi, as the chemical fungicidal seed treatment and the mycosymbiont are incompatible.

The mass fraction of wet gluten in the grain ranged from 25.8% to 26.6%. Variations in this parameter across the treatments fell within the margin of analytical error. Gluten protein quality was characterized as good in 2018 (60–75 GDI units) and as satisfactorily weak in 2019 (78–80 units). No effect of the tested preparations on grain quality parameters was observed.

CONCLUSION

The application of the mycorrhizal product Rizomax (as a seed treatment) on spring wheat under the arid conditions of the Trans-Urals region was more effective at an application rate of 2 L/t, as well as when combined with the Aquamix micro-fertilizer and a bacterial complex (*Bacillus subtilis* + *Bacillus megatherium* + *Azotobacter chroococcum* + *Metarhizium anisopliae* + *Beauveria bassiana*). A significant yield increase of 2.0–2.7 c/ha was observed. The use of the mycosymbiont in combination with an amino acid preparation did not result in a statistically significant increase in productivity. The incidence of root rots (Helminthosporium and Fusarium) in spring wheat during the tillering stage did not exceed the economic injury threshold, amounting to 7.9%. In the variants treated with the test preparations, the infection intensity ranged from 5.8% to 6.4%, being slightly lower in the variant treated with Biocomplex. In the seed-treatment variants, a reduction was observed in the number of plants showing signs of infection—36–40% compared to 58% in the control.

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Стафилиниды (Coleoptera, Staphylinidae) в ягодных насаждениях юга Западной Сибири

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Изучены фауна и сезонная динамика активности стафилинид на плантациях ягодных культур в агроценозах юга Западной Сибири. Проведенный обзор исследований показывает, что жуки-стафилиниды представляют собой важный и интенсивно изучаемый компонент энтомофауны в системах биологической защиты растений. Интерес к использованию энтомофагов обусловлен высокой численностью стафилинид, разнообразием их трофических связей и способностью контролировать численность широкого круга вредителей. Исследования проведены на территории Томской и Кемеровской областей в 2010–2022 гг. Сборы стафилинид проводили на посадках смородины, жимолости, малины, облепихи и земляники. В подстилке кустарниковых насаждений (черной смородины, жимолости и крыжовника) население коротконадкрылых жуков представлено 103 видами при доминировании *Philonthus rotundicollis* Men. Также к числу доминантов относятся *Drusilla canaliculata* F. и *Mocyta fungi* Grav., встречающиеся преимущественно в верхних слоях почвы и под опавшими листьями, на плантациях садовой земляники и под насаждениями облепихи. Кроме того, на ягодниках обычны *Philonthus varius* Gyll., *Ocypus fuscatus* Grav., *Tachinus rufipes* Deg*., Conosoma littoreum* L., *Gyrohypnus angustatus* Grav., *Xantholinus tricolor* F*., Quedius fuliginosus* F., *Oxytelus rugosus* F. и представители родов *Atheta, Oxypoda, Falagria, Geostiba*. В садовых насаждениях преобладают виды стафилинид с широкими ареалами, что свойственно для агроценозов не только Сибири, но и других регионов России. Для большинства видов характерны два пика активности в течение вегетационного периода. Большинство стафилинид не имеют пищевой специализации и питаются мелкими насекомыми, хотя представители рода *Tachyporus* питаются преимущественно тлями.

Ключевые слова: стафилиниды, фауна, динамика численности, ягодные культуры, Западная Сибирь

Staphylinids (Coleoptera, Staphylinidae) in berry plantations in the south of Western Siberia

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The fauna and seasonal dynamics of staphylinid activity in berry plantations within the agrocenoses of southern Western Siberia have been studied. The review of the conducted research shows that staphylinid beetles are an important and extensively studied component of the entomofauna within biological plant protection systems. Interest in using entomophages arises from the high abundance of staphylinids, the diversity of their trophic interactions, and their ability to control a wide range of pests. The research was conducted in the Tomsk and Kemerovo regions between 2010 and 2022. Collections of staphylinida were carried out in plantings of currants, honeysuckle, raspberries, sea buckthorn, and strawberries. The population of short-winged beetles is represented by 103 species, with *Philonthus rotundicollis* Men. dominating in the litter of shrub plantations (black currants, honeysuckles, and gooseberries). Other dominant species include *Drusilla canaliculata* F.. and *Mocyta fungi* Grav. which occur mainly in the upper layers of the soil and under fallen leaves on strawberry plantations and under sea buckthorn plantations. Additionally, *Philonthus varius* Gyll*., Ocypus fuscatus* Grav., *Tachinus rufipes* Deg., *Conosoma littoreum* L., *Gyrohypnus angustatus* Grav., *Xantholinus tricolor* F*., Quedius fuliginosus* F*., Oxytelus rugosus* F. and the representatives of the genera *Atheta*, *Oxypoda, Falagria*, and *Geostiba* are commonly found on berry bushes. Staphylinid species with broad distributions dominate in garden plantings, a pattern typical of agrocenoses in Siberia and other

regions of Russia. Most species exhibit two peaks of activity throughout the growing season. Most staphylinids lack food specialization and feed on small insects, though representatives of the genus *Tachyporus* primarily consume aphids.

Keywords: staphylinids, fauna, population dynamics, berry crops, Western Siberia

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INTRODUCTION

Rove beetles (Staphylinidae) constitute the largest group of coleopterous beetles. To date, more than 63,000 species within this family have been described[1]. Along with ground beetles, rove beetles (staphylinids) are among the most common soil-dwelling entomophages found in agroecosystems. Living in the top layers of soil and various soil substrates and having a wide range of food sources, staphylinids play an important role in controlling invertebrate populations[2] [1]. Information about the fauna and ecology of staphylinids in agroecosystems is scarce, and data on the trophic relationships of family members in most agrocenoses is available for only a limited number of species. The lifestyle of only some representatives of the subfamilies Aleocharinae and Paederinae, which are important natural enemies of agricultural pests, has been studied in some detail [2, 3].

Earlier, staphylinids was studied in European countries and North America, more closely on cereal crops[3–5]. In Russia, staphylinids in agroecosystems have been studied quite thoroughly in the agricultural landscapes of the Leningrad region – 147 species have been recorded here[6]. It has been noted that the species diversity of beetles is higher in perennial grasses compared to agrocenoses of annual grasses, cereals, and arable crops. Their role in regulating the population of the cabbage root fly has been emphasized[7].

The study of the fauna and some aspects of the ecology of staphylinids in garden agrocenoses was carried out on strawberry and raspberry plantations in Canada[8], in the apple orchards of the Czech Republic[9] and fruit orchards in Hungary[10].

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The influence of agricultural techniques and the characteristics of agrocenosis structure on the species composition, activity dynamics of staphylinids, and the choice of prey by predatory beetles has been analyzed[11].

The staphylinid fauna across all types of agricultural land is dominated by species with broad geographic ranges that function as generalist predators. Due to a lack of research, the role of staphylinids in agroecosystems is frequently underestimated. Among recent publications on the staphylinid fauna of horticultural agroecosystems, it is worth noting a study by researchers from Slovenia, who identified *Holobus flavicornis* (Boisduval & Lacordaire) and *Oligota oviformis* Casey, 1893, as promising biological control agents (specifically against *Tetranychus urticae* Koch) [4].

In recent years, research on staphylinids in agroecosystems has been conducted primarily in South Asian countries. For instance, *Bledius latiusculus* Kraatz has been recorded in India in flax fields, where it acts as an entomophage of the linseed bud fly (*Dasyneura lini* Barnes), preying on the pest during its larval stage [5]. Staphylinids have also been recorded as entomophages in the rice fields of Indonesia, where *Paederus fuscipes* Curtis was among the dominant species of all Coleoptera present [6]. In a study of the pest complex affecting cotton and their associated entomophages in India (Hyderabad), researchers examined the activity dynamics of these entomophages—including staphylinids—across various developmental stages of the crop. It was shown that the abundance of these beetles reaches its peak during the flowering phase of the cotton plant [7].

Staphylinids have been identified as entomophages with potential for controlling cutworm caterpillars in corn fields within tropical regions [8]. Metrics of species diversity and the spatiotemporal structure of staphylinid populations have been used to assess the condition of coffee plantations in Colombia [9, 10]. The need for widespread use of entomophages, including rove beetles, in modern integrated plant protection systems has been noted [11], including based on the study and use of staphylinid pheromones [12, 13].

A number of studies have looked at the effect of plant protection products on staphylinids. In pea crops in India, when testing five types of biological pesticides, *Paederus fuscipes* Curtis was used as the test subject. Relatively high resistance of beetles to *Bacillus thuringiensis* var. *kurstaki* was observed, along with a significant decrease in the population of the entomophage (by 26%) when agricultural crops were treated with azadirachtin [14]. Another species – *Dalotia coriaria* (Kraatz), used as a plant biological control agent in greenhouses, was used as a test subject in trials of a new generation of insecticides [15].

The purpose of the work is to identify the species diversity and the characteristics of the spatial and temporal distribution of staphylinids in berry crop plantations in the south of the taiga zone of Western Siberia.

MATERIAL AND METHODS

Research on staphylinid beetles in horticultural plantings was conducted between 2010 and 2022 in the Tomsk and Kemerovo regions. Specimens were collected throughout the growing season (from mid-May to the end of September) in plantations of currants, gooseberries, honeysuckle, raspberries, sea buckthorn, and strawberries located in the southern and western parts of the Tomsk Region (Bakcharsky, Krivosheinsky, and Tomsky districts) and the northern part of the Kemerovo Region (Tyazhinsky, Tisulsky, and Mariinsky districts). To collect staphylinids, Barber traps (200 ml plastic cups) with a

[11] *Balog A.*, *Marko V.*, *Imre A.* Farming system and habitat structure effect on rove beetles (Coleoptera, Staphylinidae) assembly in Central European apple and pear orchards // Biologia (Bratislava), 2009, vol. 64, pp. 343–349.

fixative (ethylene glycol) were used, along with sieving of soil and litter, and manual collection of beetles. In total, about 3,600 rove beetle specimens were collected. The faunal material was identified using basic identifiers, including all the main groups of staphylinids[12, 13] with verification of species identification according to the collections of the Zoological Institute of the Russian Academy of Sciences and the Zoological Museum of the University of Oslo (Norway).

RESULTS AND DISCUSSION

Currently, in the garden plantings in the studied area, we have noted 103 species of staphylinids, belonging to 32 genera of seven subfamilies. The subfamily Staphylininae has the largest number of species (37). Among the common species in the study area is *Philonthus rotundicollis* Men., which is found mainly in the leaf litter of shrub plantings and reaches quite high density in the root zone (20–23 ind./m²). This species is also common in the litter of aspen-birch forest areas located near agrocenoses, where its density reaches 30 ind./m². *Philonthus varius* Gyll., *Ocypus fuscatus* Grav., *Gyrohypnus angustatus* Grav., *Xantholinus tricolor* F., *Quedius fuliginosus* F. are also consistently found in decomposing plant debris and leaf litter in garden plantings, and their numbers range from 10 to 14 ind./ m². A common, but relatively few in berry plantations, species is *Philonthus decorus* Grav. – the dominant species in aspen and mixed forests in the south of Western Siberia.

The subfamily Aleocharinae is represented by 28 species in garden plantings. In strawberry and sea buckthorn plantations, the aleocharine species *Drusilla canaliculata* F. and *Mocyta fungi* Grav. are dominant; they are found in the upper soil layers and beneath fallen leaves. *D. canaliculata* is typically found in open areas, mostly in strawberry plantings, where its population reaches 28 individuals per m², while *M. fungi* is more often found in the leaf litter at the base of berry bushes (like currants and gooseberries). In the plantings of all berry crops, small numbers of *Atheta elongatula* Grav., *Oxypoda spectabilis* Markel, *Falagria nigra* Grav, *Geostiba circellaris* Grav have been regularly noted.

Staphylinids of the subfamily Tachyporinae are represented by 12 species, among which *Tachinus rufipes* Deg. (15–18 specimens/m² in shrub plantings of currants, gooseberries, and honeysuckle) and *Conosoma littoreum* L. (11–13 specimens/m² in the same plantings) were the most common. Members of the *Tachyporus* genus (*T. chrysomelinus* L., *T. solutus* Erich., *T. nitidulus* F. и *T. obtusus* L.) inhabit not only soil substrates but also the lower branches of shrubs and fruit trees. We found them on currant leaves, where the beetles were feeding on aphids and tiny mites.

Among the five species of staphylinids belonging to the subfamily Paederinae, *Lathrobium brunnipes* F. was dominant (6–8 individuals/m² in sea buckthorn plantations, and occurring only sporadically in all other crops). *Stilicus orbiculatus* Paykull has also been observed sporadically on strawberries and raspberries. Among the six representatives of the subfamily Omaliinae, *Aploderus caelatus* Grav. and *Megarthrus depressus* Payk. are worth noting; they occur in small numbers (up to 3 individuals/m²) in currant and honeysuckle plantings. *Acidota crenata* F. was also found in strawberry plantings at a similar density.

Among the nine species of staphylinids in the Oxytelinae subfamily, *Anotylus rugosus* F. was most often found in berry plantations. For this species and its close relative in terms

[12]*Freude H.*, *Harde K.W.*, *Lohse G.A*. Die Käfer Mitteleuropas. Band 4, Staphylinidae I (exklusive Aleocharinae, Pselaphinae und Scydmaeninae). Heidelberg: Spektrum Akademischer Verlag, 2012, 560 p.

[13]*Freude H.*, *Harde K.W.*, *Lohse G.A*. Die Käfer Mitteleuropas. Band 5, Staphylinidae II (Hypocyphtinae, Aleocharinae und Pselaphidae). Heidelberg: Spektrum Akademischer Verlag, 1999, 382 p.

of systematics, *Oxytelus laqueatus* Marsh., a mass flight of adults during the breeding period (the second half of June) is typical. In berry fields, the beetles are mostly found in decomposing plant debris under the bushes. All three representatives of the subfamily Steninae (*Stenus comma* Lec., *S. clavicornis* Scopoli, and *S. humilis* Erich.) are typical inhabitants of semi-aquatic ecosystems; within berry plantations, they are found only occasionally among shaded shrubs. Like *Tachyporus* beetles, members of the genus *Stenus* are capable of climbing onto the lower branches of berry-bearing shrubs in search of prey (small dipteran insects).

A study of the seasonal activity dynamics of staphylinid beetles in berry plantations revealed that most species exhibit two peaks in locomotor activity. In the study area, the first peak occurs in early June and is associated with the mass emergence of beetles from their overwintering sites and the onset of reproduction. A second, less pronounced increase in activity is driven by the emergence of a new generation of adults during the first and second ten-day periods of August. An exception is *D. canaliculata*, which displays a single peak of activity in midsummer.

Most staphylinid beetles inhabiting berry-crop agroecosystems are generalist predators and do not target specific prey. However, laboratory observations of staphylinids have shown that members of the genus *Tachyporus*, when given a choice of prey, exhibit a preference for aphids. For instance, *T. chrysomelinus* showed a preference for two aphid species: *Aphis pomi* and *Aphis grossulariae* over all other food sources offered; a single beetle could consume up to 25 aphids in a 24-hour period[14]. For these species, feeding on aphids has also been observed on the leaves of the lower branches of blackcurrant bushes and in the leaf litter.

The formation of the staphylinid fauna in berry plantations in the southern part of the taiga zone of Western Siberia is largely driven by the colonization of these agrocenoses by forest and meadow-dwelling species. Due to their strong dispersal capabilities, staphylinid beetles (rove beetles) are present in berry crops throughout the entire growing season and are capable of regulating the populations of many small invertebrates in the soil and surface substrates. In the berry plantations studied, the staphylinid species present are predominantly those with broad geographic ranges—a characteristic typical of agrocenoses not only in Western Siberia but also in other regions of Russia.

CONCLUSION

Research conducted in berry-crop agroecosystems in the southern taiga zone of Western Siberia has identified 103 species of staphylinid beetles (rove beetles). Due to their high population density, these beetles, along with ground beetles, rank among the primary generalist predators in the berry plantations of the studied region. Their high level of activity throughout the growing season suggests that staphylinids play a significant role in regulating the populations of small ground-dwelling invertebrates, including agricultural pests.

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Микробиологический фунгицид как инструмент повышения биологической эффективности протравливания семян

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В 2025 и 2026 гг. проведена оценка фитосанитарного состояния семенного материала в отношении грибных инфекций отдельных партий пшеницы и льна, возделываемых на сельскохозяйственных предприятиях Новосибирской и Курганской областей. Свободных от семенных инфекций партий не выявлено: зачастую семенной материал высокоинфицирован опасными возбудителями заболеваний. Ввиду формирования устойчивости фитопатогенными объектами к используемым химическим протравителям на основе пираклостробина (40 г/л) и тритиконазола (80 г/л) и тирама (400 г/л), дифеноконазола (30 г/л), на примере партии пшеницы сорта Новосибирская 41, РС 1 и льна масличного сорта Северный, РС 1 показана необходимость введения в протравливание микробиологического фунгицида с биологическим агентом *Bacillus subtilis*. По результатам испытаний установлено, что биологическая эффективность при условии использования баковой смеси на основе химического и микробиологических протравителей по *Alternaria* spp. и *Fusarium* spp. на пшенице Новосибирская 41 возрастает на 97 и 24% в сравнении с использованием исключительно химического протравителя. Аналогичная ситуация наблюдается в отношении опасного возбудителя крапчатости семядолей льна *Fungus sterilis* – биологическая эффективность возрастает на 58%. При введении в обработку семян микробиологического фунгицида отмечено ингибирование роста колоний грибов из рода *Alternaria* и *Fusarium*, формирующихся вокруг зерновок. Отмечено, что радиальный рост микромицетов *Alternaria* spp. и *Fusarium* spp. в варианте совместного применения химического препарата и препарата на основе *Bacillus subtilis* снижался в 4,8 и 5,4 раза по отношению к контролю против 1,6 и 2,9 раза в варианте с химическим протравителем. Установлено, что в 70% случаев *Alternaria* spp. при использовании баковой смеси не имела активного спороношения и находилась в стадии формирования хламидоспор.

Ключевые слова: семена, фунгицид-резистентность, химический протравитель, микробиологический фунгицид, инфицированность, биологическая эффективность, лен, пшеница

Microbiological fungicide as a tool for increasing the biological efficiency of seed treatment

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In 2025–2026, an assessment of the phytosanitary condition of seed material with respect to fungal infections was conducted in individual batches of wheat and flax grown at the agricultural enterprises in the Novosibirsk and Kurgan regions. No batches free from seed-borne infections were identified: often the seed material is highly infected with dangerous disease pathogens. Due to the development of resistance by phytopathogens to the used chemical seed treatments based on pyraclostrobin (40 g/l), triticonazole (80 g/l), thiram (400 g/l), and difenoconazole (30 g/l), the need for the introduction of a microbiological fungicide, the biological agent of which is *Bacillus subtilis*, into the seed treatment was demonstrated using the example of a batch of Novosibirskaya 41, RS 1 wheat and Severny, RS 1 oilseed flax. Test results revealed that the biological effectiveness of a tank mixture of chemical and microbiological seed treatment agents against *Alternaria* spp. and *Fusarium* spp. on Novosibirskaya 41 wheat increased by 97% and 24%, respectively, compared to using only a chemical seed treatment agent. A similar situation was observed with respect to *Fungus sterilis*, a dangerous flax cotyledon mottle pathogen, where biological effectiveness increased by 58%. Inhibition of the

growth of *Alternaria* and *Fusarium* fungal colonies forming around the kernels was observed with the introduction of a microbiological seed treatment agent. Radial growth of *Alternaria* spp. and *Fusarium spp*. micromycetes was reduced by 4.8 and 5.4 times, respectively, in the case of a combined use of the chemical and *Bacillus subtilis*-based seed treatments, compared to 1.6 and 2.9 times, respectively, in the case of using only a chemical seed treatment agent. It was found that in 70% of cases, *Alternaria* spp., when using a tank mixture, did not actively sporulate and was in the chlamydospore formation stage.

Keywords: seeds, fungicide resistance, chemical seed treatment, microbial fungicide, infestation, biological efficacy, flax, wheat

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The authors declare no conflict of interest.

INTRODUCTION

In the 1970s, the basics of integrated pest management (IPM) were developed and implemented – an internationally recognized model in agriculture, based on managing plant health risks and balancing production economics with environmental protection. In this approach, one of the goals is to introduce biologized technologies for growing crops using biological methods to protect plants from a range of harmful organisms, which minimizes chemical impact on agro-ecosystems [1]. In modern agricultural production, integrated approaches are especially important when dealing with emerging stable strains of pathogenic microorganisms. According to FRAC, by 2020, resistance was detected in over 230 plant pathogenic fungi to more than 100 active substances across various crops [2]. Resistance is a general biological trait and is a natural process of microorganisms adapting to changes in environmental conditions[1] [3, 4]. It's known that using fungicides with similar modes of action leads to selective pressure on pathogenic fungi, which increases the risk of developing resistance to antifungal drugs [5]. Because of this, there is a need for multiple treatments during the growing season, which only makes the problem worse. This makes the issue of creating new alternative products based on antagonist microorganisms and tank mixes of fungicides to control phytopathogenic microorganisms especially urgent [6–8]. It has been noted that combining chemical and microbiological components in a tank mix is the most effective way to inhibit the growth of plant pathogens [9].

It is known that using strains from the *Bacillus* genus as bioagents allows the creation of bacterial products with multiple effects: they induce systemic resistance in plants to phytopathogens, and have antibiotic, growth-promoting, and anti-stress activity [10]. The antifungal compounds produced by this group of microorganisms (fengycin, iturin, pumilacidin, mycosubtilin, and surfactin) help protect crops in the rhizosphere [11]. Bacteria of the *Bacillus* genus are interesting for creating commercial products also because the spores they form are resistant to extreme environmental conditions,

[1]*Siraeva Z.Yu., Vasilchenko E.V., Vasilchenko N.G.* Isolation and evaluation of micromycete resistance from genera *Alternaria*, *Fusarium*, and *Bipolaris* to fungicides // Actual problems in biodiversity and biotechnology: proceedings of the III international scientific and practical conference, Astrakhan, March 15, 2024. – Astrakhan: Astrakhan Tatishchev State University, 2024, pp. 239–240.

can survive the winter, and restore their protective effect in subsequent growing seasons. Using *Bacillus* microorganisms together with a chemical seed treatment reduces the level of infection by plant pathogens [12].

The purpose of the study is to look at how a microbiological preparation mixed with a chemical seed treatment affects the infection levels of spring wheat Novosibirsk 41 and oil flax Northern variety seeds.

MATERIAL AND METHODS

The objects of the study were spring wheat (cultivar Novosibirskaya 41, first generation/reproduction [RS 1]), oil flax (cultivar Severny, RS 1), fungal phytopathogens isolated from seeds, chemical seed treatment agents, and mixtures of these agents with the biofungicide Bactophyt.

The soft spring wheat variety Novosibirskaya 41 is middle-early, medium-height, drought-resistant, and intended for making high-quality bread for food purposes. The variety is included in the State Register for the West Siberian and East Siberian regions[3].

The "Severny" oilseed flax is an early-ripening variety intended for the production of high-quality industrial oil (with an oil content of 46.4–48.6%); its straw is suitable for obtaining short fiber. It is approved for cultivation in the following regions: Volga-Vyatka, North Caucasus, Middle Volga, Lower Volga, Ural, West Siberian, and East Siberian. Due to its high adaptability, it can be grown across a range of environments, from the steppe zone to the sub-taiga zone[4].

On wheat, trials were conducted using a two-component chemical seed treatment containing pyraclostrobin (40 g/l) and triticonazole (80 g/l), as well as the biofungicide Bactophyt, which is based on a strain of the spore-forming bacterium *Bacillus subtilis* IPM 215 (initial titer of at least 2 billion spores/g). For oilseed flax, a two-component seed treatment agent based on thiram (400 g/l) and difenoconazole (30 g/l) was used, along with the biofungicide Bactophyt. Two seed treatment options were evaluated for each crop (see Table 1).

Studies on the level of seed infection were conducted using a biological method on potato-dextrose agar (PDA) plates[5]. Eight seeds were placed in each Petri dish. A total of 280 seeds were analyzed, with 4 replicates. Incubation was carried out in an incubator at a constant temperature of 23 °C. On the 7th day after the incubation period, the fungal colonies that had formed around the seeds were examined under a binocular magnifier, and the genus of the

Табл. 1. Варианты протравливания семян
Table 1. Seed treatment options

Option	Culture, variety	
	Novosibirskaya 41 wheat	Severny flax
Control	without treatment	
Experiment 1	Pyraclostrobin (40 g/l), triticonazole (80 g/l) – application rate 0.6 l/t	Thiram (400 g/l), difenoconazole (30 g/l) – application rate 2,0 l/t
Experiment 2 (tank mix)	Pyraclostrobin (40 g/l), triticonazole (80 g/l) – 0,6 l/t *Bacillus subtilis* (at least 2 billion spores/g) – 3,0 l/t	Thiram (400 g/l) difenoconazole (30 g/l) – 2,0 l/t *Bacillus subtilis* (at least 2 billion spores/g) – 1,5 l/t

[2]*Osmanov M.A.* Efficacy of using chemical and biological fungicides in spring wheat crops // Forum of Young Scientists, 2020, No. 10 (50), pp. 526–532.

[3]URL: https://direct.farm/knowledge/plant/pshenica-myagkaya-yarovaya/537

[4]URL: https://direct.farm/knowledge/plant/len-maslichnyj/528

[5]GOST 12044–93. Agricultural seeds. Methods for determination of disease infestation. Minsk: Interstate Council for Standardization, Metrology and Certification, 2011. 57 p.

pathogen was determined through microscopic analysis.

The percentage of seed infection was calculated using the formula [13]

$$X_4 = \frac{N_1}{n} \times 100\%,$$

where N_1 – total number of infected seeds in four samples, pcs.; n – total number of seeds taken for analysis, pcs.

The biological effectiveness of seed treatment, expressed as a percentage, was evaluated using the formula [14]

$$C = \frac{Ab - Ba}{Ba} \times 100\%$$

where C – biological effectiveness, Ab – the rate of seed infection in the control; Ba – the rate of seed infection in the experimental variant.

The speed of infection development was assessed on the 5th day. The starting point was considered to be the first day without visible growth of fungal colonies. The radial growth rate of the mycelium of phytopathogenic micromycetes was determined using the formula [15]

$$\text{PCP} = R / \Delta t,$$

where PCP – radial colony growth rate, mm/day; R – colony radius, mm; Δt – cultivation duration, days.

The spread of sample mean values and the significance of differences between them in the experimental variants were determined using analysis of variance in Snedecor and Microsoft Excel.

RESULTS AND DISCUSSION

During the research, a critically high level of wheat seed infection with the causative agents of alternaria and fusarium was found – 73% and 57% (see Table 2). The infection of seed material with *Alternaria* spp. and *Fusarium* spp. in the control group and with the use of chemical seed treatment was practically the same. Using a tank mix based on a chemical seed treatment and *Bacillus subtilis* reduced the level of Fusarium infection by 24%. Adding the microbial component helped suppress the Alternaria infection with a biological effectiveness rate of 97%.

The biological effectiveness against the pathogen of helminthosporium rot (*Bipolaris* sp.) was 69% when using a chemical seed treatment and 100% with a tank mix.

The study of fungal colonies forming around the caryopsis showed that the rate of infection development varied significantly across the experimental variants (see Figs. 1 and 2). The tank mixture had the highest inhibitory activity compared to the control – the growth of *Alternaria* spp. and *Fusarium* spp. colonies was reduced by 4.8 and 5.4 times, versus 1.6 and 2.9 times with the chemical seed treatment.

When examining *Alternaria* spp. colonies under a microscope in the tank mix variant, it was found that in 70% of cases the fungus had no active sporulation and was in the stage of chlamydospore formation (see Fig. 3). This fact points to unfavorable conditions for the fungus,

Табл. 2. Влияние протравливания на инфицированность семян пшеницы Новосибирская 41
Table. 2. The effect of seed treatment on the infection of the Novosibirskaya 41 wheat seeds

Experiment option	Infestation, %			
	Alternaria spp.	*Fusarium* spp.	*Bipolaris* sp.	*Mucor* spp.
Control	73,0 ± 13,0	57,0 ± 14,2	13,0 ± 2,5	6,0 ± 1,5
Pyraclostrobin (40 g/l), triticonazole (80 g/l)	74,0 ± 7,0	52,0 ± 8,7	4,0 ± 1,2	2,0 ± 0,6
Tank mix: Pyraclostrobin (40 g/l), triticonazole (80 g/l), *Bacillus subtilis*	2,0 ± 1,5	33,0 ± 7,0	0	0

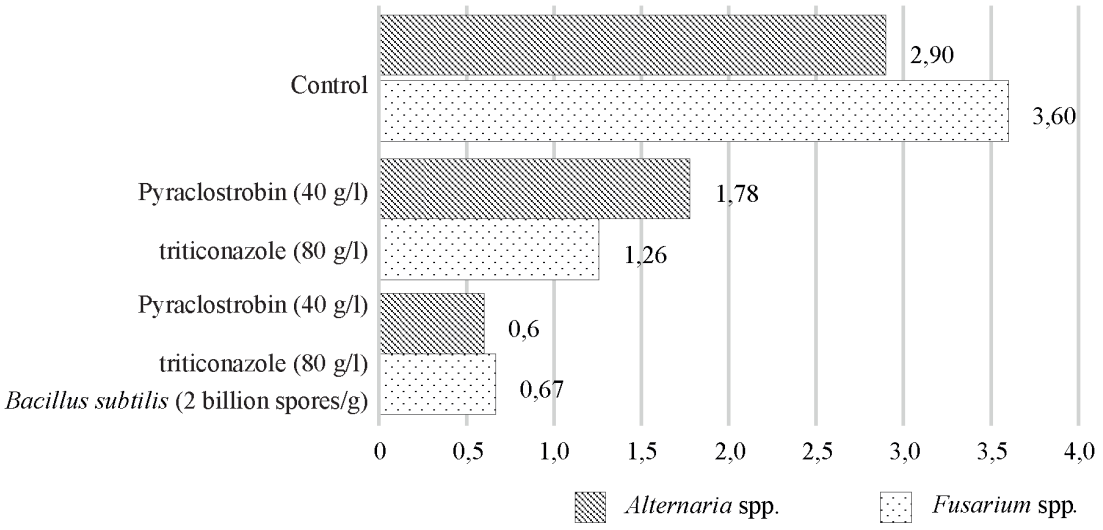


Рис. 1. Радиальная скорость роста грибов по вариантам опыта, мм/сут
$НСР_{05}$ по скорости роста *Fusarium* spp. – 0,69
$НСР_{05}$ по скорости роста *Alternaria* spp. – 0,64

Fig. 1. Radial growth rate of fungi according to the experimental variants, mm/day
LSD_{05} for *Fusarium* spp. growth rate – 0.69
LSD_{05} for *Alternaria* spp. growth rate – 0.64

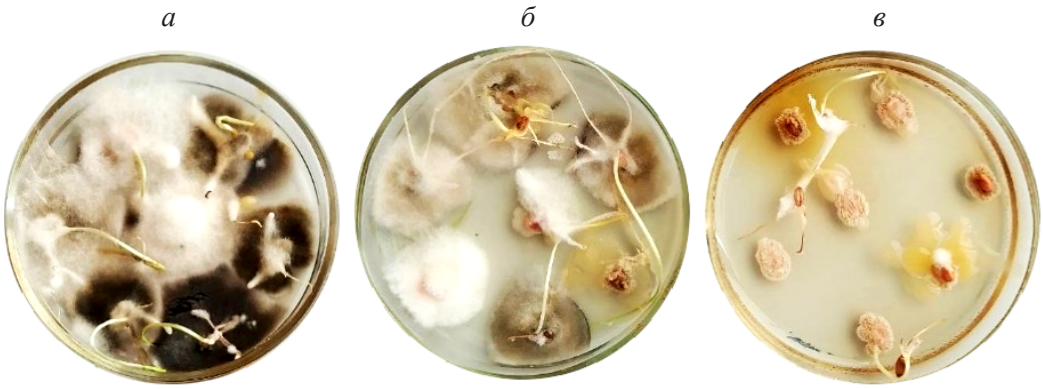


Рис. 2. Размер колоний фитопатогенных грибов вокруг зерновок пшеницы по вариантам опыта
а – контроль, *б* – химический протравитель, *в* – баковая смесь

Fig. 2. The size of phytopathogenic fungi colonies around wheat grains according to the experimental variants
а – control, *б* – chemical treatment, *в* – tank mixture

which triggers a protective mechanism aimed at survival.

An assessment of flax seed infection showed a high level of contamination by Alternaria pathogens (*Alternaria* spp.) and on such a dangerous disease as cotyledon blotch (*Fungus sterilis*) (see Table 3).

From the obtained data, it can be seen that the biological effectiveness against alternaria when using only a chemical seed treatment and a tank mix (chemical seed treatment and a microbiological biofungicide) differs only slightly – 57.8% and 73.5%. Introducing Bactophyt allows you to most effectively reduce the infection level of flax cotyledon spotting. The biological effectiveness when using a tank mix increases by 58% compared to using a pure chemical treatment.

Figure 4 shows that when a microbiological fungicide is added to the flax seed protection

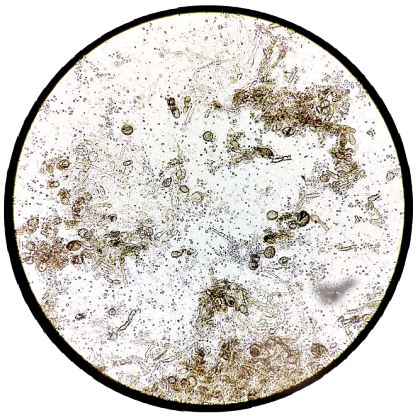


Рис. 3. Кусочки мицелия и хламидоспоры *Alternaria* spp.

Fig. 3. Pieces of mycelium and chlamydospores of *Alternaria* spp.

Табл. 3. Влияние протравливания на инфицированность семян льна масличного сорта Северный

Table. 3. The effect of dressing on the infection of flax seeds of the Severny oilseed variety

Experiment option	Infestation, %		
	Alternaria spp.	*Fusarium* spp.	*Fungus sterilis*
Control	23,8 ± 3,1	2,0 ± 0,6	15,0 ± 4,0
Thiram (400 g/l), difenoconazole (30 g/l)	10,0 ± 2,5	0	11,3 ± 2,5
Tank mix: Thiram (400 g/l) Difenoconazole (30 g/l) *Bacillus subtilis*	6,3 ± 1,5	0	3,8 ± 2,0

а



б



в

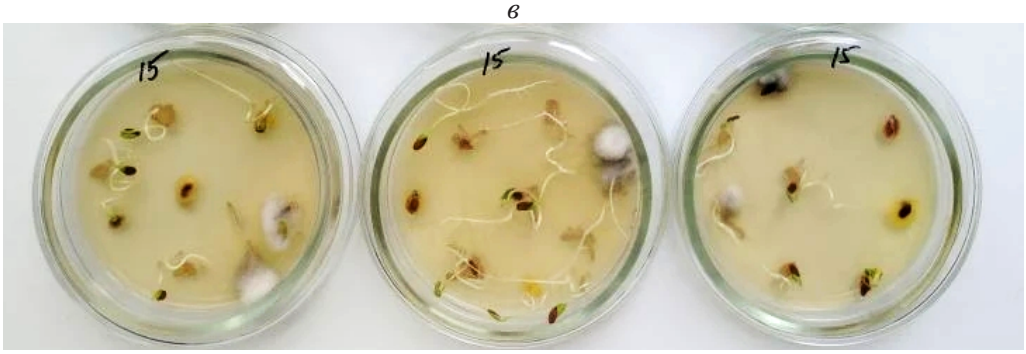


Рис. 4. Размер колоний фитопатогенных грибов вокруг семян льна по вариантам опыта
а – контроль; *б* – Тирам (400 г/л), дифеноконазол (30 г/л); *в* – Тирам (400 г/л), дифеноконазол (30 г/л), *Bacillus subtilis*

Fig. 4. The size of phytopathogenic fungi colonies around flax seeds according to the experimental variants
а – control, *б* – thiram (400 g/l), difenoconazole (30 g/l); *в* – thiram (400 g/l), difenoconazole (30 g/l), *Bacillus subtilis*

system, the radial growth of the disease-causing agent is inhibited.

CONCLUSION

It was found that using only chemical seed treatments didn't properly eliminate the seed infection. The clearly noticeable loss of sensitivity of the plant-pathogenic fungi to the active substances used suggests that fungicide resistance may have developed. The data presented above show that using a microbiological preparation based on *Bacillus subtilis* when treating seeds helps improve the plant health situation regarding pathogenic fungi, significantly reducing the infection level of wheat and flax seeds. Introducing a microbiological fungicide inhibits the growth of plant pathogens, helping create unfavorable conditions for the development of a harmful complex of microorganisms. This study suggests that the biofungicide Bactophyt contains compounds that might act as chemosensitizers, allowing the identified *Alternaria* spp. and *Fusarium* spp. to partially or fully overcome resistance to a seed treatment based on pyraclostrobin (40 g/l) and triticonazole (80 g/l), and *Fungus sterilis* to a seed treatment based on thiram (400 g/l) and difenoconazole (30 g/l).

The data obtained confirm the need for integrated approaches in agricultural production with elements of biological methods to improve the effectiveness of plant protection measures.

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AUTHOR GUIDELINES

The guidelines are drawn up in accordance with the ethical principles, common for all the members of the scientific community, and the rules for publications in international and local scientific periodic magazines as well as in compliance with the requirements stipulated by the State Commission for Academic Degrees and Titles for the periodicals included in the List of Russian peer-reviewed scientific journals in which the major scientific outcomes of theses for the degrees of Doctor or Candidate of Sciences must be published.

The journal publishes original articles on fundamental and applied issues by the following directions:

general agriculture and crop production;

plant breeding, seed production and biotechnology;

agrochemistry, soil science, plant protection and quarantine;

fodder production;

infectious diseases and animal immunology;

private zootechnics, feeding, technology of feed preparation and production of livestock products;

breeding, selection, genetics, and animal biotechnology;

technologies, machinery and equipment for the agro-industrial complex;

food systems.

The article sent to the editorial board must correspond to the thematic sections of the journal "Siberian Herald of Agricultural Science":

Section name	Code and name of the scientific specialty in accordance with the Nomenclature of Scientific Specialties, for which academic degrees are awarded
Agriculture and chemicalization	4.1.1. General agriculture and crop production 4.1.3. Agrochemistry, soil science, plant protection and quarantine
Plant growing and breeding	4.1.1. General agriculture and crop production 4.1.2. Plant breeding, seed production and biotechnology
Plant protection	4.1.3. Agrochemistry, soil science, plant protection and quarantine
Fodder production	4.1.1. General agriculture and crop production 4.1.2. Plant breeding, seed production and biotechnology 4.1.3. Agrochemistry, soil science, plant protection and quarantine
Zootechnics and veterinary medicine	4.2.3. Infectious diseases and animal immunology 4.2.4. Private zootechnics, feeding, technology of feed preparation and production of livestock products 4.2.5. Breeding, selection, genetics, and animal biotechnology
Mechanization, automation, modelling and dataware	4.3.1. Technologies, machinery and equipment for the agro-industrial complex
Agriproducts processing	4.3.3. Food systems
Problems. Opinions Scientific relations From the history of agricultural science Brief reports From dissertations	4.1.1. General agriculture and crop production 4.1.2. Plant breeding, seed production and biotechnology 4.1.3. Agrochemistry, soil science, plant protection and quarantine 4.2.3. Infectious diseases and animal immunology 4.2.4. Private zootechnics, feeding, technology of feed preparation and production of livestock products 4.2.5. Breeding, selection, genetics, and animal biotechnology 4.3.1. Technologies, machinery and equipment for the agro-industrial complex 4.3.3. Food systems

RECOMMENDATIONS TO THE AUTHOR BEFORE SUBMITTING AN ARTICLE

Submission of an article to the journal "Siberian Herald of Agricultural Science" implies that:

an article has not been published before in any other journal;

an article is not subject to review in any other journal;

all co-authors agree with the publication of the current version of the article.

Before submitting an article, it is necessary to make sure that the file (files) contains all the information required in Russian and English, tables and figures provide the source of the information presented, all references are written correctly.

PROCEDURE FOR SENDING MANUSCRIPTS OF ARTICLES

1. Submission of the article is carried out through the electronic editorial board on the journal's website https://sibvest.elpub.ru/jour/index. After preliminary registration of the author, choose the option "Send a manuscript" in the upper right corner of the page. Then download the manuscript (in *.doc or *.docx format) and the accompanying documents. When you have finished uploading, be sure to select the option "Send a Letter", in which case the editorial board will be automatically notified of the receipt of the new manuscript.

Accompanying documents to the manuscript of an article:

a scanned copy of a letter from the organization confirming authorship and permission to publish (sample cover letter);

a scanned copy of the author's note in the form provided (sample author's note), in which consent must be expressed for the open publication of the article in the printed version of the journal and its electronic copy in the Internet;

a scanned copy of the manuscript with the authors' signatures. The author, by signing the manuscript and sending it to the editorial office, thereby transfers the copyright for the publication of this article to SFSCA RAS;

author questionnaires in Russian and English (sample author questionnaire);

a scanned copy of your post-graduate school transcript (for full-time postgraduate students).

2. All manuscripts received by the editorial board are registered via the electronic editorial system. The author's personal account shows the current status of the manuscript.

3. Non-reviewed materials (scientific chronicles, reviews, book reviews, materials on the history of agricultural science and activities of institutions and scientists) are sent to the e-mail: sibvestnik@sfsca.ru and are registered by the executive secretary.

ARTICLE DESIGN PROCEDURE

The text of the manuscript is printed in Times New Roman font, type size 14 with 1.5 spacing, all margins 2.0 cm, page numbering at the bottom. The size of a manuscript should not exceed 15 pages (including tables, illustrations and bibliography); the articles placed in the sections "From dissertations" and " Brief reports" should not exceed 7 pages.

Article design structure:

UDC

2. Title of an article in Russian and English (no more than 70 characters).

3. Surnames and initials of the authors, full official name of the scientific institution where the research was conducted in Russian and English.

If authors from different institutions took part in the preparation of the article, it is necessary to indicate the affiliation of each author to a particular institution using the superscript index.

4. Abstract in Russian and English. The size of the abstract should not be less than 200-250 words. The abstract is a brief and consistent presentation of the material of the article on the main sections and should reflect the main content, follow the logic of the presentation of the material and description of the results in the article with the provision of specific data. The abstract should not include the newly introduced terms, abbreviations (with the exception of common knowledge), references to the literature. The abstract should not emphasize the novelty, relevance and personal contribution of the author; the place of research should be indicated to the district (region), specific organizations should not be mentioned.

5. Keywords in Russian and English. There should be up to 5–7 words by the topic of the article. It is desirable that the keywords support the abstract and the title of the article.

6. Information on the conflict of interests or its absence. The author should notify the editor on the real or potential conflict of interests by including the information in the appropriate section of the article. If there is no conflict of interests, the author should also inform the editor about it.

Example wording: "The author declares no conflict of interest".

7. Acknowledgements in Russian and English. This section lists all sources of funding for the study, as well as acknowledgements to people who contributed to the article but are not the authors.

8. The main body of the article. When presenting original experimental data, it is recommended to use subheadings:

INTRODUCTION (problem statement, goal and tasks of the study)

MATERIAL AND METHODS (conditions, methods (methodology) of research, object description, place and time of research)

RESULTS AND DISCUSSION

CONCLUSION

REFERENCES. The number of sources must be at least 12. The list of references includes only peer-reviewed sources: articles from scientific journals and monographs. Self-citation of no more than 10% of the total number. The bibliography list should be designed as a general list in the order of mention in the text, it is desirable to refer to sources 2-3 years old. The rules for the list of references are in accordance with GOST R 7.05-2008 (requirements and rules for compiling a bibliographical reference). In the text the reference to the source is marked by a serial number in square brackets, for example [1]. Literature in the list is given in the languages in which it was published. In the bibliographic description of the publication, it is necessary to include all authors, without abbreviating them by one, three, etc. It is unacceptable to abbreviate the names of articles, journals, publishing houses.

1. If it is necessary to refer to abstracts, dissertations, collections of articles, textbooks, recommendations, manuals, GOSTs, information from websites, statistical reports, articles in socio-political newspapers, etc., such information should be placed in a footnote at the end of the page. Footnotes are numbered in Arabic numerals and placed page by page through continuous page numbering.

Attention! Theoretical, review and problem articles can have any structure, but must contain an abstract, keywords, list of references.

EXAMPLE OF REFERENCES IN RUSSIAN AND ENGLISH AND FOOTNOTES

REFERENCES (in Russian):

Monograph

Klimova E.V. Field crops of Zabaikalya: monograph. Chita: Poisk, 2001. 392 p.

Part of a book

Kholmov V.G. Minimum tillage of coulisse-strip fallow for spring wheat with intensification of arable agriculture in southern forest-steppe of Western Siberia// Resource-saving tillage systems. Moscow: Agropromizdat, 1990. pp. 230-235.

Periodical publication

Pakul A.L., Lapshinov N.A., Bozhanova G.V., Pakul V.N. Technological grain qualities of spring common wheat depending on the system of soil tillage // Siberian Herald of Agricultural Science. 2018. vol. 48. № 4. pp. 27-35. DOI: 10.26898/0370-8799-2018-4-4.

REFERENCES (in English):

References are compiled in the same order as the Russian version, according to the following rules:

Names and surnames of the authors are given in the established way of transliteration, English title of the article, *transliteration of the name of the Russian-language source (for example through the site: https://antropophob.ru/translit-bsi) = English title of the source*. The order of presentation for a monograph is the following: city, English name of the publisher, year, number of pages; for a journal: year, volume, number, pages. (In Russian).

Example: Author A.A., Author B.B., Author C.C. Title of article.

Transliteration of the authors. English title of the article.

Zaglavie jurnala = Title of Journal, 2012, vol. 10, no. 2, pp. 49–54.

Transliteration of the source = English name of the source

Monograph

Klimova E.V. *Field crops of Zabaikalya*. Chita, Poisk Publ., 2001, 392 p. (In Russian).

Part of a book

Kholmov V.G. Minimum tillage of coulisse-strip fallow for spring wheat with intensification of arable agriculture in southern forest-steppe of Western Siberia. *Resource-saving tillage systems*, Moscow, Agropromizdat Publ., 1990, pp. 230–235. (In Russian).

Periodical publication

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FOOTNOTES:

Quated $text_1$.

1*Klimova E.V., Andreeva O.T., Temnikova G.P.* Ways to stabilize food production in Transbaikalia // Problems and prospects of perfecting zonal farming systems in modern conditions: materials of the scientific and practical conf. (Chita, October 16-17 2008). Chita, 2009, pp.36-39.

Digital Object Identifier – DOI (when the cited material has it) should be indicated at the end of the bibliographic reference.

Example:

Chu T., Starek M.J., Brewer M.J., Murray S.C., Pruter L.S. Assessing lodging severity over an experimental maize (Zea mays L.) field using UAS images // Remote Sensing. 2017. Vol. 9. P. 923. DOI: 10.3390/rs9090923.

The DOI of the article should be checked on the website http://search.crossref.org/ or https://www.citethisforme.com. To do this, enter the title of the article in English in the search bar.

FIGURES, GRAPHS, TABLES, SCREENSHOTS, PHOTOGRAPHS AND FORMULAS

The figures must be of good quality, suitable for printing. All figures must have captions. The caption must be translated into English. Figures should be numbered in Arabic numerals according to the order in the text. If there is only one figure in the text, it is not numbered. References to figures should be formatted as follows: “Fig. 3 indicates that ...” or “It is indicated that ... (see Fig. 3)”. The caption under the figure includes a figure number and its title. “Figure 2. Description of vital processes.” The translation of the figure caption should be placed after the figure caption in Russian.

Tables should be of good quality, suitable for printing. Tables suitable for editing are preferred, not scanned or

as figures. All tables should have headings. The title of the table should be translated into English. Tables should be numbered in Arabic numerals according to the order in the text. If there is only one table in the text, it is not numbered. References to tables should be formatted as follows: “Table 3 states that ...” or “It is stated that ... (see Table 3)”. The title of the table includes a table number and its title: “Table 2. Description of Vital Processes.” The translation of the table title should be placed after the table title in Russian.

Photos, screenshots must be uploaded separately as files of the following format*.jpeg files (*.doc and *.docx if the image has additional marks). The resolution of the image should be >300 dpi. The image files should be given a name corresponding to the figure number in the text. In the description of the file a caption should be given separately, which should correspond to the name of the picture placed in the text.

Graphs, charts, histograms, etc. should be attached as a separate file in Microsoft Excel program.

Attention should be paid to the spelling of formulas in the article. All formulas must be editable, i.e. it must be possible to make changes to them. To avoid confusion, it is necessary to write Greek (α, β, π, etc.), Russian (A, a, B, b, etc.) letters and numbers in straight font, Latin letters in italics (*W, Z, m, n*, etc.). Mathematical signs and symbols should also be written in straight font. It is necessary to clearly indicate upper and lower superscript characters (W_1, F_1, etc.).

INTERACTION BETWEEN THE JOURNAL AND THE AUTHOR

The Editorial Board asks the authors to be guided by the above stated rules when preparing the article.

All the articles submitted to “Siberian Herald of Agricultural Science” go through preliminary check for compliance with formal requirements. At this stage the Editorial Board reserves the right to:

• accept the article for review;

• return the article to the author (authors) for revision with a request to correct the mistakes or add the missing data;

• return the article which is designed not according to the journal’s requirements to the author (authors) without consideration;

• reject the article due to its inconsistency to the journal’s goals, lack of originality and little scientific significance.

Correspondence with the authors of the manuscript is maintained through a key contact mentioned in the manuscript.

All scientific articles submitted to the editorial board of the journal “Siberian Herald of Agricultural Science” undergo obligatory double-blind reviewing (author and reviewer do not know about each other). Manuscripts are sent in accordance with their research profile for reviewing to the members of the Editorial Board.

In controversial cases, the editor may involve several specialists in the review process, as well as the Editor-in-Chief. If the reviewer’s opinion is positive, the article is submitted to the editor for preparation for publication.

In case a decision is made to have the manuscript revised, reviewer’s comments and remarks are passed to the author. The latter is given two months to make amendments. If, within this period, the author has not notified the editors about the actions planned, the article is removed from the publication waiting list.

In case there is a decision to reject the article, the notification with the editorial decision is sent to the author.

The designated author (contact author) is sent the final version of the manuscript accepted for publication, which he/she must check.

REVERSAL OF EDITOR/ REVIEWER’S DECISION

In case the author does not agree with the conclusions of the reviewer and/or editor, they can dispute the decision made. In order to do this, the author should:

• amend the manuscript in compliance with the comments substantiated by reviewers and editors;

• clearly outline their stance on the issue under question.

The editors facilitate the second submission of manuscripts that could potentially be accepted but were rejected due to the need of significant amendments or collection of the additional data, and are ready to clearly explain what must be rectified in the manuscript for it to be accepted for publication.

ACTIONS OF THE EDITORIAL BOARD IN CASE OF PLAGIARISM AND DATA FALSIFICATION DETECTION

The Editorial Board of the “Siberian Herald of Agricultural Science” follows the conventional ethical principles for scientific periodicals and guidelines of the “Publication Ethics Code” developed and approved of by the Committee on Publication Ethics (COPE) and demands that all those involved in the publishing process should obey these principles.

ERRORS RECTIFICATION AND ARTICLE WITHDRAWAL

In case of error detection that affect understanding of an article but do not distort the results of research, they can be rectified by replacing the pdf-file of an article. In case of error detection that distort the results of research or in case of plagiarism or misconduct of the author (authors) connected with data falsification, the article can be withdrawn. The withdrawal can be initiated by the editors, the author, organization or private individual. Such article is marked with the note “Article withdrawn”, the page of the article gives the reason for withdrawal. Information about the article withdrawal is sent to data bases where the journal is indexed.