



ISSN 0370-8799 (Print)
ISSN 2658-462X (Online)



SIBERIAN HERALD OF AGRICULTURAL SCIENCE

Volume 56 No 1 2026

SIBERIAN HERALD OF AGRICULTURAL SCIENCE



No 1

Volume 56

JANUARY 2026



THE SCIENTIFIC JOURNAL
**SIBERIAN HERALD
OF AGRICULTURAL SCIENCE**

SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

FOUNDERS: SIBERIAN FEDERAL SCIENTIFIC CENTRE OF AGRO-BIOTECHNOLOGIES OF THE RUSSIAN ACADEMY OF SCIENCES;
SIBERIAN BRANCH OF THE RUSSIAN ACADEMY OF SCIENCES

ESTABLISHED IN 1971

12 ISSUES PER YEAR

Volume 56, No. 1 (326)

DOI: 10.26898



**2026
January**

The purpose of the journal is to promptly inform scientists and practitioners of agricultural production about the latest achievements of agricultural science. The "Siberian Herald of Agricultural Science" publishes original articles on fundamental and applied problems in the following areas: 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.

Acting Editor-in-Chief – Tatyana A. Lombanina, Head of the "Agronauka" Publishing House of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences, Novosibirsk, Russia

Editorial board:

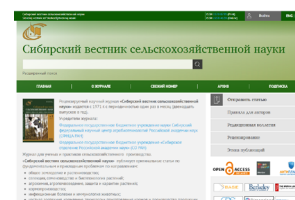
Vladimir V. Azarenko
Victor V. Alt
Olga S. Afanasenko
Gennady P. Gamzikov
Kirill S. Golokhvast
Nikolay P. Goncharov
Mikhail I. Gulyukin
Valery N. Delyagin
Seyed Ali Johari
Irina M. Donnik
Asankadyr T. Zhunushov

Nikolay M. Ivanov
Andrey Yu. Izmailov
Nikolay I. Kashevarov
Valery I. Kiryushin
Akhyrbek K. Kurishbaev

Sergey N. Mager
Muhammad A. Nawaz
Askar M. Nametov

Vasil S. Nikolov
Sergey P. Ozornin
Valery L. Petukhov
Revмира I. Polyudina
Amonullo F. Salimzoda
Marina I. Selionova
Vladimir A. Soloshenko
Nikolay A. Surin
Aristidis M. Tsatsakis
Alexander A. Shpedt
Sezai Ercisli
Seung H. Yang

Dr. Sci. in Engineering, Cor. Mem. of the Nat. Acad. Sci. of Belarus, Minsk, Belarus
Acad. of Russ. Acad. Sci., Dr. Sci. in Engineering, Novosibirsk, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Biology, Saint-Petersburg, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Biology, Novosibirsk, Russia
Cor. Mem. of Russ. Acad. Edu., Dr. Sci. in Biology, Novosibirsk, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Biology, Novosibirsk, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Veterinary Medicine, Moscow, Russia
Dr. Sci. in Engineering, Novosibirsk, Russia
Associate Professor, PhD, Sanandaj, Iran
Acad. of Russ. Acad. Sci., Dr. Sci. in Biology, Moscow, Russia
Dr. Sci. in Veterinary Medicine, Acad. of the Nat. Acad. Sci. Rep. of Kyrgyzstan, Bishkek, Kyrgyzstan
Cor. Mem. of Russ. Acad. Sci., Dr. Sci. in Engineering, Novosibirsk, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Engineering, Moscow, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Agriculture, Novosibirsk, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Biology, Moscow, Russia
Dr. Sci. in Agriculture, Acad. of Nat. Acad. Sci. Rep. of Kazakhstan, For. Mem. of the Russ. Acad. Sci., Alma-Ata, Kazakhstan
Dr. Sci. in Biology, Novosibirsk, Russia
Professor, PhD, Tomsk, Russia
Dr. Sci. in Veterinary Medicine, Cor. Mem. of the Nat. Acad. Sci. Rep. of Kazakhstan, Uralsk, Kazakhstan
Dr. Sci. in Veterinary Medicine, Sofia, Bulgaria
Dr. Sci. in Engineering, Chita, Russia
Dr. Sci. in Biology, Novosibirsk, Russia
Dr. Sci. in Agriculture, Novosibirsk, Russia
Dr. Sci. in Agriculture, Acad. of the Acad. of Agr. Sci. of Tajikistan, Dushanbe, Tajikistan
Dr. Sci. in Biology, Moscow, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Agriculture, Novosibirsk, Russia
Acad. of Russ. Acad. Sci., Dr. Sci. in Agriculture, Krasnoyarsk, Russia
Dr. Sci. in Biology, For. Mem. of the Russ. Acad. Sci., Crete, Greece
Dr. Sci. in Agriculture, Krasnoyarsk, Russia
Professor, PhD, Erzurum, Turkey
Professor, PhD, Gwangju, Korea



www.sibvest.elpub.ru



Editors *Evgeniya M. Isaevich, Galina N. Yagupova*. Corrector *Valentina E. Selyanina*.

Desktop Publisher *Natalya Yu. Borisko*. Translator *Marina Sh. Gatsenko*.

Certificate PI FS77-64832 issued by the Federal Service for Supervision of Media, Communications and Information Technologies on February 2, 2016

Publisher: Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences

Editorial and publisher's address: PO Box 463, office 456, SFSCA RAS Building, Krasnoobsk, Novosibirsk District, Novosibirsk Region, 630501, Russia

Printing house address: room 156, SRI of Fodder Crops building, Krasnoobsk, Novosibirsk District, Novosibirsk Region, 630501, Russia

Tel/fax: +7-383-348-37-62; **e-mail:** sibvestnik@sfsca.ru; <https://sibvest.elpub.ru>

Published on 10.02.2026. Format 60 × 84/8. Paper type. No. 1. Offset printing. Printer's sheet 15,5.

Publisher's signature 15,5. Circulation 500 copies. The price is free

Printed at the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences

© Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences, 2026

© Siberian Branch of the Russian Academy of Sciences, 2026



СОДЕРЖАНИЕ

CONTENTS

ЗЕМЛЕДЕЛИЕ
И ХИМИЗАЦИЯ

AGRICULTURE
AND CHEMICALIZATION

Рассохина И.И., Сухарева Л.В., Ерегина С.В., Платонов А.В. Первичные результаты оценки потенциала микробиома *Heracleum sosnowskyi* для агропроизводства Нечерноземной зоны России

5 Rassokhina I.I., Sukhareva L.V., Ereгина S.V., Platonov A.V. Initial results of the assessment of the microbiome potential of *Heracleum sosnowskyi* for agricultural production in the Non-Chernozem Zone of Russia

РАСТЕНИЕВОДСТВО И СЕЛЕКЦИЯ

PLANT GROWING AND BREEDING

Агеева Н.М., Ульяновская Е.В., Щеглов С.Н., Ширшова А.А., Храпов А.А., Чернуцкая Е.А., Богданович Т.В. Оценка влияния сортовых признаков яблони на содержание микро- и макроэлементов в сидре

16 Ageyeva N.M., Ulyanovskaya E.V., Shcheglov S.N., Shirshova A.A., Khrapov A.A., Chernutskaya E.A., Bogdanovich T.V. Assessment of the influence of apple tree varietal characteristics on the content of micro- and macroelements in cider

Луговцова С.Ю., Ступко В.Ю., Нешумаева Н.А., Герасимов С.А. Оценка устойчивости овса к корневым гнилям *in vitro*: опыт применения в селекции

25 Lugovtsova S.Yu., Stupko V.Yu., Neshumaeva N.A., Gerasimov S.A. *In vitro* evaluation of oat resistance to root rot: experience of application in breeding

- | | |
|---|---|
| <p>Малюга А.А., Батов А.С., Гуреева Ю.А.
Влияние средств интенсификации на выход семенной фракции у сортов картофеля сибирской селекции</p> | <p>34 Malyuga A.A., Batov A.S., Gureeva Yu.A.
The influence of intensification agents on the yield of seed fraction in Siberian potato varieties</p> |
| <p>Азопкова М.А. Оценка себестоимости производства посадочного материала чеснока стрелкующегося (<i>Allium sativum</i> L.) с использованием технологии <i>in vitro</i></p> | <p>48 Azopkova M.A. Estimation of the production cost of the planting material of bolting garlic (<i>Allium sativum</i> L.) using <i>in vitro</i> technology</p> |
| <p>Андреева О.Т. Фенологическое развитие и урожайность ромашки аптечной и календулы лекарственной в зависимости от сроков посева в Забайкалье</p> | <p>55 Andreeva O.T. Phenological development and productivity of wild chamomile and calendula officinalis depending on the sowing time in Transbaikalia</p> |

ЗАЩИТА РАСТЕНИЙ

PLANT PROTECTION

- | | |
|--|---|
| <p>Васильченко А.В., Прах С.В., Подгорная М.Е. Сезонная динамика лёта доминирующих чешуекрылых вредителей в современных садах</p> | <p>64 Vasilchenko A.V., Prach S.V., Podgornaya M.E. Seasonal flight dynamics of dominant Lepidoptera pests in modern gardens</p> |
| <p>Федина Л.А., Маркова Т.О., Маслов М.В. Распространение <i>Cephalophilon nepalense</i> (Polygonaceae) и <i>Rorippa sylvestris</i> (Brassicaceae) в агроценозах юга Приморского края</p> | <p>72 Fedina L.A., Markova T.O., Maslov M.V. Distribution of <i>Cephalophilon nepalense</i> (Polygonaceae) and <i>Rorippa sylvestris</i> (Brassicaceae) in agrocenoses of the south of the Primorsky Territory</p> |

ЗООТЕХНИКА И ВЕТЕРИНАРИЯ

ZOOTECHNICS AND VETERINARY MEDICINE

- | | |
|---|--|
| <p>Задорожная М.В., Лыско С.Б., Гофман А.А., Сунцова О.А. Гематологический и биохимический состав крови цыплят-бройлеров при применении биологически активной добавки на фоне вакцинации</p> | <p>79 Zadorozhnaya M.V., Lysko S.B., Gofman A.A., Suntsova O.A. Hematological and biochemical composition of the blood of broiler chickens when using a biologically active supplement during vaccination</p> |
|---|--|

*МЕХАНИЗАЦИЯ, АВТОМАТИЗАЦИЯ,
МОДЕЛИРОВАНИЕ
И ИНФОРМАЦИОННОЕ ОБЕСПЕЧЕНИЕ*

*MECHANISATION, AUTOMATION,
MODELLING
AND DATAWARE*

**Манцуров К.Н., Барабанов В.Г., Кух-
тик М.П., Федорова Н.В.** Система
автоматического сбора яблок в интен-
сивных садах с использованием пери-
стальтической системы транспорти-
ровки плодов

**86 Mantsurov K.N., Barabanov V.G., Kukh-
tik M.P., Fedorova N.V.** An automa-
tic apple harvesting system for intensive
orchards using a peristaltic fruit transport
system

**Иванников А.Б., Деменок И.В., Ко-
ноненко Н.В., Ильиченков А.С.**
Влияние климатических условий на
эффективность использования ма-
шинно-тракторного парка в агропро-
мышленном комплексе

**95 Ivannikov A.B., Demenok I.V., Kononen-
ko N.V., Ilyichenkov A.S.** The influence
of climatic conditions on the efficiency of
using the machine and tractor fleet in the
agro-industrial complex

**Яковлев Н.С., Рассомахин Г.К., Чер-
нышов А.П.** Применение кольцевых
и винтовых катков при посеве пшени-
цы по обработанной залежной почве

**107 Yakovlev N.S., Rassomakhin G.K., Cher-
nyshov A.P.** Using ring and screw rollers
when sowing wheat on cultivated fallow
soil



<https://doi.org/10.26898/0370-8799-2026-1-1>

УДК 579.64

Тип статьи: оригинальная

Type of article: original

Первичные результаты оценки потенциала микробиома *Heracleum sosnowskyi* для агропроизводства Нечерноземной зоны России

Рассохина И.И., Сухарева Л.В., Ерегина С.В., (✉) Платонов А.В.

Вологодский научный центр Российской академии наук

Вологда, Россия

(✉) e-mail: platonov70@yandex.ru

Отставание АПК России от стратегических установок на внедрение экологически безопасных технологий в сельскохозяйственное производство подчеркивает необходимость исследований, направленных в том числе на создание и изучение новых микробных препаратов. Цель исследования – поиск перспективных для агропроизводства Нечерноземной зоны России бактерий. Объектом для получения таких бактерий выбран борщевик Сосновского (*Heracleum sosnowskyi*), обладающий высокой экологической пластичностью и способностью к быстрой экспансии. В рамках исследования в 2025 г. проведен выезд в луговое сообщество с плотными зарослями *H. sosnowskyi* неподалеку от д. Мухино Череповецкого округа Вологодской области. Собрано 36 растительных образцов различных органов данного вида, из которых в лаборатории выделено 76 бактериальных изолятов (44 эпифитных штамма и 32 эндофитных). Оценке подвергали следующие свойства штаммов: способность синтезировать индолилуксусную кислоту, фиксировать молекулярный азот, трансформировать фосфаты в доступную для растений форму, проявлять целлюлозо-, протео- и амилолитическую активность. Результаты изучения выделенных изолятов показали, что штаммы БЛ-02-25эн и БЛ-03-25эн обладают высоким ростостимулирующим потенциалом, синтезируют индолилуксусную кислоту в количестве 129,8–151,7 мг/л, отличаются развитой способностью трансформировать фосфаты и фиксировать атмосферный азот. К тому же данные изоляты не проявили целлюлозолитической активности. При этом для разложения растительных остатков перспективным оказался изолят БС-05-25эн, который одновременно достаточно хорошо гидролизует целлюлозу, крахмал и казеин. Штаммы БК-11-25, БЛ-03-25, БП-11-25, БК-02-25эн, БЛ-01-25эн, БС-04-25эн, БС-05-25эн обладают высокой амило- и протеолитической активностью, что может указывать на их потенциальную способность подавлять развитие фитопатогенов.

Ключевые слова: борщевик Сосновского, микробиом, стимуляция роста, ауксины, фосфор, азот

Initial results of the assessment of the microbiome potential of *Heracleum sosnowskyi* for agricultural production in the Non-Chernozem Zone of Russia

Rassokhina I.I., Sukhareva L.V., Ereghina S.V., (✉) Platonov A.V.

Vologda Research Center of the Russian Academy of Sciences

Vologda, Russia

(✉) e-mail: platonov70@yandex.ru

The Russian agro-industrial complex's disadvantage in strategic directions for the introduction of environmentally friendly technologies into agricultural production highlights the need for research aimed, among other things, at the creation and study of new microbial preparations. The purpose of the study is to search for bacteria that are promising for agricultural production in the Non-Chernozem Zone of Russia. The object chosen for obtaining such bacteria was Sosnowsky's hogweed (*Heracleum*

sosnowskyi), which has high ecological plasticity and the ability to rapidly expand. As part of the study, in 2025 a field visit was made to a meadow community with dense thickets of *H. sosnowskyi* near the village of Mukhino in the Cherepovets district of the Vologda region. 36 plant samples of various organs of this species were collected, from which 76 bacterial isolates (44 epiphytic strains and 32 endophytic) were isolated in the laboratory. The following properties of the strains were assessed: the ability to synthesize indoleacetic acid, fix molecular nitrogen, transform phosphates into a form accessible to plants, and exhibit cellulose, proteolytic, and amylolytic activity. The results of the study of the isolated strains showed that the BL-02-25en and BL-03-25en strains have a high growth-stimulating potential, synthesize indoleacetic acid in an amount of 129.8–151.7 mg/l, and are distinguished by a developed ability to transform phosphates and fix atmospheric nitrogen. Moreover, these isolates did not exhibit cellulolytic activity. Moreover, the isolate BS-05-25en has proven promising for the decomposition of plant residues, as it hydrolyzes cellulose, starch, and casein quite well at the same time. Strains BK-11-25, BL-03-25, BP-11-25, BK-02-25en, BL-01-25en, BS-04-25en, BS-05-25en have high amylolytic and proteolytic activity, which may indicate their potential ability to suppress the development of phytopathogens.

Keywords: *Heracleum sosnowskyi*, microbiome, growth stimulation, auxins, phosphorus, nitrogen

Для цитирования: Рассохина И.И., Сухарева Л.В., Ерегина С.В., Платонов А.В. Первичные результаты оценки потенциала микробиома *Heracleum sosnowskyi* для агропроизводства Нечерноземной зоны России // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 5–15. <https://doi.org/10.26898/0370-8799-2026-1-1>

For citation: Rassokhina I.I., Sukhareva L.V., Ereina S.V., Platonov A.V. Initial results of the assessment of the microbiome potential of *Heracleum sosnowskyi* for agricultural production in the Non-Chernozem Zone of Russia. *Sibirskii vestnik sel'skookhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 5–15. <https://doi.org/10.26898/0370-8799-2026-1-1>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

Благодарность

Исследование выполнено при поддержке гранта Российского научного фонда № 25-26-00204 «Биотехнологические потенциал микробиома *Heracleum sosnowskyi* Manden. для агропроизводства Нечерноземной зоны России» (<https://rscf.ru/project/25-26-00204/>).

Acknowledgements

The study was supported by the Russian Science Foundation Grant No. 25-26-00204 "Biotechnological potential of the *Heracleum sosnowskyi* Manden. microbiome for agricultural production in the Non-Chernozem Zone of Russia" (<https://rscf.ru/project/25-26-00204/>).

INTRODUCTION

Modern high-yield agricultural production is inextricably linked with the use of fertilizers and pesticides [1]. Due to the increasing relevance of environmental conservation and public health issues, Russian agricultural policy has recently been shifting its focus more towards organic farming [2]. This is confirmed by adopted pro-

gram documents: Strategy for Scientific and Technological Development of the Russian Federation¹, Development Strategy for the Production of Organic Products in the Russian Federation until 2030², Strategy for the Development of the Agro-Industrial and Fisheries Complexes of the Russian Federation for the period up to 2030³, Food Security Doctrine of the Russian Federation⁴.

¹Strategy for Scientific and Technological Development of the Russian Federation: approved by the Decree of the President of the Russian Federation No. 145 of February 28, 2024 // Official website of the Administration of the President of the Russian Federation. URL: <http://www.kremlin.ru/acts/bank/50358>.

²Development Strategy for the Production of Organic Products in the Russian Federation until 2030: approved by the Government of the Russian Federation Order No. 1788-r of 04.07.2023 // Official website of the Government of the Russian Federation. URL: <http://static.government.ru/media/files/8tJynEn7pLVLfdqqL6p3BhArPtCQW9Aw.pdf>.

³Strategy for the Development of the Agro-Industrial and Fisheries Complexes of the Russian Federation for the period up to 2030: approved by RF Government Order No. 993-r of 12.04.2020 // ConsultantPlus: reference and legal system. URL: https://www.consultant.ru/document/cons_doc_LAW_350437/.

⁴Food Security Doctrine of the Russian Federation: approved by the Decree of the President of the Russian Federation No. 20 of January 21, 2020 // Official website of the Administration of the President of the Russian Federation. URL: <http://www.kremlin.ru/acts/bank/45106>.

One of the common methods in global practice for increasing the productivity of agricultural crops and the quality of products is the introduction of multifunctional microbial consortia that exhibit enzymatic activity and synthesize biologically active compounds [3, 4]. Researchers note that it is precisely rhizospheric and endophytic bacteria, being in close association with host plants, that are capable of significantly influencing the growth and productivity of agricultural crops [5–7].

However, despite the obvious potential of this direction and global trends, the practical implementation of microbial preparations in domestic crop production is difficult, including due to their limited range. Thus, only 10% of farms in the European North of Russia use biological plant protection agents in their practice [8]. The obvious lag behind strategic guidelines, which imply the introduction of environmentally safe technologies in agricultural production, confirms the relevance of scientific research in this field.

It is necessary to increase the range of microbial preparations primarily for regions where agriculture, being one of the priority areas of activity, faces certain difficulties. For example, in the Vologda region, located in the Non-Black Earth zone of Russia, difficult natural and climatic conditions hinder the production of crop products.

As plant objects that can serve as donors of promising bacterial strains, it is advisable to use species that are widely distributed in the region of potential use of the future preparation. One of such species in the Non-Black Earth zone of Russia (in particular, in the Vologda region) is Sosnowsky's hogweed (*Heracleum sosnowskyi* Manden). This species acquires special interest due to its high ecological plasticity and ability for rapid expansion [9]. In addition, in the soils of communities with a high proportion of *H. sosnowskyi*, changes in the composition and ratio of microbiota are observed compared to meadow cenoses, while the identified microorganisms exhibit bactericidal, antifungal, and complex activities, as well as the ability to synthesize phytohormones [10–12].

In connection with the above, the purpose of the work was to search for bacteria promising for agricultural production in the Non-Black Soil Zone of Russia, isolated from the microbiome of *H. sosnowskyi*.

MATERIAL AND METHODS

In 2025, as part of the study, a field trip was conducted to a plot with dense *H. sosnowskyi* thickets (vicinity of the village of Mukhino, Yaganovskoye rural settlement, Cherepovetsky district, Vologda region; plot coordinates: 59.296602° N, 38.220652° E). During the expedition, the species diversity of the communities was assessed and plant samples of hogweed were collected (root system, stem, leaves, fruits).

On the day of departure, the samples were delivered to the laboratory of the Vologda Scientific Center of the Russian Academy of Sciences, where the sowing of epi- and endophytic bacteria in Petri dishes was carried out. The bacterial sowing was carried out on the LB (Luria Bertani Broth, Miller) nutrient medium. To clean the hogweed plant samples from epiphytic microflora, 70% ethyl alcohol and 18.5% hydrogen peroxide were used. After disinfection, the samples were rinsed of aggressive substances with sterile water. To assess the cleanliness of plant samples after sterilization, an aliquot was plated; only in the case of a clean aliquot was the extraction of endophytic bacteria carried out. In total, 36 samples from plant materials were plated in triplicate. As a result, 76 bacterial isolates were obtained: 44 epiphytic strains and 32 endophytic strains. Isolation of the isolates at this stage of the study was carried out visually, based on morphological characteristics. However, at the next stage of the work, isolates promising for agricultural production will be identified through molecular-genetic analysis of 16S rRNA gene fragments.

The ability of the isolated bacteria to synthesize auxins (indoles) was evaluated by culturing them on LB nutrient medium supplemented with tryptophan (500 mg/l). On the third day of cultivation, the culture was centrifuged (2 min at 14,000 rpm) and the culture fluid was fil-

tered from bacteria (Millipore membrane filter, pore size 0.22 μm), after which the Salkowski reagent was added (500:1000 μl). The level of indoles was determined spectrophotometrically at a wavelength of 540 nm. To calculate the quantitative content of the analyzed substance, a calibration curve was constructed using pure indole-3-acetic acid (IAA).

The ability of bacteria to dissolve calcium orthophosphates was determined by culturing on the Muromtsev's glucose-asparagine medium with the addition of $\text{Ca}_3(\text{PO}_4)_2$, and the ability to fix nitrogen was assessed using the Ashby's medium. The ability of bacteria to fix nitrogen was judged by the intensity of mucous formation ("0" – absent; "+" – present; "++" – strongly expressed), and the ability to transform phosphates was judged by the appearance of a phosphate dissolution zone ("0" – no zone; "+" – present, but the size does not exceed the size of the colony; "++" – significantly larger than the size of the colony). The Hutchinson medium was used to assess the cellulolytic activity, and a specialized nutrient media with the addition of starch and casein, respectively, were used to assess the amylolytic and proteolytic activity. To reveal the zones of casein hydrolysis, 10 ml of a 10% tri-

chloroacetic acid solution was placed in the Petri dishes after incubation; to reveal the zones of starch and cellulose hydrolysis, a diluted Lugol's solution was used.

Cultivation was carried out in a thermostat at a temperature of 25 °C. To assess the nitrogen-fixing properties of the bacteria, cultivation was carried out for one day; to assess the enzymatic and phosphate-mobilizing properties, for 3 days.

RESULTS AND DISCUSSION

The sample collection site is represented by a meadow mixed-grass community with dense thickets of *H. sosnowskyi* (see Fig. 1). In addition to the dominant hogweed, the community included a large number of grass species such as cocksfoot and meadow fescue, and outside the dense thickets, narrow-leaved fireweed grew abundantly. Less abundant were bluegrass, field milk thistle, woodland beakchervil, chickweed, field vetch, cleavers, common wormwood, red clover, common nettle, and occasionally found were spotted St. John's wort, great burdock, field daisy, and field horsetail.

A key aspect of the physiological impact of symbiotic microbes on higher plants is their abil-



Рис. 1. Место сбора растительных образцов
Fig. 1. The place for collecting plant samples

ity to biosynthesize a wide range of phytohormones, including auxins, gibberellins, and cytokinins [13, 14]. The most studied mechanism in this context is the synthesis of indole-3-acetic acid. Its exogenous secretion by microorganisms into the rhizosphere has a multifaceted stimulating effect on the root system of the host plant. When microbial IAA reaches the root zone, it induces cell elongation, which directly accelerates growth. Furthermore, it stimulates the intensive formation of lateral roots and root fibrils, significantly increasing the overall absorptive surface area of the root system. This, in turn, increases the efficiency of plant absorption of water and nutrients from the soil [15].

Among the isolates obtained in the study, 86% demonstrated the ability to synthesize indoles. Of these, 67% were capable of synthesizing them in quantities of 10 mg/l or higher, 41% – 20 mg/l or higher, 33% – 30 mg/l or higher, and 25% – 50 mg/l or higher. It is noteworthy that the proportion of the strains whose synthesis yielded culture fluid with a high indole content (50 mg/l or higher) was higher among the endophytes: BP-04-25en – 161.3 mg/l, BL-03-25en – 151.7 mg/l, BL-02-25en – 129.8 mg/l, BL-01-25en – 129.6 mg/l, BK-05-25en – 118.6 mg/l, BS-02-25en – 97.8 mg/l, BP-05-25en – 97.0 mg/l, BP-03-25en – 73.7 mg/l. Among epiphytic bacteria, the following isolates showed the greatest biosynthetic activity: BP-08-25 (143.4 mg/l), BP-03-25 (139.6 mg/l), BP-15-25 (134.4 mg/l), BP-06-25 (102.1 mg/l), BP-01-25 (100.1 mg/l), BS-03-25 (97.8 mg/l), BS-01-25 (86.4 mg/l), BL-06-25 (86.0 mg/l), BS-06-25 (64.5 mg/l). In general, the strains isolated from the surface and internal tissues of *H. sosnowskyi* fruits synthesized indoles in greater quantities (see Fig. 2).

The significant contribution of microbial associates to the stimulation of plant growth processes is associated with their ability to increase the bioavailability of nutrients critical for ontogenesis [16, 17]. Of particular interest in this regard is the mobilization of phosphorus, since a significant portion of its soil reserves is represented by insoluble forms that are difficult for plants to access—stable organic compounds and

inorganic salts (calcium, iron, and aluminum phosphates).

To overcome the phosphorus limit, solubilizing microorganisms are used, transforming bound forms of phosphorus into soluble forms available for plant uptake. This process occurs through several mechanisms: acidification of the rhizosphere environment through the excretion of organic acids (gluconic, oxalic, and citric acids), the production of chelating compounds, and enzymes (e.g., phosphatases) that hydrolyze organic phosphate esters [18, 19]. The introduction of such strains into the rhizosphere or their use in biopreparations can significantly reduce the dependence of agricultural systems on the application of mineral phosphorus fertilizers, increasing the efficiency of nutrient use by plants and facilitating the transition to more sustainable and environmentally friendly agriculture [20].

An equally important mechanism by which associative microorganisms contribute to the productivity of agrocenoses and natural ecosystems is the biological fixation of molecular nitrogen. The introduction of effective diazotrophic strains into agrosystems allows for a significant reduction in the use of mineral nitrogen fertilizers, the nitrates of which are a source of water and atmospheric pollution, and also reduces the carbon footprint of agricultural production [21].

Considering that microbial phosphate solubilization and molecular nitrogen fixation are key components of the integrated plant nutrition management system, the 76 isolates obtained were studied for their ability to exhibit these properties. It was found that 45% of the strains were capable of fixing molecular nitrogen, and 42% were capable of transforming phosphates. However, the most interesting for further research were 20% of isolates (ten epiphytic and five endophytic), which could simultaneously fix molecular nitrogen, transform phosphates, and also synthesize the IAA (see the table).

As can be seen from the results presented in the table, further work is advisable primarily with the following isolates: BL-06-25, BP-01-25, BP-03-25, BP-07-25, BP-15-25, BK-07-25en, BL-02-25en, BL-03-25en. At the same

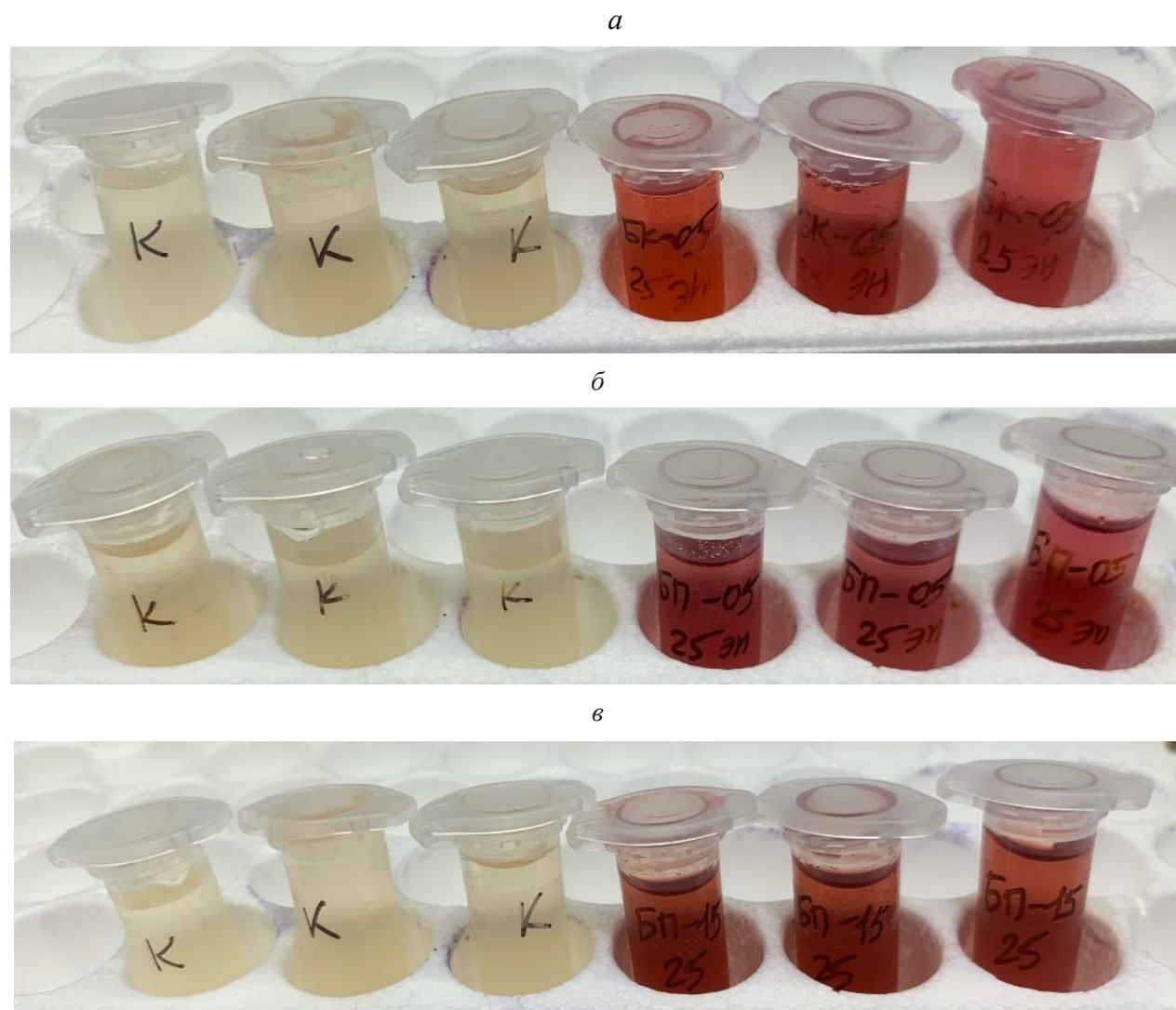


Рис. 2. Качественная реакция на содержание индолов в культуральной жидкости штаммов БК-05-25эн (а), БП-05-25эн (б) и БП-15-25 (в)

Fig. 2. Qualitative reaction for the content of indoles in the culture fluid of the strains BK-05-25en (a), BP-05-25en (b) and BP-15-25 (c)

time, strains BL-02-25en and BL-03-25en, isolated from the internal tissues of *H. sosnowskyi* leaves, will be subject to further detailed study, since they demonstrated the best ability to synthesize IAA (100 mg/l and higher), fix nitrogen and transform phosphates (see Fig. 3). It is likely that the endophytic strains BL-02-25en and BL-03-25en will be able to exert a growth-stimulating effect on plants, which is associated with their ability to provide plants with nitrogen and phosphorus in an accessible form, as well as actively synthesize auxin.

Considering that many phytopathogenic organisms are capable of hydrolyzing plant resi-

dues, including cellulose [22, 23], when selecting isolates promising for stimulating the growth of agricultural crops, their enzymatic (primarily cellulolytic) activity was assessed. In this regard, it is important to note that this property was not expressed in the most promising strains BL-02-25en and BL-03-25en, which indicates a low probability of phytopathogenicity in these bacteria.

In addition, 17% of the isolated isolates exhibited amylolytic activity, 53% - proteolytic, 30% - cellulolytic. The most pronounced activity in relation to cellulose hydrolysis was recorded in the following strains: BK-06-25

Результаты изучения ростостимулирующего потенциала наиболее перспективных для агропроизводства штаммов

Results of a study of the growth-promoting potential of the most promising strains for agricultural production

Strain	Amount of IAA, mg/l	Nitrogen fixation	Transformation of phosphates	Activity, mm		
				amylolytic	proteolytic	cellulolytic
BK-01-25	14,4 ± 0,77	+	+	18	0	13
BL-02-25	16,2 ± 0,75	+	+	0	0	0
BL-03-25	17,0 ± 3,53	+	+	26	74	0
BL-06-25	86,0 ± 3,25	+	+	0	0	15
BS-01-25	4,9 ± 1,46	++	+	0	0	22
BS-08-25	5,0 ± 1,26	+	+	76	0	17
BP-01-25	100,1 ± 9,91	+	+	29	0	24
BP-03-25	139,6 ± 8,76	+	+	6	0	5
BP-07-25	91,7 ± 1,85	+	+	9	0	0
BP-15-25	134,4 ± 4,96	+	+	0	0	5
BK-07-25en	46,0 ± 3,34	++	+	0	0	0
BL-02-25en	129,8 ± 9,27	++	++	0	0	0
BL-03-25en	151,7 ± 10,65	++	++	0	0	0
BL-07-25en	14,2 ± 4,80	+	+	0	0	0
BS-03-25en	2,3 ± 1,65	+	++	13	0	18

Note. “+” – this feature is expressed; “++” – this feature is strongly expressed; “0” – this feature is not expressed.

(23 mm), BS-01-25 (22 mm), BP-01-25 (24 mm), BK-01-25en (32 mm), BS-05-25en (41 mm), BS-06-25en (25 mm). The synthesis of proteases was more characteristic of BK-11-25(83mm),BL-03-25(74mm),BP-08-25 (73 mm), BP-11-25 (76 mm), BK-01-25en (62 mm), BK-04-25en (31 mm), amylases – for BK-02-25(34mm),BL-04-25(57mm),BS-07-25

(75 mm), BS-08-25 (76 mm), BK-02-25en (61 mm), BK-05-25en (30 mm), BL-01-25en (70 mm). Only 7% of the isolates, all of which were isolated from the internal tissues of *H. sosnowskyi*, were capable of simultaneously performing the three enzymatic activities studied: BK-01-25en, BK-02-25en, BL-01-25en, BS-04-25en, and BS-05-25en. These strains can

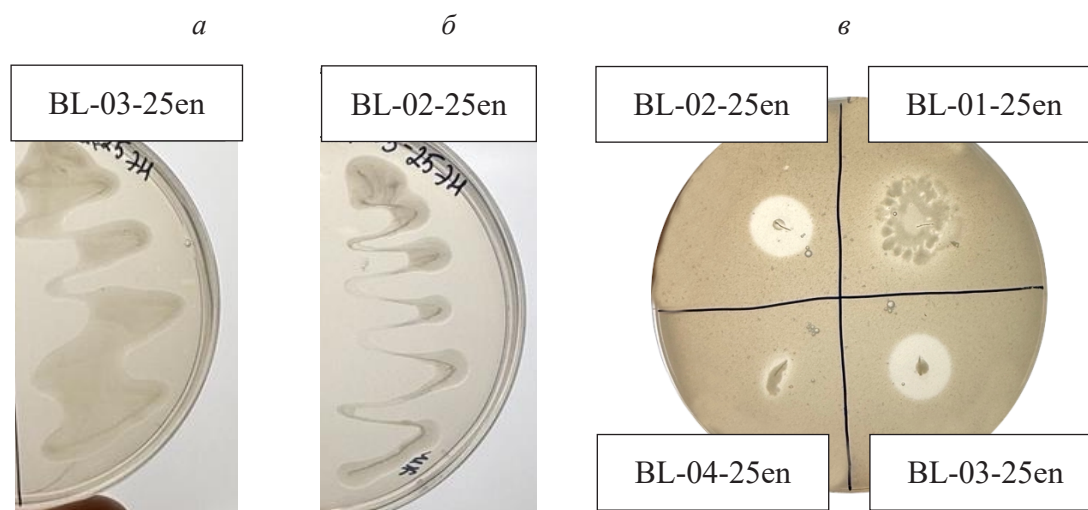


Рис. 3. Результаты оценки способности изолятов БЛ-02-25эн и БЛ-03-25эн фиксировать молекулярный азот (а, б) и трансформировать фосфаты (в)

Fig. 3. Results of assessing the ability of the isolates BL-02-25en and BL-03-25en to fix molecular nitrogen (а, б) and transform phosphates (в)

be used in the methods for increasing soil fertility by breaking down plant residues. It should be noted that of the selected strains, isolate BS-05-25en proved to be the most active: the hydrolysis zone reached 21–41 mm.

Considering that one of the mechanisms providing biocontrol of phytopathogenic microflora is also the synthesis of hydrolytic enzymes, including proteases, amylases, etc. [23, 24], the isolates with high amylolytic and proteolytic activity can also be used to protect plants. The following strains turned out to be the most active here: BK-11-25 (hydrolysis zone 16–83 mm), BL-03-25 (26–74 mm), BP-11-25 (14–76 mm), BK-02-25en (14–61 mm), BL-01-25en (21–70 mm), BS-04-25en (17–24 mm), BS-05-25en (21 mm).

CONCLUSION

Among 76 isolates obtained from various parts of *H. sosnowskyi*, strains BL-02-25en and BL-03-25en, isolated from the internal leaf tissues, are of greatest interest for promoting plant growth. These strains are capable of significant synthesis of indoleacetic acid (129.8–151.7 mg/l), significant nitrogen fixation, and phosphate transformation. However, these strains demonstrated negative cellulolytic activity, reducing the likelihood of virulence of the bacteria studied.

In addition, isolate BS-05-25en has shown promise for decomposing plant residues, as it simultaneously hydrolyzes cellulose, starch, and casein in significant quantities. Strains BK-11-25, BL-03-25, BP-11-25, BK-02-25en, BL-01-25en, BS-04-25en, and BS-05-25en exhibit high amylolytic and proteolytic activity, which may indicate their potential ability to suppress the development of phytopathogens.

СПИСОК ЛИТЕРАТУРЫ

1. Шуганов В.М., Лешкенов А.М. Современное состояние и перспективы повышения производства органической растениеводческой продукции в России на основе применения цифровых и умных технологий // Известия Кабардино-Балкарского научного центра РАН. 2025. Т. 27. № 1. С. 31–41. DOI: 10.35330/1991-6639-2025-27-1-31-41.
2. Кориунов С.А., Любеведская А.А., Асатурова А.М., Исмаилов В.Я., Коноваленко Л.Ю. Закон об органической продукции есть: что меняется в России // Контроль качества продукции. 2019. № 12. С. 25–31.
3. Maitra S., Brestic M., Bhadra P., Shankar T., Praharaj S., Palai J.B., Rahman Shah M.M., Barek V., Ondrisik P., Skalický M., Hossain A. Bioinoculants-Natural Biological Resources for Sustainable Plant Production // Microorganisms. 2021. Vol. 10 (1). P. 51. DOI: 10.3390/microorganisms10010051.
4. Knežević M., Berić T., Buntić A., Delić D., Nikolić I., Stanković S., Stajković-Srbinić O. Potential of root nodule nonrhizobial endophytic bacteria for growth promotion of *Lotus corniculatus* L. and *Dactylis glomerata* L. // Journal of applied microbiology. 2021. Vol. 131 (6). P. 2929–2940. DOI: 10.1111/jam.15152.
5. Бушнев А.С., Курилова Д.А., Котлярова И.А. О ризосфере полевых культур и факторах, влияющих на динамику ее микробиоты (обзор) // Масличные культуры. 2023. № 4 (196). С. 97–109. DOI: 10.25230/2412-608X-2023-4-196-97-109.
6. Максимов И.В., Сингх Б.П., Черепанова Е.А., Бурханова Г.Ф., Хайруллин Р.М. Перспективы применения бактерий – продуцентов липопептидов для защиты растений (обзор) // Прикладная биохимия и микробиология. 2020. Т. 56. № 1. С. 19–34. DOI: 10.31857/S0555109920010134.
7. Soumya P., Jayachandran K., Radhakrishnan E.K. Endophytic Microbiome: An Insight into the Hidden World of Microorganisms Within Plants // Plant-Microbe Interaction and Stress Management. Singapore: Springer Nature Singapore, 2024. P. 265–287. DOI: 10.1186/s12934-023-02234-8.
8. Иванов В.А. Стратегия развития сельского хозяйства Европейского Севера России: монография. Сыктывкар, 2023. 140 с.
9. Озерова Н.А., Кривошеина М.Г. Особенности формирования вторичных ареалов борщевиков Сосновского и Мантегацци (*Heracleum sosnowskyi*, *H. mantegazzianum*) на территории России // Российский журнал биологических инвазий. 2018. № 1. С. 78–87.
10. Товстик Е.В., Широких И.Г., Соловьёва Е.С., Широких А.А., Ашихмина Т.Я., Савиных В.П. Изменение почвенной актинобиоты под влиянием инвазии борщевика Сосновского // Теоретическая и прикладная экология. 2018.

- № 4. С. 114–118. DOI: 10.25750/1995-4301-2018-4-114-118.
11. Товстик Е.В., Широких А.А., Широких И.Г. Микробиологическое состояние почв под инвазивными зарослями борщевика Сосновского (*Heracleum sosnowskyi*) // Вестник современных исследований. 2018. № 2.2 (17). С. 5–8.
 12. Товстик Е.В., Широких И.Г., Сазанов А.В. Биотехнологический потенциал актинобактерий, выделенных из почв под *Heracleum sosnowskyi* Manden // Актуальная биотехнология. 2019. № 3. С. 153–155. DOI: 10.20914/2304-4691-2019-3-153-155.
 13. Timofeeva A.M., Galyamova M.R., Sedykh S.E. How do plant growth-promoting bacteria use plant hormones to regulate stress reactions // Plants. 2024. N 13 (17). P. 2371. DOI: 10.3390/plants13172371.
 14. Gupta R., Anand G., Bar M. Developmental phytohormones: key players in host-microbe interactions // Journal of Plant Growth Regulation. 2023. Vol. 42. N 12. P. 7330–7351. DOI: 10.1007/s00344-023-11030-y.
 15. Etesami H., Glick B.R. Bacterial indole-3-acetic acid: A key regulator for plant growth, plant-microbe interactions, and agricultural adaptive resilience // Microbiological Research. 2024. Vol. 281. P. 127602. DOI: 10.1016/j.micres.2024.127602.
 16. Etesami H., Adl S.M. Plant growth-promoting rhizobacteria (PGPR) and their action mechanisms in availability of nutrients to plants // Phyto-Microbiome in stress regulation. Singapore: Springer Nature Singapore, 2020. P. 147–203. DOI: 10.1007/978-981-15-2576-6_9.
 17. Singh S.K., Wu X., Shao C., Zhang H. Microbial enhancement of plant nutrient acquisition // Stress Biology. 2022. Vol. 2. N 1. P. 3. DOI: 10.1007/s44154-021-00027-w.
 18. Mitra R., Yadav P., Usha K., Singh B. Regulatory role of organic acids and phytochelators in influencing the rhizospheric availability of phosphorus and iron and their uptake by plants // Plant Physiology Reports. 2022. Vol. 27. N 2. P. 193–206. DOI: 10.1007/s40502-022-00650-3.
 19. Rawat P., Das S., Shankhdhar D., Shankhdhar S.C. Phosphate-solubilizing microorganisms: mechanism and their role in phosphate solubilization and uptake // Journal of Soil Science and Plant Nutrition. 2021. Vol. 21 (1). P. 49–68. DOI: 10.1007/s42729-020-00342-7.
 20. Minhas W.A., Hussain M., Mehboob N., Nawaz A., UL-Allah S., Rizwan M.S., Hassan Z. Synergetic use of biochar and synthetic nitrogen and phosphorus fertilizers to improves maize productivity and nutrient retention in loamy soil // Journal of plant nutrition. 2020. Vol. 43. N 9. P. 1356–1368. DOI: 10.1080/01904167.2020.1729804.
 21. Юсова О.А., Шулико Н.Н., Николаев П.Н., Киселёва А.А., Тукмачева Е.В. Влияние ассоциативной азотфиксации в ризосфере на рост и развитие зернофуражных культур // Плодородие. 2025. № 1 (142). С. 46–50. DOI: 10.25680/S19948603.2025.142.10.
 22. Гальперина А.Р., Пархоменко А.Н., Сопрунова О.Б. Эпифитные микроорганизмы растений Астраханской области и оценка их фитопатогенных свойств // Бюллетень Государственного Никитского ботанического сада. 2024. № 150. С. 50–57. DOI: 10.25684/0513-1634-2024-150-50-57.
 23. Panicker S., Sayyed R.Z. Hydrolytic enzymes from PGPR against plant fungal pathogens // Antifungal Metabolites of Rhizobacteria for Sustainable Agriculture. Cham: Springer Int. Publ., 2022. P. 211–238. DOI: 10.1007/978-3-031-04805-0_10.
 24. Riseh R.S., Vatankhah M., Hassanisaadi M., Ait Barka E. Unveiling the role of hydrolytic enzymes from soil biocontrol bacteria in sustainable phytopathogen management // Frontiers in Bioscience-Landmark. 2024. Vol. 29. N 3. P. 105. DOI: 10.31083/j.fbl2903105.

REFERENCES

1. Shuganov V.M., Leshkenov A.M. Current state and prospects for increasing production of organic crop products in Russia based on the use of digital and smart technologies. *Izvestiya Kabardino-Balkarskogo nauchnogo tsentra RAN = News of the Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences*, 2025, vol. 27, no. 1, pp. 31–41. (In Russian). DOI: 10.35330/1991-6639-2025-27-1-31-41.
2. Korshunov S.A., Lyubovetskaya A.A., Asaturova A.M., Ismailov V.Ya., Konovalenko L.Yu. The law on organic products is in place: what is changing in Russia? *Kontrol' kachestva produktsii = Product Quality Control*, 2019, no. 12, pp. 25–31. (In Russian).
3. Maitra S., Brestic M., Bhadra P., Shankar T., Praharaj S., Palai J.B., Rahman Shah M.M., Barek V., Ondrisik P., Skalický M., Hossain A.

- Bioinoculants-Natural Biological Resources for Sustainable Plant Production. *Microorganisms*, 2021, vol. 10 (1), p. 51. DOI: 10.3390/microorganisms10010051.
4. Knežević M., Berić T., Buntić A., Delić D., Nikolić I., Stanković S., Stajković-Srbinić O. Potential of root nodule nonrhizobial endophytic bacteria for growth promotion of *Lotus corniculatus* L. and *Dactylis glomerata* L. *Journal of applied microbiology*, 2021, vol. 131 (6), pp. 2929–2940. DOI: 10.1111/jam.15152.
5. Bushnev A.S., Kurilova D.A., Kotlyarova I.A. About rhizosphere of field crops and factors influencing on dynamics of its microbiota (review). *Maslichnyye kul'tury = Oil Crops*, 2023, no. 4 (196), pp. 97–109. (In Russian). DOI: 10.25230/2412-608X-2023-4-196-97-109.
6. Maksimov I.V., Singkh B.P., Cherepanova Ye.A., Burkhanova G.F., Khayrullin R.M. Prospects and applications of lipopeptide – producing bacteria for plant protection (review). *Prikladnaya biokhimiya i mikrobiologiya = Applied Biochemistry and Microbiology*, 2020, vol. 56, no. 1, pp. 19–34. (In Russian). DOI: 10.31857/S0555109920010134.
7. Soumya P., Jayachandran K., Radhakrishnan E.K. Endophytic Microbiome: An Insight into the Hidden World of Microorganisms Within Plants. *Plant-Microbe Interaction and Stress Management*. Singapore: Springer Nature Singapore, 2024, pp. 265–287. DOI: 10.1186/s12934-023-02234-8.
8. Ivanov V.A. *Strategy for the Development of Agriculture in the European North of Russia*. Syktyvkar, 2023, 140 p. (In Russian).
9. Ozerova N.A., Krivosheina M.G. Patterns of secondary range formation for *Heracleum sosnowskyi* and *H. mantegazzianum* on the territory of Russia. *Rossiyskiy zhurnal biologicheskikh invaziy = Russian Journal of Biological Invasions*, 2018, no. 1, pp. 78–87. (In Russian).
10. Tovstik E.V., Shirokikh I.G., Solovyova E.S., Shirokikh A.A., Ashikhmina T.Ya., Savinykh V.P. The changes in soil actinobiota under the influence of *Heracleum sosnowskyi* invasion. *Teoreticheskaya i prikladnaya ekologiya = Theoretical and Applied Ecology*, 2018, no. 4, pp. 114–118. (In Russian). DOI: 10.25750/1995-4301-2018-4-114-118.
11. Tovstik E.V., Shirokikh A.A., Shirokikh I.G. Microbiological state of soils under invasive thickets of *Sosnovsky hogweed* (*Heracleum sosnowskyi*). *Vestnik sovremennykh issledovaniy = Vestnik sovremennykh issledovaniy*, 2018, no. 2.2 (17), pp. 5–8. (In Russian).
12. Tovstik E.V., Shirokikh I.G., Sazanov A.V. Biotechnological potential of actinobacteria isolated from soils under *Heracleum sosnowskyi* Manden. *Aktual'naya biotekhnologiya = Topical Biotechnology*, 2019, no. 3, pp. 153–155. (In Russian). DOI: 10.20914/2304-4691-2019-3-153-155.
13. Timofeeva A.M., Galyamova M.R., Sedykh S.E. How do plant growth-promoting bacteria use plant hormones to regulate stress reactions. *Plants*, 2024, no. 13 (17), p. 2371. DOI: 10.3390/plants13172371.
14. Gupta R., Anand G., Bar M. Developmental phytohormones: key players in host-microbe interactions. *Journal of Plant Growth Regulation*, 2023, vol. 42, no. 12, pp. 7330–7351. DOI: 10.1007/s00344-023-11030-y.
15. Etesami H., Glick B.R. Bacterial indole-3-acetic acid: A key regulator for plant growth, plant-microbe interactions, and agricultural adaptive resilience. *Microbiological Research*, 2024, vol. 281, p. 127602. DOI: 10.1016/j.micres.2024.127602.
16. Etesami H., Adl S.M. Plant growth-promoting rhizobacteria (PGPR) and their action mechanisms in availability of nutrients to plants. *Phyto-Microbiome in stress regulation*. Singapore: Springer Nature Singapore, 2020, pp. 147–203. DOI: 10.1007/978-981-15-2576-6_9.
17. Singh S.K., Wu X., Shao C., Zhang H. Microbial enhancement of plant nutrient acquisition. *Stress Biology*, 2022, vol. 2, no. 1, p. 3. DOI: 10.1007/s44154-021-00027-w.
18. Mitra R., Yadav P., Usha K., Singh B. Regulatory role of organic acids and phytochelators in influencing the rhizospheric availability of phosphorus and iron and their uptake by plants. *Plant Physiology Reports*, 2022, vol. 27, no. 2, pp. 193–206. DOI: 10.1007/s40502-022-00650-3.
19. Rawat P., Das S., Shankhdhar D., Shankhdhar S.C. Phosphate-solubilizing microorganisms: mechanism and their role in phosphate solubilization and uptake. *Journal of Soil Science and Plant Nutrition*, 2021, vol. 21 (1), pp. 49–68. DOI: 10.1007/s42729-020-00342-7.
20. Minhas W.A., Hussain M., Mehboob N., Nawaz A., UL-Allah S., Rizwan M.S., Hassan Z. Synergetic use of biochar and synthetic nitrogen and phosphorus fertilizers to improves maize productivity and nutrient re-

- tention in loamy soil. *Journal of plant nutrition*, 2020, vol. 43, no. 9, pp. 1356–1368. DOI: 10.1080/01904167.2020.1729804.
21. Yusova O.A., Shuliko N.N., Nikolayev P.N., Kiselova A.A., Tukmacheva Ye.V. The influence of associative nitrogen fixation in the rhizosphere on the growth and development of forage crops. *Plodorodie = Plodorodie*, 2025, no. 1 (142), pp. 46–50. (In Russian). DOI: 10.25680/S19948603.2025.142.10.
22. Gal'perina A.R., Parkhomenko A.N., Soprunova O.B. Epiphytic microorganisms of plants of the Astrakhan region and assessment of their phytopathogenic properties. *Byulleten' Gosudarstvennogo Nikitskogo botanicheskogo sada = Bulletin of the State Nikitsky Botanical Gardens*, 2024, no. 150, pp. 50–57. (In Russian). DOI: 10.25684/0513-1634-2024-150-50-57.
23. Panicker S., Sayyed R.Z. Hydrolytic enzymes from PGPR against plant fungal pathogens. *Antifungal Metabolites of Rhizobacteria for Sustainable Agriculture*. Cham: Springer Int. Publ., 2022, pp. 211–238. DOI: 10.1007/978-3-031-04805-0_10.
24. Riseh R.S., Vatankhah M., Hassanisaadi M., Ait Barka E. Unveiling the role of hydrolytic enzymes from soil biocontrol bacteria in sustainable phytopathogen management. *Frontiers in Bioscience-Landmark*, 2024, vol. 29, no. 3, p. 105. DOI: 10.31083/j.fbl2903105.

ИНФОРМАЦИЯ ОБ АВТОРАХ

Рассохина Ирина Игоревна, научный сотрудник; SPIN-код 8216-9895, ORCID 0000-0002-6129-6912

Сухарева Любовь Владимировна, научный сотрудник; SPIN-код 6212-2390, ORCID 0000-0002-1069-0856

Ерегина Светлана Викторовна, старший научный сотрудник, кандидат географических наук; SPIN-код 4282-9160, ORCID 0000-0001-8136-4663

✉ **Платонов Андрей Викторович**, ведущий научный сотрудник, кандидат биологических наук, доцент; SPIN-код 9123-2449, ORCID 0000-0002-1110-7116; **адрес для переписки:** Россия, 160014, Вологда, ул. Горького, 56А; e-mail: platonov70@yandex.ru

AUTHOR INFORMATION

Irina I. Rassokhina, Researcher; SPIN-code 8216-9895, ORCID 0000-0002-6129-6912

Lubov V. Sukhareva, Researcher; SPIN-code 6212-2390, ORCID 0000-0002-1069-0856

Svetlana V. Eregina, Senior Researcher, Candidate of Science in Geography; SPIN-code 4282-9160, ORCID 0000-0001-8136-4663

✉ **Andrey V. Platonov**, Lead Researcher, Candidate of Science in Biology, Associate Professor; SPIN-code 9123-2449, ORCID 0000-0002-1110-7116; **address:** 56 A, Gorkogo St., Vologda, 160014, Russia; e-mail: platonov70@yandex.ru

Дата поступления статьи / Received by the editors 22.09.2025
Дата принятия к публикации / Accepted for publication 10.11.2025
Дата публикации / Published 10.02.2026



Оценка влияния сортовых признаков яблони на содержание микро- и макроэлементов в сидре

Агеева Н.М.¹, Ульяновская Е.В.¹, Щеглов С.Н.², Ширшова А.А.¹, Храпов А.А.¹, Чернуцкая Е.А.¹, (✉) Богданович Т.В.¹

¹Северо-Кавказский федеральный научный центр садоводства, виноградарства, виноделия
Краснодар, Россия

²Кубанский государственный университет

Краснодар, Россия

(✉) e-mail: tatyanka-bogdanovich@mail.ru

Постоянное совершенствование сортового состава яблони региона актуализирует проблему селекционного отбора на основе методов биохимии, сортоизучения, статистики наиболее перспективных генотипов для получения качественных отечественных продуктов переработки с улучшенным макро- и микроэлементным составом. Цель исследования – на основе комплекса методов статистического анализа выявить долю влияния различных фенотипических признаков генотипа яблони на содержание макро- и микроэлементов в сидре; выделить перспективные по составу макро- и микроэлементов в сидре сорта. В ходе статистического анализа данных сидра из 25 различных сортов и форм яблони не установлено влияние на содержание микро- и макроэлементов в сидре плоидности генотипа, срока созревания и степени зрелости плодов. Сравнение средних значений содержания химических элементов у сортов и кребов яблони позволило выявить статистически достоверные различия по содержанию калия ($t = 3,22$ при $p < 0,01$), натрия ($t = 2,83$ при $p < 0,01$), магния ($t = 2,22$ при $p < 0,05$), кальция ($t = 2,40$ при $p < 0,05$), железа ($t = 3,22$ при $p < 0,05$), кадмия ($t = 2,39$ при $p < 0,05$). На основе применения кластерного анализа по методу Уорда все изученные генотипы яблони распределены на три группы, различные по содержанию в сидре макро- и микроэлементов. При сравнении распределения по группам выделены для селекции и производства сорта Орфей и Кетни с более ценным биохимическим составом, ярким ароматом, гармоничным вкусом плодовой продукции и плодов, что, возможно, обусловлено наличием в их родословной видовых форм и старинных сортов с ценными технологическими свойствами.

Ключевые слова: яблоня, сорт, элитная форма, сидр, макро- и микроэлементы

Assessment of the influence of apple tree varietal characteristics on the content of micro- and macroelements in cider

Ageyeva N.M.¹, Ulyanovskaya E.V.¹, Shcheglov S.N.², Shirshova A.A.¹, Khrapov A.A.¹, Chernutskaya E.A.¹, (✉) Bogdanovich T.V.¹

¹North Caucasian Federal Scientific Center of Horticulture, Viticulture, Wine-making
Krasnodar, Russia

²Kuban State University

Krasnodar, Russia

(✉) e-mail: tatyanka-bogdanovich@mail.ru

The constant improvement of the varietal composition of apple trees in the region actualizes the problem of breeding selection based on a set of biochemistry methods, variety study, statistics of the most promising genotypes for obtaining high-quality domestic processed products with improved macro- and microelement composition. The purpose of the study is to apply a set of statistical analysis

methods in order to identify the share of influence of various phenotypic characteristics of the apple tree genotype on the content of macro- and microelements in cider, as well as to identify the varieties that are promising in terms of the composition of macro- and microelements in cider. During the statistical analysis of cider data from 25 different apple varieties and forms, no influence of genotype ploidy, ripening period, and degree of fruit maturity on the content of micro- and macroelements in cider was established. Comparison of the average values of the content of chemical elements in apple varieties and crabs made it possible to identify statistically significant differences in potassium content ($t = 3,22$ at $p < 0,01$), sodium ($t = 2,83$ at $p < 0,01$), magnesium ($t = 2,22$ at $p < 0,05$), calcium ($t = 2,40$ at $p < 0,05$), iron ($t = 3,22$ at $p < 0,05$), cadmium ($t = 2,39$ at $p < 0,05$). Based on the application of cluster analysis using the Ward's method, all studied apple tree genotypes are divided into 3 groups, different in the content of macro- and microelements in the cider. When comparing the distribution by groups, Orfey and Ketni varieties with a more valuable biochemical composition, bright aroma, harmonious taste of fruit products and fruits were chosen for selection and production, which may be due to the presence of species forms and ancient varieties with valuable technological properties in their pedigree.

Keywords: apple tree, variety, elite form, cider, macro- and microelements

Для цитирования: Агеева Н.М., Ульяновская Е.В., Щеглов С.Н., Ширишова А.А., Храпов А.А., Чернуцкая Е.А., Богданович Т.В. Оценка влияния сортовых признаков яблони на содержание микро- и макроэлементов в сидре // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С.16–24. <https://doi.org/10.26898/0370-8799-2026-1-2>

For citation: Ageyeva N.M., Ulyanovskaya E.V., Shcheglov S.N., Shirshova A.A., Khrapov A.A., Chernutskaya E.A., Bogdanovich T.V. Assessment of the influence of apple tree varietal characteristics on the content of micro- and macroelements in cider. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 16–24. <https://doi.org/10.26898/0370-8799-2026-1-2>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

Благодарность

Исследование выполнено при финансовой поддержке Кубанского научного фонда в рамках научного проекта № МФИ-20.1/100.

Acknowledgements

The study was carried out with the financial support of the Kuban Science Foundation within the framework of scientific project No. MFI-20.1/100.

INTRODUCTION

Apple cultivation (*Malus × domestica* Borkh.) occupies a leading position among the world's fruit crops due to its important agricultural significance, demand in the agricultural sector, and constant consumer popularity. It is the leading fruit crop in the North Caucasus region, characterized by high profitability, early fruiting, technological suitability, long storage period, and adaptability to growing conditions [1–3]. A large-scale import substitution program in the country's resource markets and the need to increase the competitiveness of domestic fruit

products make the tasks of creating and selecting adaptive high-quality apple varieties of the Russian breeding [4–6] relevant, including based on accelerated breeding selection methods [7–9]. The assortment of apple trees in the region has been significantly expanded recently, including commercially attractive domestic and foreign varieties with increased adaptability, resistance to scab, and other fungal diseases of the crop¹ [10–12].

Apples are mainly used fresh, but in recent years their use for the production of cider and low-alcohol fruit products has been increasing. It is known that a significant number of apple

¹State Register of Breeding Achievements Approved for Use. Plant Varieties (official edition). Moscow: Rosinformzagrotekh, 2023, vol. 1, 631 p.

fruits (up to 15–32%)² either do not meet the variety standards of the consumer market or have low marketability. In addition, producers do not always manage to sell all the fruit they grow. In this regard, the task of identifying apple varieties and forms of different genetic origins growing in the North Caucasus region, suitable for cider production, is relevant. Research questions regarding the concentration of metals in cider are important for assessing the quality, safety, origin, and authenticity. Minerals and trace elements have significant biological value, influence biochemical processes in cider, and affect its taste characteristics. There can be substantial differences in cider in terms of macro- and trace element content, even when fruits from apple varieties grown under the same agroclimatic conditions with similar agricultural practices are used, but they differ in genotype and origin.

The purpose of the study is to determine the influence of various phenotypic traits of apple varieties and forms on the content of macro- and microelements in cider using statistical analysis methods and to identify the most promising apple genotypes in terms of microelement composition.

MATERIAL AND METHODS

The subject of the study was 25 varieties and elite forms of apple trees of various origins and ploidy from the genetic collection of the North Caucasian Federal Scientific Center of Horticulture, Viticulture, Wine-making (NCFSC HVW).

Fresh fruits from 25 samples (3 summer, 9 autumn, and 13 winter varieties) were used to make cider, among which 19 are of domestic selection and 6 are foreign, grown at the Central Farming Enterprise (Krasnodar), at the Collective Use Center “Research and Breeding Col-

lection of Genetic Resources of Horticultural Crops”.

The studied samples Jin, Soyuz, Exotica, 12/2-21-36, 12/3-21-6 are triploids ($2n = 3x$), the others are diploids ($2n = 2x$). Apple fruits at the stage of harvest maturity were selected from 3–5 trees of each variety from different sides of the crown. Sampling and description of the samples were carried out according to the standard methodology³. The processing of fruits and the study of fresh apple juice parameters were carried out at the SC “Winemaking” and the Collective Use Center “Instrumental and Analytical” of the NCFSC HVW. To obtain cider, each sample was crushed separately using a crusher-grinder. The mash wort was separated by pressing the pomace using a hydraulic press (OOO “Rectify”, Saint Petersburg), fermented under the conditions of the “Microwinemaking” unit using the yeast strain Fruit (genus *Saccharomyces cerevisiae*, Germany, “Erbsle Geisenheim”) at a temperature of 18 ± 1 °C. The clarification of the cider was carried out by settling it followed by sediment separation and filtration. The mass concentration of macroelements was determined by the capillary electrophoresis method according to the techniques developed at the SC “Winemaking”, and trace elements – by the atomic absorption method (Quant Z spectrometer, OOO “KORTEK”)^{4, 5}. The mass concentrations of titanium, nickel, arsenic, and mercury were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) using the iCAP 7400 spectrometer (Thermo Scientific, USA), and by inductively coupled plasma mass spectrometry (ICP-MS) on the iCAP RQ spectrometer (Thermo Scientific, USA).

To assess the variability of the studied traits and to verify the correctness of the distribution,

²Apple market balance: market volume, consumption, self-sufficiency // Expert-Analytical Center of Agribusiness “AB-Center”, 2022. URL: <https://ab-centre.ru/news/balans-rynka-yablok-obem-rynka-potreblenie-samoobespechennost>.

³Program and methodology for the study of fruit, berry, and nut crops. Orel, 1999, 606 p.

⁴Methodology for measuring the mass concentration of ammonium, potassium, sodium, magnesium, and calcium ions in wine products using capillary electrophoresis (certification certificate No. 01.00225/61-10, PM registration code in the Federal Register FR.1.31.2011.09326)

⁵GOST R 51309–99. Drinking water. Determination of element content by atomic spectrometry. Moscow: Standartinform, 2006, 21 p.

analysis of variance was applied; for the correct construction of homogeneous groups, hierarchical cluster analysis using Ward's method and Student's *t*-test were used⁶. Statistical processing was carried out based on the integrated system StatSoft Statistica 10.0.

RESULTS AND DISCUSSION

Based on a set of statistical analysis methods, the degree of variation in the content of 15 micro- and macroelements in cider from the fruits of 25 samples of domestic and foreign apple breeding germplasm of the NCFSC HVW was studied (see Table 1).

In terms of the content of micro- and macroelements in cider from the fruits of various apple samples, a different degree of dispersion of these around the mean value (standard deviation) has been revealed, according to which three groups are conditionally distinguished based on the level of variability in the content of chemical elements:

– with low variability (from 0 to 10) – iron, titanium, cesium, cadmium, lead, magnesium, nickel, and calcium;

– with an average level (from 10 to 75) – molybdenum, sodium, zinc, and manganese;

– with high (75 and above) – copper, rubidium, and potassium.

A series of variance analyses were conducted to quantitatively account for the influence of various cultivar characteristics on the content of micro- and macroelements: ploidy, country of origin, fruit ripening period, the degree of fruit pulp maturity, fruit mass, the presence of skin color, and the intensity of skin color. It was established that ploidy, fruit ripening period, and the degree of fruit maturity did not have a significant effect on the content of the considered chemical elements.

When comparing the average values of chemical element content in cultivars and crabs (small-fruited interspecific cultivars and forms of apple), statistically significant differences were found in the content of potassium (1012.21 versus 1650.00; $t = 3.22$ at $p < 0.01$), sodium (22.02 versus 42.55; $t = 2.83$ at $p < 0.01$), magnesium (19.82 versus 29.75; $t = 2.22$ at $p < 0.05$), cal-

Табл. 1. Основные статистические характеристики содержания микро- и макроэлементов в сидре
Table 1. Main statistical characteristics of the content of micro- and macroelements in cider

Macro- and microelements	Average	Minimum	Maximum	Standard deviation
Macroelement content, $\mu\text{g}/\text{dm}^3$:				
potassium	$1063,24 \pm 63,27$	696,00	1920,00	316,37
sodium	$23,67 \pm 2,24$	6,70	44,10	11,18
magnesium	$20,62 \pm 1,30$	10,20	36,80	6,52
calcium	$16,22 \pm 1,36$	4,30	42,30	9,82
ferrum	$1,58 \pm 0,08$	0,86	2,26	0,41
Microelement content, $\mu\text{g}/\text{dm}^3$:				
copper	$122,00 \pm 15,08$	31,10	375,90	75,42
zinc	$161,98 \pm 5,89$	88,40	213,70	29,43
manganese	$116,46 \pm 11,09$	46,10	212,60	55,44
molybdenum	$17,08 \pm 2,19$	6,30	53,10	10,95
rubidium	$564,85 \pm 22,49$	424,60	796,30	112,47
cesium	$1,69 \pm 0,16$	0,24	2,92	0,78
nickel	$19,35 \pm 1,87$	2,44	36,82	9,36
titanium	$1,58 \pm 0,14$	0,45	2,82	0,69
lead	$12,84 \pm 1,17$	3,80	22,60	5,84
cadmium	$7,78 \pm 0,39$	4,80	11,70	1,93

⁶Eszergár-Kiss D., Eszergár-Kiss D., Caesar B. Definition of user groups applying Ward's method // Transportation Research Procedia, 2017, vol. 22, pp. 25–34.

cium (14.95 versus 30.85; $t = 2.40$ at $p < 0.05$), iron (1.52 versus 2.19; $t = 3.22$ at $p < 0.05$), cadmium (7.52 versus 10.65; $t = 2.39$ at $p < 0.05$).

The Russian-origin varieties differed from the American ones in cesium content (1.79 vs. 0.84; $t = 2.12$ at $p < 0.05$), nickel (16.91 vs. 31.34; $t = 2.99$ at $p < 0.01$), lead (11.27 vs. 19.43; $t = 2.39$ at $p < 0.05$), cadmium (7.05 vs. 9.83; $t = 2.95$ at $p < 0.01$). A difference was found in cadmium content between Russian-origin varieties and Polish (7.05 vs. 11.20; $t = 2.81$ at $p < 0.05$) and Czech varieties (7.05 vs. 10.70; $t = 2.47$ at $p < 0.05$).

Grouping of samples by macroelement content was carried out using the cluster analysis by the Ward's method (see Fig. 1).

At the merging level of 40 units, three groups can be distinguished:

– 14 – Orfey, 12 – Virginia;

– 21 – 12/2-21-15, 19 – Florina, 10 – Margo, 7 – Bagryanets Kubani, 3 – Interprice, 25 – 12/1-20-16, 15 – Ketni, 11 – Persikovoe, 2 – Djin;

– 20 – 12/2-20-23, 9 – Ligol, 6 – Renet Platona, 16 – Champion, 5 – Carmen, 17 – Zolotoe letnee, 13 – Amulet, 4 – Liberty, 24 – 12/3-21-6, 18 – Prikubanskoe, 8 – Soyuz, 23 – 12/1-20-3, 22 – 12/2-21-36, 1 – Ekzotika.

The average indicators of macroelement content in the identified clusters are given in Table 2.

The highest content of macronutrients was found in the samples included in the first cluster, and the lowest in the third. Grouping of the varieties and forms by micronutrient content was carried out using cluster analysis by Ward's method (see Fig. 2).

At the fusion level of 40 conditional units, the varieties and forms can be combined into three groups:

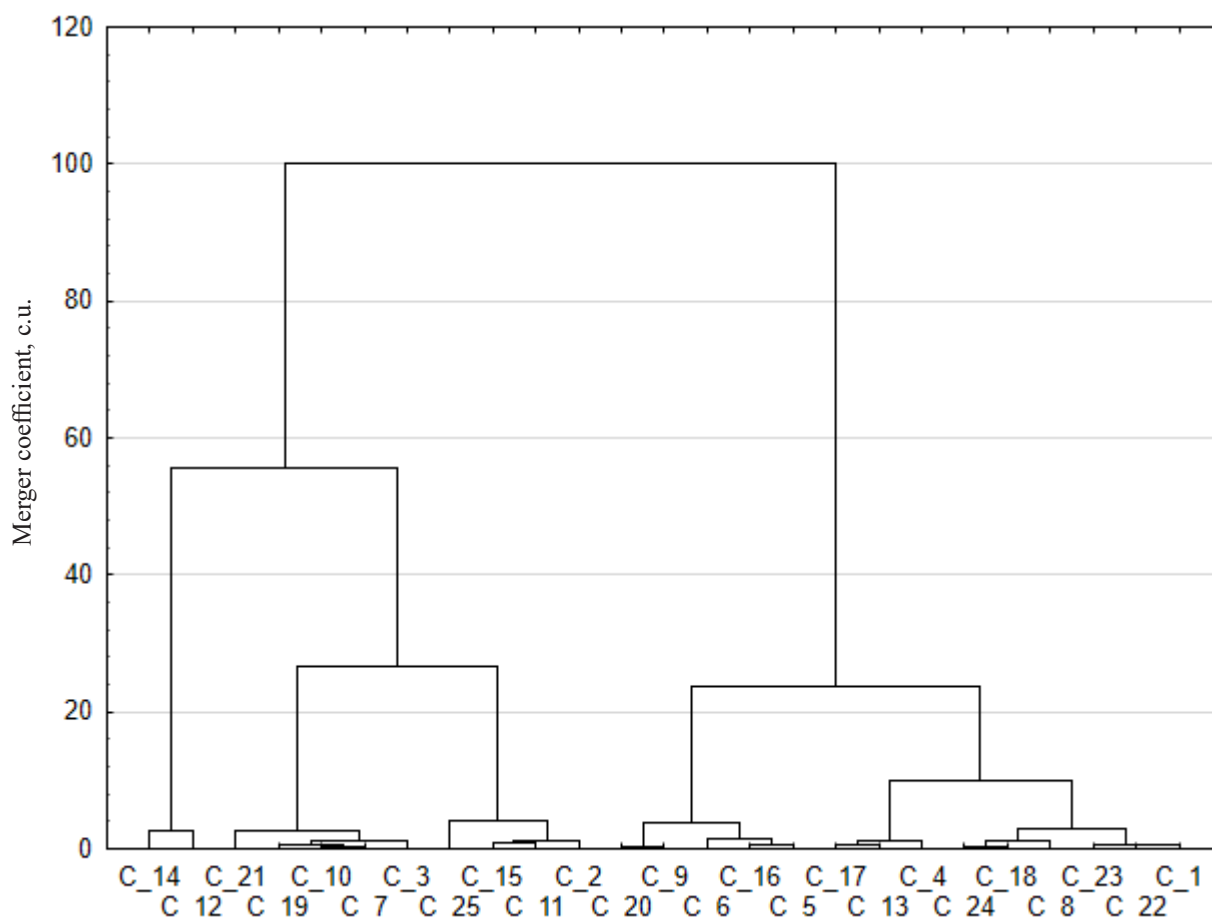


Рис. 1. Результаты кластерного анализа сортов и гибридов яблони по содержанию макроэлементов
Fig. 1. Results of the cluster analysis of apple varieties and hybrids by macronutrient content

Табл. 2. Средние показатели содержания макроэлементов в выделенных кластерах

Table 2. Average content of macroelements in the selected clusters

Macronutrient	Cluster		
	first	second	third
Potassium	1875,00	1208,88	853,64
Sodium	43,20	25,14	19,92
Magnesium	30,95	21,82	18,37
Calcium	20,80	19,96	13,16
Ferrum	1,89	1,53	1,55

– 20 – 12/2-20-23, 23 – 12/1-20-3, 21 – 12/2-21-15, 17 – Zolotoe letnee, 16 – Champion, 15 – Ketni, 22 – 12/2-21-36, 19 – Florina, 14 – Orfey, 10 – Margo, 9 – Ligol, 6 – Renet Platona, 5 – Carmen, 4 – Liberty, 3 – Interprice;

– 25 – 12/1-20-16, 12 – Virginia, 24 – 12/3-21-6, 11 – Persikovoe, 8 – Soyuz, 7 – Bagryanets Kubani;

– 18 – Prikubanskoe, 13 – Amulet, 2 – Djin, 1 – Ekzotika.

The average values of macroelement content in the clusters are given in Table 3.

According to the analysis of variance, the differences in the content of zinc, cesium, nickel, titanium, lead, and cadmium are statistically insignificant. This allowed adjusting the result of the cluster analysis by establishing the distinction of genotypes from different clusters: in the first cluster – the minimum rubidium content and maximum molybdenum content, in the second – the minimum copper, manganese, and molybdenum content, maximum rubidium content, in the third – the maximum copper and manganese content.

Due to the fact that molybdenum affects the rate of synthesis of amino acids, proteins, nucleic acids, chlorophyll, and a number of vitamins in apple plants, it can be concluded that the gen-

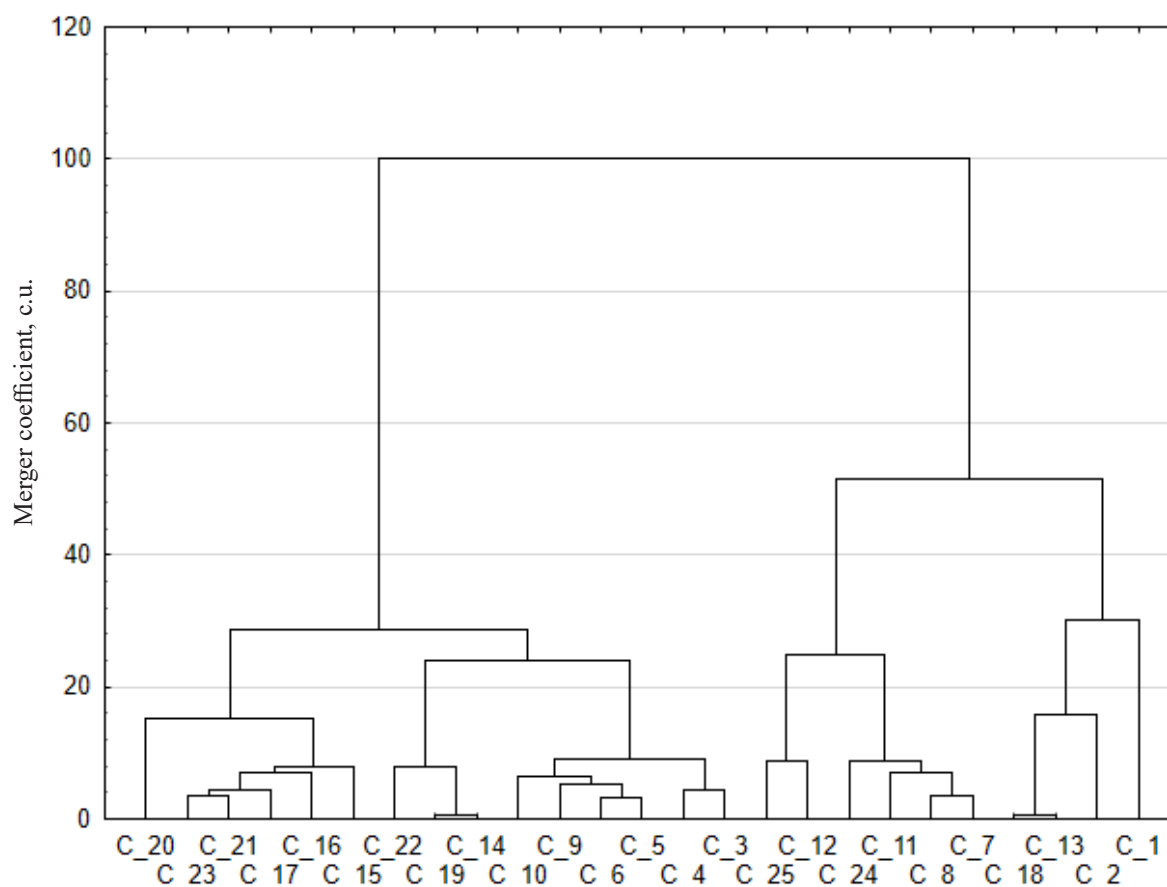


Рис. 2. Результаты кластерного анализа сортов и гибридов яблони по содержанию микроэлементов

Fig. 2. Results of the cluster analysis of apple varieties and hybrids by microelements content

Табл. 3. Средние значения содержания микро-элементов в выделенных кластерах

Table 3. Average values of microelements content in the selected clusters

Microelement	Cluster		
	first	second	third
Copper	107,16	73,93	249,70
Zinc	160,49	166,73	160,45
Manganese	115,85	69,40	189,32
Molybdenum	16,02	10,13	11,50
Rubidium	490,53	678,80	672,60
Cesium	1,77	1,34	1,86
Nickel	19,92	20,58	15,33
Titanium	1,49	1,67	1,78
Lead	13,02	13,23	11,60
Cadmium	7,96	7,40	7,62

otypes from the first cluster possess a valuable combination of increased fruit quality indicators and yield, often determined by enhanced adaptability to the region's stress factors, which is consistent with previously obtained data from many years of field and laboratory studies assessing this group of cultivars [3, 13].

The varieties and forms included in the second cluster may have good growth vigor characteristics, since rubidium is necessary for the growth and development of plants. Indeed, the second cluster lacks weak-growing and moderate-growth genotypes that are present in the first and third clusters. Genotypes included in the third cluster may have a valuable combination of improved fruit quality traits and disease resistance, as copper is present in enzymes and some amino acids, positively affects the taste and color of fruits, and enhances the plant's immunity. Manganese, in turn, contributes to the uptake of nitrogen, potassium, and magnesium by plants. Most of the four varieties included in the group have large, high-quality fruits (Prikubanskoe, Djin, Ekzotika), are resistant to scab (Amulet, Djin, Ekzotika). It is noteworthy that two of the five studied triploid varieties were included in this group (Djin, Ekzotika).

CONCLUSIONS

1. The content of micro- and macroelements in cider was not affected by such factors as genotype ploidy, ripening time, and fruit maturity.

2. Comparison of the average values of chemical element content in apple varieties and crabs revealed statistically significant differences in the content of potassium ($t = 3.22$ at $p < 0.01$), sodium ($t = 2.83$ at $p < 0.01$), magnesium ($t = 2.22$ at $p < 0.05$), calcium ($t = 2.40$ at $p < 0.05$), iron ($t = 3.22$ at $p < 0.05$), and cadmium ($t = 2.39$ at $p < 0.05$).

3. It has been established that the Russian-bred varieties differ from the American ones in cesium content ($t = 2.12$ at $p < 0.05$), nickel ($t = 2.99$ at $p < 0.01$), lead ($t = 2.39$ at $p < 0.05$), and cadmium ($t = 2.95$ at $p < 0.01$). A difference was found in cadmium content between the Russian varieties and the Polish ($t = 2.81$ at $p < 0.05$) and Czech ($t = 2.47$ at $p < 0.05$) varieties.

4. Cluster analysis using the Ward's method made it possible to identify three groups of apple genotypes based on the content of macro- and microelements in cider. For industrial use and further breeding, the Orfey and Ketni varieties can be highlighted, possessing valuable biochemical composition, a bright aroma, and a rich harmonious taste of fruit products and fruits, which may be due to their genetic origin, including the presence of ancient varieties, species, and interspecies forms with valuable technological properties in their pedigree.

СПИСОК ЛИТЕРАТУРЫ

1. Халилов Э.С., Смыков А.В., Челебиев Э.Ф., Усков М.К. Степень морозостойкости генеративных почек перспективных селекционных форм яблони в условиях Предгорной зоны Крыма // Труды Кубанского государственного аграрного университета. 2021. № 92. С. 183–189. DOI: 10.21515/1999-1703-92-183-189.
2. Челебиев Э.Ф. Комплексная оценка сортов и селекционных форм яблони в условиях Предгорной зоны Крыма // Труды Кубанского государственного аграрного университета. 2021. № 93. С. 238–245. DOI: 10.21515/1999-1703-93-238-245.

3. Чепинога И.С. Предварительная селекция в генофонде яблони (*Malus* Mill.) Крымской ОСС филиала ВИР для органического садоводства // Труды Кубанского государственного аграрного университета. 2023. № 105. С. 278–283. DOI: 10.21515/1999-1703-105-278-283.
4. Егоров Е.А., Шадрина Ж.А., Кочьян Г.А., Куликов И.М., Борисова А.А. Роль селекционно-питомниководческих центров в инновационном развитии отрасли садоводства // Садоводство и виноградарство. 2020. № 4. С. 49–57. DOI: 10.31676/0235-2591-2020-4-49-57.
5. Седов Е.Н., Корнеева С.А., Янчук Т.В. Роль отечественной селекции в совершенствовании сортимента яблони в России // Вестник российской сельскохозяйственной науки. 2021. № 4. С. 17–19. DOI: 10.30850/vrsn/2021/4/17-19.
6. Седов Е.Н., Корнеева С.А., Янчук Т.В., Вепринцева М.В. Новые конкурентоспособные сорта яблони селекции ВНИИСПК для интенсивных промышленных садов // Вестник Мичуринского государственного аграрного университета. 2023. № 3 (74). С. 12–17.
7. Шидаков Р.С., Шидакова А.С., Халилов Б.Х. Генотипическая взаимозависимость признаков и свойств при их наследовании гибридным потомством яблони // Вестник российской сельскохозяйственной науки. 2022. № 6. С. 62–66. DOI: 10.31857/2500-2082/2022/6/62-66.
8. Супрун И.И., Токмаков С.В., Аль-Накиб Е.А., Лободина Е.В. Идентификация аллелей генов *Md-Exp7* и *Md-PG1* в селекционных формах яблони, устойчивых к парше // Вавиловский журнал генетики и селекции. 2022. Т. 26. № 7. С. 645–651. DOI: 10.18699/VJGB-22-79.
9. Супрун И.И., Егоров Е.А., Насонов А.И., Лободина Е.В., Токмаков С.В., Степанов И.В. Маркер-опосредованный отбор в создании селекционных образцов и комплексных доноров яблони с устойчивостью к парше и повышенным потенциалом лежкоспособности плодов // Труды по прикладной ботанике, генетике и селекции. 2023. Т. 184. № 3. С. 135–145. DOI: 10.30901/2227-8834-2023-3-135-145.
10. Помология: в 5 т. Т. 1. Яблоня / под общ. ред. академика РАН Е.Н. Седова: монография. М.: РАН, 2020. 634 с.
11. Седов Е.Н., Янчук Т.В., Корнеева С.А. Лучшие районированные сорта яблони селекции ВНИИСПК для разных регионов России // Аграрная наука. 2020. № 10. С. 92–94. DOI: 10.32634/0869-8155-2020-342-10-92-94..
12. Челебиев Э.Ф., Халилов Э.С., Усков М.К. Новые сорта яблони селекции Никитского бота-

нического сада // Плодоводство, семеноводство, интродукция древесных растений. 2023. Т. 26. С. 201–206.

13. Ульяновская Е.В., Атабиев К.М. Селекционное совершенствование сортимента яблони для южного садоводства // Садоводство и виноградарство. 2023. № 1. С. 18–23. DOI: 10.31676/0235-2591-2023-1-18-23.

REFERENCES

1. Khalilov E.S., Smykov A.V., Chelebiev E.F., Uskov M.K. The degree of frost resistance of generative buds of promising breeding forms of apple trees in the conditions of the foothill zone of the Crimea. *Trudy Kubanskogo gosudarstvennogo agrarnogo universiteta = Proceedings of the Kuban State Agrarian University*, 2021, no. 92, pp. 183–189. (In Russian). DOI: 10.21515/1999-1703-92-183-189.
2. Chelebiev E.F. Comprehensive assessment of apple varieties and breeding forms in the conditions of the Crimean foothill zone. *Trudy Kubanskogo gosudarstvennogo agrarnogo universiteta = Proceedings of the Kuban State Agrarian University*, 2021, no. 93, pp. 238–245. (In Russian). DOI: 10.21515/1999-1703-93-238-245.
3. Chepinoga I.S. Preliminary selection in the apple (Mill.) gene pool of the Krymsk EBS, VIR Branch for organic gardening. *Trudy Kubanskogo gosudarstvennogo agrarnogo universiteta = Proceedings of the Kuban State Agrarian University*, 2023, no. 105, pp. 278–283. (In Russian). DOI: 10.21515/1999-1703-105-278-283.
4. Egorov E.A., Shadrina Zh.A., Kochyan G.A., Kulikov I.M., Borisova A.A. The role of breeding and nursery centers in the innovative development of the horticulture branch. *Sadovodstvo i vinogradarstvo = Horticulture and viticulture*, 2020, no. 4, pp. 49–57. (In Russian). DOI: 10.31676/0235-2591-2020-4-49-57.
5. Sedov E.N., Korneeva S.A., Yanchuk T.V. The role of domestic selection in improving the apple assortment in Russia. *Vestnik rossiiskoi sel'skokhozyaistvennoi nauki = Vestnik of the Russian Agricultural Science*, 2021, no. 4, pp. 17–19. (In Russian). DOI 10.30850/vrsn/2021/4/17-19.
6. Sedov E.N., Korneeva S.A., Yanchuk T.V., Vepintseva M.V. New competitive apple cultivars of VNIISPК breeding for intensive industrial orchards. *Vestnik Michurinskogo gosudarstvennogo agrarnogo universiteta = Bulletin of Michurinsk State Agrarian University*, 2023, no. 3 (74), pp. 12–17. (In Russian).

7. Shidakov R.S., Shidakova A.S., Khalilov B.Kh. Genotypic interdependence of traits and properties when they are inherited by hybrid offspring of an apple tree. *Vestnik rossiiskoi sel'skokhozyaistvennoi nauki = Vestnik of the Russian Agricultural Science*, 2022, no. 6, pp. 62–66. (In Russian). DOI: 10.31857/2500-2082/2022/6/62-66.
8. Suprun I.I., Tokmakov S.V., Al-Nakib E.A., Lobodina E.V. Identification of apple genes Md-Exp7 and Md-PG1 alleles in advanced selections resistant to scab. *Vavilovskii zhurnal genetiki i seleksii = Vavilov Journal of Genetics and Breeding*, 2022, vol. 26, no. 7, pp. 645–651. (In Russian). DOI 10.18699/VJGB-22-79.
9. Suprun I.I., Egorov E.A., Nasonov A.I., Lobodina E.V., Tokmakov S.V., Stepanov I.V. Marker-assisted selection in the development of advanced apple-tree forms and donors combining scab resistance with increased fruit storability. *Trudy po prikladnoi botanike, genetike i seleksii = Proceedings on applied botany, genetics and selection*, 2023, vol. 184, no. 3, pp. 135–145. (In Russian). DOI: 10.30901/2227-8834-2023-3-135-145.
10. Pomology: In 5 vol. Vol. 1. Apple tree under the general editorship of Academician of the Russian Academy of Sciences E.N. Sedova. Moscow, RAS, 2020, 634 p. (In Russian).
11. Sedov E.N., Yanchuk T.V., Korneeva S.A. The best zoned apple cultivars of VNIISPK breeding for different regions of Russia. *Agrarnaya nauka = Agrarian Science*, 2020, no. 10, pp. 92–94. (In Russian). DOI: 10.32634/0869-8155-2020-342-10-92-94.
12. Chelebiev E.F., Khalilov E.S., Uskov M.K. New apple varieties of the Nikitsky Botanical Garden selection. *Plodovodstvo, semenovodstvo, introduktsiya drevesnykh rastenii = Gardening, seed growing, introduction of woody plants*, 2023, vol. 26, pp. 201–206. (In Russian).
13. Ulyanovskaya E.V., Atabiev K.M. Selection improvement of apple tree assortment for southern horticulture. *Sadovodstvo i vinogradarstvo = Horticulture and viticulture*, 2023, no. 1, pp. 18–23. (In Russian). DOI: 10.31676/0235-2591-2023-1-18-23

ИНФОРМАЦИЯ ОБ АВТОРАХ

Агеева Наталья Михайловна главный научный сотрудник, доктор технических наук, профессор; SPIN-код 3807-3865

Ульяновская Елена Владимировна, заведующая лабораторией, доктор сельскохозяйственных наук; SPIN-код 5577-5173

Щеглов Сергей Николаевич, профессор кафедры, заместитель декана, доктор биологических наук; SPIN-код 7906-7974

Ширшова Анастасия Александровна старший научный сотрудник, кандидат технических наук; SPIN-код 6175-5869

Храпов Антон Александрович, научный сотрудник, кандидат технических наук; SPIN-код 6182-5762

Чернуцкая Евгения Анатольевна, младший научный сотрудник; кандидат сельскохозяйственных наук; SPIN-код 2219-0777

✉ **Богданович Татьяна Валерьевна**, старший научный сотрудник, кандидат сельскохозяйственных наук; SPIN-код 7519-3784; **адрес для переписки:** Россия, 350901, Краснодар, ул. 40 лет Победы, 39; e-mail: tatyanka-bogdanovich@mail.ru

AUTHOR INFORMATION

Natalia M. Ageyeva, Head Researcher, Doctor of Science in Engineering, Professor; SPIN-code 3807-3865

Elena V. Ulyanovskaya, Laboratory Head, Doctor of Science in Agriculture, SPIN-code 5577-5173

Sergey N. Shcheglov, Assistant Professor, Deputy Dean, Doctor of Science in Biology, SPIN-code 7906-7974

Anastasia A. Shirshova, Senior Researcher, Candidate of Science in Engineering; SPIN-code 6175-5869

Anton A. Khrapov, Researcher, Candidate of Science in Engineering; SPIN-code 6182-5762

Evgenia A. Chernutskaya, Junior Researcher, Candidate of Science in Agriculture, SPIN-code 2219-0777

✉ **Tatyana V. Bogdanovich**, Senior Researcher, Candidate of Science in Agriculture, SPIN-code 7519-3784; **address:** 39, 40 Let Pobedy St., Krasnodar, 350901, Russia; e-mail: tatyanka-bogdanovich@mail.ru

Дата поступления статьи / Received by the editors 22.09.2025
Дата принятия к публикации / Accepted for publication 06.11.2025
Дата публикации / Published 10.02.2026

Оценка устойчивости овса к корневым гнилям *in vitro*: опыт применения в селекции

Луговцова С.Ю., (✉) Ступко В.Ю., Нешумаева Н.А., Герасимов С.А.

Красноярский научно-исследовательский институт сельского хозяйства – обособленное подразделение Федерального исследовательского центра «Красноярский научный центр Сибирского отделения Российской академии наук»
Красноярск, Россия
(✉) e-mail: stupko@list.ru

В рамках селекционного процесса на второй год КСИ проведена оценка устойчивости к токсинам корневых гнилей *Fusarium poae* перспективных селекционных линий ярового пленчатого овса (Б-5, Б-1, Б-22, Б-45, Б-70) в условиях каллусной культуры. Индукцию каллусогенеза проводили добавлением 2,4-Д (3 мг/л) в среду Мурасиге-Скуга (МС) у незрелых зародышей в стадию молочно-восковой спелости. Полученные каллусы культивировали на средах пролиферации (МС + 1,5 мг/л 2,4-Д), содержащих 30 и 50% фильтрата культуральной жидкости (ФКЖ) *F. poae*, а также на контрольной среде. Линии Б-5 и Б-70, как и стандартный сорт Тубинский, не снижали пролиферативной активности в присутствии ФКЖ в сравнении с контролем (60–70%). Также не отмечено уменьшения и частоты стебленегенеза у этих генотипов. У линии Б-70 частота некроза каллусов была на уровне контроля (15%) даже при концентрации ФКЖ 50%. При ранжировании по совокупности параметров роста каллусов максимальную сумму рангов имела линия Б-70. Линии, выделившиеся по результатам комплексной оценки в условиях *in vitro*, превышали стандартный сорт Тубинский по данным полевых испытаний в 2022 г., как и в 2021 г., по массе 1000 зерен: 39,3 и 39,7 г соответственно против 35,6 г у сорта Тубинский. Визуальная оценка 12-дневных проростков сорта Тубинский и линии Б-70 в вегетационных сосудах с почвой, инокулированной суспензией спор *F. poae*, показала отсутствие видимых следов поражения корневой зоны и coleoptilya. Однако зафиксировано снижение максимального квантового выхода фотосистемы 2 у сорта Тубинский от 0,804 [0,798/0,809] до 0,794 [0,790/0,802], но не у линии Б-70, что подтверждает результаты оценки *in vitro*. По совокупности проведенных испытаний линия Б-70 отнесена к категории ценных.

Ключевые слова: *Avena sativa*, устойчивость, *Fusarium*, культуральный фильтрат, каллусная культура, селекция

In vitro evaluation of oat resistance to root rot: experience of application in breeding

Lugovtsova S.Yu., (✉) Stupko V.Yu., Neshumaeva N.A., Gerasimov S.A.

Krasnoyarsk Research Institute of Agriculture – Separate Subdivision of the Federal Research Center “Krasnoyarsk Scientific Center of the Siberian Branch of the Russian Academy of Sciences”
Krasnoyarsk, Russia
(✉) e-mail: stupko@list.ru

As part of the selection process in the second year of the competitive variety trial, the resistance to *Fusarium poae* root rot toxins of the promising breeding lines of spring hasty oats (B-5, B-21, B-22, B-45, B-70) under callus culture conditions was assessed. Induction of callusogenesis of immature embryos at the stage of milky-wax ripeness was carried out by adding 2,4-D (3 mg/l) to Murashige and Skoog medium (MS). The developed calli were then cultivated on proliferation media (MS + 1.5 mg/l 2,4-D) containing 30% and 50% *F. poae* culture filtrate (CLF), as well as on the control one. Lines B-5 and B-70, as well as the standard variety Tubinsky, did not reduce their proliferative activity in the presence of CLF in comparison with the control medium (60–70%). There was also no decrease in the frequency of stem regeneration in callus culture of these genotypes. In the B-70 line, the frequency of callus necrosis was at the control level (15%) even at a CLF concentration of 50%. When ranking by a set of calli growth parameters, line B-70 had the maximum sum of ranks. The lines that

were identified as outstanding by the results of a comprehensive assessment *in vitro* also exceeded the standard Tubinsky variety according to field tests in 2022, as before in 2021, in terms of 1000-grain weight: 39.3 g and 39.7 g, respectively, versus 35.6 g for the Tubinsky variety. Visual assessment of the 12-day-old seedlings of the Tubinsky variety and line B-70 in growing vessels with soil inoculated with a suspension of *F.poae* spores showed the absence of visible traces of damage to the root zone and coleoptile. However, a decrease in the maximum quantum yield of photosystem 2 was recorded for the Tubinsky variety from 0.804 [0.798/0.809] to 0.794 [0.790/0.802], but not for the B-70 line, confirming the results of the *in vitro* assessment. Based on the totality of tests carried out, the B-70 line was classified as valuable.

Keywords: *Avena sativa*, resistance, *Fusarium*, culture filtrate, callus culture, breeding

Для цитирования: Луговцова С.Ю., Ступко В.Ю., Нешумаева Н.А., Герасимов С.А. Оценка устойчивости овса к корневым гнилям *in vitro*: опыт применения в селекции // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 25–33. <https://doi.org/10.26898/0370-8799-2026-1-3>

For citation: Lugovtsova S.Yu., Stupko V.Yu., Neshumaeva N.A., Gerasimov S.A. *In vitro* evaluation of oat resistance to root rot: experience of application in breeding. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 25–33. <https://doi.org/10.26898/0370-8799-2026-1-3>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

Благодарность

Работа выполнена при поддержке Министерства образования и науки Российской Федерации в рамках государственного задания КрасНИИСХ – обособленное подразделение ФИЦ КНЦ СО РАН (тема № 124012900555-6).

Acknowledgments

The work was carried out with the support of the Ministry of Education and Science of the Russian Federation within the framework of the State Assignment of the KrasNIISKh – a separate division of the Federal Research Center KSC SB RAS (topic No. 124012900555-6).

INTRODUCTION

Oat (*Avena sativa*) is one of the main cereal crops for agricultural producers in Russia. However, despite having high genetic productivity potential, oats show low yields under production conditions. One of the reasons is the high level of oat infection by various species of fungi of the genus *Fusarium*¹ [1, 2]. This pathogen is recognized as the causative agent of one of the main diseases affecting the quality of oat grain [3, 4]. Also, compared to wheat and barley, oat is more susceptible to infection by root rot pathogens of this type of fungus². This makes resistance to phytopathogens an important characteristic of any variety, especially an adaptive one.

Currently, active work is being carried out on the development of the varieties that, along with high grain quality, possess genetic resistance to fungal diseases [5, 6], and the assessment of resistance plays an important role in it [7, 8]. Field tests for resistance, despite being highly close to production conditions, are labor-intensive and time-consuming. In addition, due to the peculiarities of the pathogenesis of oat diseases caused by fungi of the genus *Fusarium*, there are no reliable criteria for resistance³ [9]. One of the approaches to evaluation is selection of the genotypes resistant to pathogens using biotechnological methods, in particular *in vitro* culture of plant cells, tissues, and organs [10, 11]. Ap-

¹Vargach Yu.I., Golovin S.E., Loskutov I.G. Research on micromycetes in oats (*Avena Sativa* L.) under the conditions of Stupino district, Moscow province // Proceedings on applied botany, genetics and breeding, 2019, N 3 (180), pp. 96–105. DOI: 10.30901/2227-8834-2019-3-96-105.

²Efimochkina N.R., Sedova I.B., Sheveleva S.A., Tutelyan V.A. Toxigenic properties of mycotoxin-producing fungi // Tomsk State University Journal of Biology, 2019, N 45, pp. 6–33. DOI: 10.17223/19988591/45/1.

³Loskutov I. G., Blinova E. V., Gavrilova O. P., Gagkaeva T. Yu. The valuable characteristics of oats genotypes and resistance to *Fusarium* disease // Vavilov Journal of Genetics and Breeding, 2016, N 3 (20), pp. 286–294. DOI: 10.18699/VJ16.151.

plication of the *in vitro* evaluation methods can significantly accelerate the creation of promising initial material for breeding⁴.

At the Krasnoyarsk Research Institute of Agriculture (KrasNIISKh), oat breeding was resumed in 2013⁵. Based on data on the reaction of oat cultures to various levels of culture liquid filtrate (CLF), a screening method for resistance has been developed, which is being implemented in the breeding process along with other parameters for evaluating genotypes [12].

The aim of the study is to assess the resistance to infection by the most aggressive strain of the fungus *Fusarium poae* in five promising spring oat lines: B-5, B-21, B-22, B-45, B-70.

MATERIAL AND METHODS

The research objects were spring oat lines B-5, B-21, B-22, B-45, B-70 from the competitive variety testing nursery of the Coarse Grain Crops Laboratory of KrasNIISKh, obtained by traditional breeding methods.

Field trials of competitive variety testing were established in 2021–2023 on the experi-

mental fields of the agricultural production site "Minino" (Krasnoyarsk Krai). The soil was ordinary low-power chernozem, humus content (according to Tyurin) – 5.10%, nitrate nitrogen N-NO₃ (ionometric express method) – from 3.3 to 10.12 mg/kg of soil, phosphorus P₂O₅ (according to Chirikov) – from 188 to 250 mg/kg of soil, exchangeable potassium K₂O (according to Chirikov) – from 139 to 190 mg/kg of soil, soil solution reaction in water extract pH – 6.4–6.6.

Weather conditions at the Minino agricultural production site were as follows: with an average long-term HTC of 1.25 (sufficient moisture) the HTC of the 2021 growing season was 1.38 (sufficient moisture), HTC in 2022 was 1.04 (moderate moisture), HTC in 2023 was 0.82 (generally characterized as dry). The dryness of the 2023 growing season was primarily influenced by insufficient moisture in the first ten-day period of June, July, and the first and second ten-day periods of August (see Table 1).

The experiments were initiated on complete fallow. Sowing was carried out in the second and third ten-day periods of May (May 22–30)

Табл. 1. Характеристика весенне-летних месяцев вегетационного периода, ОПХ «Минино» (2021–2023 гг.)

Table 1. Characteristics of the spring and summer months of the growing season, experimental production farm "Minino" (2021–2023)

Year	May			June			July			August		
	Ten-day period											
	I	II	III	I	II	III	I	II	III	I	II	III
Total precipitation by ten-day period, mm												
2021	1,0	22,0	7,3	27,0	4,8	90,0	9,0	29,0	10,0	32,0	28,0	3,0
2022	0,1	0,0	15,0	23,0	15,0	37,0	20,0	20,0	9,0	3,1	41,0	21,0
2023	5,3	3,7	31,0	6,0	19,0	17,0	2,1	19,0	28,0	0,9	26,0	3,4
Average temperature, °C												
2021	9,6	9,6	10,5	15,1	16,5	15,1	19,4	20,2	19,4	18,9	17,3	16,1
2022	7,7	17,4	16,2	10,4	20,1	20,4	18,1	16,5	18,3	17,1	14,7	13,0
2023	8,6	7,0	12,4	22,5	16,4	16,9	19,9	20,1	20,4	19,9	16,0	18,3

⁴Voloshchuk S.I., Voloshchuk A.D., Girko V.S. Morphological and biochemical characteristics of wheat calluses during cultivation with pathogenic fungi // Reports of the Russian Academy of Agricultural Sciences, 2005, N 3, pp. 35–38.

⁵Lipshin A.G., Gerasimov S.A. The sources of the gene pool of oats of VIR collection for selection in Eastern Siberia // Bulletin of KrasSAU, 2017, N 12 (135), pp. 16–21.

using an SSFK-7 selection seeder in triplicate, with a seeding rate of 500 viable seeds/m² per plot of 2 m². Analysis of the structure of oat crop elements was carried out according to the VIR methodology⁶.

For culture initiation, immature embryos were selected at the milk-wax maturity stage in 2022. Callus induction was carried out on the Murashige and Skoog (MS) medium with the addition of 2,4-D – 3 mg/l and IAA – 2 mg/l. After 30 days, the calluses were passaged to proliferation medium (MS + 2,4-D – 1.5 mg/l) – control and selective. To simulate toxic stress, *F. poae* fungal culture filtrate (FCF) was added to the proliferation medium at concentrations of 30 and 50%. After 30 days, the proportion of calluses that had changed in size, the frequency of necrosis of callus tissues, and the frequency of shoot formation were recorded.

The assessment of the reaction of oat seedlings to root rot infection was carried out according to a modified method⁷ in the “infected” soil. The soil substrate was sterilized for 30 minutes in a drying oven at 100 °C. Cereal seeds were sown in the cooled soil. On the third day, after

the sprouts appeared, an aqueous suspension of *F. poae* spores with a final titer of at least 2×10^6 conidia/g of soil was added to the substrate. In addition to the visual inspection of the roots, the measurement of the maximum quantum yield of photosystem 2 (F_v/F_m) of the leaves of 12-day-old seedlings was carried out using a PAM fluorometer (Junior PAM, Walz, Germany).

Statistical data processing was carried out using the RStudio 1.4.1103 (2009–2024 RStudio, PBC). The reliability of differences between the mean variants and genotypes was assessed using the Fisher's criterion for four-field tables. Field experiment results were processed using the Snedecor applied software package.

RESULTS AND DISCUSSION

An assessment of cell resistance was conducted for the promising lines of spring oat B-5, B-21, B-22, B-45, B-70, obtained within the framework of the program for creating new adaptive breeding material of spring oat with increased adaptability and productivity, maximally utilizing the bioclimatic resources of the Krasnoyarsk Territory. The lines were selected

Табл. 2. Отдельные элементы структуры урожая овса в конкурсном сортоиспытании в 2021–2023 гг. (ОПХ «Минино»)

Table 2. Individual structure components of oats under competitive variety trial in 2021–2023 (experimental production farm “Minino”)

Genotype	Number of plants before harvesting, pcs/m ²			Productive plant stand, pcs/m ²			Weight of 1000 grains, g			Actual yield, t/ha		
	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023
Tubinsky (standard)	313	459	444	326	465	454	31,0	34,9	32,7	2,35	4,51	4,5
B-5	486	524	–	393	524	–	37,6*	39,7*	–	3,13*	4,16	–
B-21	455	479	–	397	479	–	32,8	33,0*	–	2,58	4,78	–
B-22	469*	495	–	393	495	–	36,4*	34,4	–	2,63	4,76	–
B-45	445*	–	–	436	–	–	33,1	–	–	2,95	–	–
B-70	511*	327	450	498	327	465	36,9*	39,5*	32,9	3,23*	4,44	4,53

* $p < 0,05$.

⁶Loskutov I.G., Kovaleva O.N., Blinova E.V. Methodological guidelines for the study and preservation of the world collection of barley and oats. St. Petersburg: VIR, 2012, 63 p.

⁷Study of genetic resources of cereal crops for resistance to harmful organisms: methodological manual / edited by E.E. Radchenko. Moscow: RAAS, 2008, 416 p.

based on the results of the field tests from the previous years. Thus, the B-5, B-40, B-45, and B-70 samples in the conditions of the first- and second-year breeding nurseries (2019–2020) exceeded the Tubinsky standard (30.9 c/ha, $LSD_{05} = 4.20$ c/ha) in yield by 0.46–0.85 t/ha (see Table 2). Under the conditions of CVT 2021, all studied lines were distinguished by the number of plants before harvesting (455–511 pcs/m²) (Tubinsky – 313 pcs/m²). B-45 and B-70 also had a productive stem stand of 436 and 498 pcs/m² respectively, compared to 326 pcs/m² for Tubinsky. Lines B-5, B-22, and B-70 had an increased 1000-grain weight (36.9–37.6 g) (Tubinsky – 31.6 g). In terms of yield, the lines that year surpassed the Tubinsky variety (2.27 t/ha) by 0.31–0.96 t/ha. The maximum gains were observed in lines B-70 (0.96 t/ha) and B-5 (0.86 t/ha).

The resistance of each sample to fusariosis was determined based on a combination of three indicators. The presence of proliferative activity in the calluses was monitored, the appearance of stems was noted, and changes in the color of the calluses toward brown or orange, indicating phenolic oxidation processes, were recorded [13]. The reaction of oat genotypes to the presence of *F. poae* CLF in the nutrient medium depended on the concentration of the agent. As the pressure of the selective factor increased, the proportion of proliferating calluses decreased in all the varieties (see Fig. 1).

The proportion of samples showing proliferation on the control medium for the Tubinsky variety was 81.8%, with a 30% concentration of CLF – 69.2%, and with 50% – 65.2% (see Fig. 1). The most resistant to the effects of toxins present in the medium was the B-70 line, for which the proliferation rate on the control reached 94.1%, at the minimum of the used CLF level (30%) – 86.4%, and on the medium with 50% CLF – 54.2%. Close to it in terms of stability, with parameters of 89.5, 75.0, and 58.3% respectively, was the B-5 line. The B-45 line turned out to be the most sensitive to an increase in the CLF level.

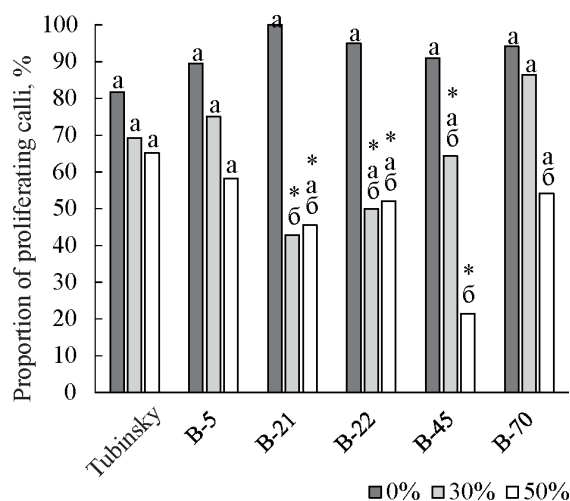


Рис. 1. Активность деления каллусных клеток овса при различном уровне ФКЖ в среде, % от общего числа каллусов, высаженных на среду. Здесь и на рис. 2, 3 одинаковыми буквами отмечены значения, не различающиеся в пределах одной концентрации ФКЖ при $p < 0,05$; *статистически значимое отличие от контрольных условий при $p < 0,05$

Fig. 1. Activity of division of oat callus cells at different levels of CLF in the medium, % of the total number of calli transplanted on the medium.

Here and in Fig. 2-3 identical letters indicate the values that do not differ within the same concentration of CLF at $p < 0.05$; *statistically significant difference from the control conditions at $p < 0.05$

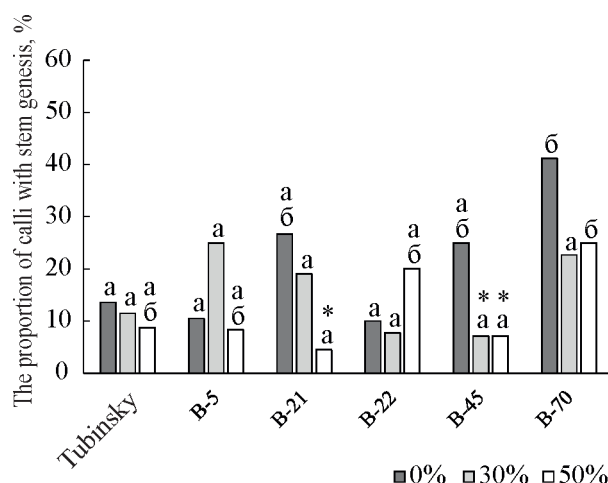


Рис. 2. Влияние различных уровней ФКЖ на регенерационную активность каллусной культуры линий овса, % от общего числа каллусов, пассивированных на среду пролиферации

Fig. 2. The influence of different levels of CLF on the regenerative activity of callus culture of oat breeding lines, % of the total number of calli passaged on the proliferation medium

In terms of an indicator such as the frequency of stem genesis, the B-70 line significantly surpassed the other lines and the standard Tubinsky variety. In the presence of 50% CLF and 25% calluses, the B-70 lines formed stems (see Fig. 2).

High regenerative activity was noted in this genotype even on the control MS medium (41.2%) (see Fig. 2). The average rate for the other genotypes reached 21.2% under control conditions, 15.5% on the medium with 30% CLF, and 12.3% at the 50% CLF level. The most sensitive lines in terms of regeneration frequency to the action of the stress factor were line B-21, which consistently decreased its ability to form shoots with an increasing level of CLF, and B-45, which had a statistically lower shoot formation frequency already at a CLF level of 30%. Lines B-5 and B-22 showed a weak response to an increase in CLF level regarding shoot formation frequency.

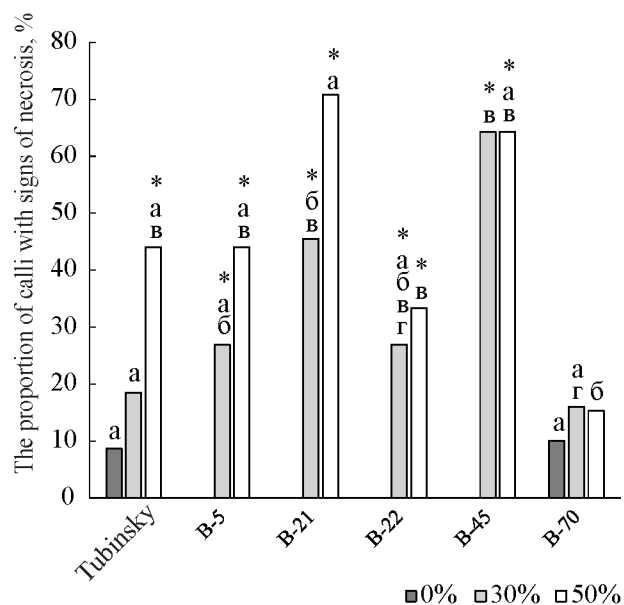


Рис. 3. Частота некроза каллусных тканей овса под влиянием ФКЖ в разных концентрациях, % от числа пассированных на среду пролиферации каллусов

Fig. 3. Frequency of necrosis of oat callus tissue under the influence of CLF in different concentrations, % of the number of calli passaged on the proliferation medium

Necrosis of callus tissues is often used to assess the *in vitro* genotype response to the action of CLF toxins⁸ [14]. An increase in the proportion of calluses with signs of necrosis at a CLF level of 50% was observed in all studied genotypes, except for line B-70 (see Fig. 3).

Among all the samples, it demonstrated a reliably minimum necrosis frequency of 15%, lower than the standard Tubinsky variety. The least resistant in this regard was line B-45. Line B-21 also had high tissue death frequencies both at a CLF level of 50% and at a lower CLF share in the medium (see Fig. 3).

Ranking was carried out based on the total of all indicators across all medium variants. The highest total rank was held by line B-70 (see Table 3). Following it in descending order are lines B-5, B-22, B-21, B-45. These results demonstrate not only the high resistance of line B-70 to *F. poae*, but also the high regenerative potential of this genotype. The lines identified based on the results of a comprehensive assessment under *in vitro* conditions also exceeded the standard Tubinsky variety according to the field-testing data of the Coarse Grain Crops Laboratory in 2022, as well as previously in 2021, in

Табл. 3. Ранжирование селекционных линий ярового овса по устойчивости к заражению грибами *Fusarium poae*

Table 3. Ranking of spring oat breeding lines based on resistance to *Fusarium poae* fungal infection

Location of the object	Genotype	Sum of ranks
<i>The group of "best" objects</i>		
1	B-70	42,0
2	B-5	33,5
<i>The group of "average" objects</i>		
3	Tubinsky	31,0
4	B-22	29,5
<i>The group of "worst" objects</i>		
5	B-21	29,5
6	B-45	23,5

⁸Yerzhebayeva, R.S., Abekova, A.M., Bersimbaeva, G.H., Konysbekov K.T., Bastaubaeva S.O., Roik N.V., Urazaliev K.R. In Vitro Cell Selection of Sugar Beet for Resistance to Culture Filtrate of the Fungus *Fusarium oxysporum* // Cytology and Genetics. 2019. Vol.53. P. 307–314. DOI: 10.3103/S0095452719040042.

1000-grain weight: 39.3 and 39.7 g respectively compared to 35.6 g for the Tubinsky variety (see Table 2).

The small number of productive stems prevented B-70 from surpassing the Tubinsky variety in yield in 2022. In turn, line B-5 stood out that year in terms of the number of productive stems. Line B-45 was excluded from the CVT in 2022 due to a high tendency to lodging. In 2023, lines B-5, B-21, and B-22 were also discarded. Under these conditions, line B-70 exceeded the standard in terms of productive stand and was at the standard level in yield and 1000-grain weight (see Table 2).

When assessing the reaction to contact with the fungal culture in the vegetative vessels, the development of fungal mycelium on the soil surface was observed just a day after the spore suspension was introduced into the substrate. A visual examination of the seedling root system, conducted immediately after the fixation of chlorophyll fluorescence parameters, revealed no visible signs of root and coleoptile damage. However, a decrease in the maximum quantum yield of photosystem 2 was recorded in the Tubinsky variety from 0.804 [0.798/0.809] to 0.794 [0.790/0.802], but not in the line whose median F_v/F_m level was 0.794 [0.788/0.802]. A decrease in F_v/F_m as a response to pathogen inoculation has been recorded in several studies previously [15, 16].

CONCLUSION

High cellular resistance of the promising B-70 line to root rots in callus culture is shown. This characteristic is confirmed in the seedlings by maintaining high photosynthetic capacity. This breeding specimen also had a high level of productivity and is considered a valuable genotype overall. The obtained results confirm the feasibility of including the assessment of cellular resistance to root rot on the media with CLF of the pathogen fungi in oat callus culture *in vitro* in the breeding process.

СПИСОК ЛИТЕРАТУРЫ

1. Гаврилова О.П., Гагкаяева Т.Ю., Орина А.С., Маркова А.С., Кабашиов А.Д., Лоскутов И.Г. Микобиота зерна селекционных линий овса ФИЦ «Немчиновка» конкурсного сортоиспытания на полях в Московской области в 2019 году // Труды по прикладной ботанике, генетике и селекции. 2020. № 2 (181). С. 134–144. DOI: 10.30901/2227-8834-2020-2-134-144.
2. Гаврилова О.П., Гагкаяева Т.Ю., Орина А.С., Гогина Н.Н. Разнообразие грибов рода *Fusarium* и их микотоксинов в зерне из азиатской части России // Микология и фитопатология. 2022. № 3 (56). С. 194–206. DOI: 10.31857/S0026364822030035.
3. Гаврилова О.П., Гагкаяева Т.Ю., Орина А.С., Маркова А.С., Кабашиов А.Д., Лоскутов И.Г. Характеристика устойчивости селекционных линий овса к заражению *Fusarium langsethiae* и накоплению Т-2/НТ-2 токсинов // Вавиловский журнал генетики и селекции. 2021. Т. 25. № 7. С. 732–739. DOI: 10.18699/VJ21.083.
4. Kahla A., Verheecke-Vaessen C., Delpino-Deelias M., Gutierrez Pozo M., Medina A., Magan N., Doohan F. Acclimatisation of *Fusarium langsethiae*, *F. poae* and *F. sporotrichioides* to elevated CO₂: Impact on fungal growth and mycotoxin production on oat-based media // International Journal of Food Microbiology. 2023. Vol. 394. DOI: 110176. 10.1016/j.ijfoodmicro.2023.110176.
5. Loskutov I.G., Khlestkina E.K. Wheat, barley, and oat breeding for health benefit components in grain // Plants. 2021. Vol. 10. Iss. 1. P. 86. DOI: 10.3390/plants10010086.
6. Morcia C., Terzi V., Ghizzoni R., Carrara I., Gazzetti K. Looking for *Fusarium* resistance in oats: an update // Agronomy. 2024. Vol. 14. Iss. 3. P. 505. DOI: 10.3390/agronomy14030505.
7. Жуйкова О.А., Градобоева Т.П., Баталова Г.А. Эффективность инфекционного фона при оценке овса на устойчивость к грибным заболеваниям // Российская сельскохозяйственная наука. 2020. № 3. С. 10–13. DOI: 10.31857/S2500262720030035.
8. Mielniczuk E., Wit M., Patkowska E., Cegiello M., Wakulinski W. Reaction of oat genotypes to *Fusarium equiseti* (Corda) Sacc. infection and mycotoxin concentrations in grain // Agronomy. 2022. Vol. 12. P. 295. DOI: 10.3390/agronomy12020295.

9. Hautsalo J., Jauhiainen L., Hannukkala A., Manninen O., Veteläinen M., Pietilä L., Peltoniemi K., Jalli M. Resistance to Fusarium head blight in oats based on analyses of multiple field and greenhouse studies // *Foundation for Plant Pathology*. 2020. Vol. 158. P. 15–33. DOI: 10.1007/s10658-020-02039-0.
10. Зинатуллина А.Е., Никонов В.И. Лабораторная оценка регенерантов гибридных комбинаций пшеницы в условиях *in vitro* и *ex vitro* // *Экобиотех*. 2021. № 2 (4). С. 81–88. DOI: 10.31163/2618-964X-2021-4-2-81-88.
11. Pathi K.M., Sprink T. From Petri dish to field: plant tissue culture and genetic engineering of oats for improved agricultural outcomes // *Plants*. 2023. Vol. 12. Iss. 21. P. 3782. DOI: 10.3390/plants12213782.
12. Луговцова С.Ю., Ступко В.Ю., Нешумаева Н.А. Влияние культуральных фильтратов грибов рода *Fusarium* на каллусные культуры овса // *Сибирский вестник сельскохозяйственной науки*. 2023. № 10 (53). С. 15–22. DOI: 10.26898/0370-8799-2023-10-2.
13. Баймухаметова Э.А., Кулуев Б.Р. Потемнение растительных тканей при культивировании *in vitro* и способы его предотвращения // *Биотехнология*. 2020. Т. 36. Вып. 2. С. 26–42. DOI: 10.21519/0234-2758-2020-36-2-26-42.
14. Shaunak I., Sharma R., Sharma P., Gupta M., Bhardwaj R.K. Developing resistance against soil-borne *Fusarium* pathogen causing tomato wilt through *in vitro* cell line selection // *Plant Cell, Tissue and Organ Culture*. 2023. Vol. 153. P. 91–104. DOI: 10.1007/s11240-023-02446-1.
15. Katanić Z., Mlinarić S., Katanić N., Ćosić J., Španić V. Photosynthetic efficiency in flag leaves and ears of winter wheat during Fusarium head blight infection // *Agronomy*. 2021. Vol. 11. Is. 12. P. 2415. DOI: 10.3390/agronomy11122415.
16. Aucique-Pérez Carlos E., Ramos R. Chlorophyll a Fluorescence: A method of biotic stress detection. In book: *Challenges in plant disease detection and recent advancements*; Bahadur, A., Ed.; IntechOpen: London, UK, 2024. DOI: 10.5772/intechopen.1004830.
1. Gavrilova O.P., Gagkaeva T.Yu., Orina A.S., Markova A.S., Kabashov A.D., Loskutov I.G. Mycobiota in the grain of the oat breeding lines produced in 2019 in competitive variety trials on the fields of Nemchinovka Federal Research Center, Moscow Province. *Trudy po prikladnoi botanike, genetike i seleksii = Proceedings on Applied Botany, Genetics and Breeding*, 2020, no. 2 (181), pp. 134–144. (In Russian). DOI: 10.30901/2227-8834-2020-2-134-144.
2. Gavrilova O.P., Gagkaeva T.Yu., Orina A.S., Gogina N.N. Diversity of Fusarium species and their mycotoxins in cereals grain from the Asian territory of Russia. *Mikologiya i fitopatologiya = Mycology and Phytopathology*, 2022, no. 3 (56), pp. 194–206. (In Russian). DOI: 10.31857/S0026364822030035.
3. Gavrilova O.P., Gagkaeva T.Yu., Orina A.S., Markova A.S., Kabashov A.D., Loskutov I.G. Resistance of oat breeding lines to grain contamination with Fusarium langsethiae and T-2/HT-2 Toxins. *Vavilovskii Zhurnal Genetiki i Seleksii = Vavilov Journal of Genetics and Breeding*, 2021, vol. 25, no. 7, pp. 732–739. (In Russian). DOI: 10.18699/VJ21.083.
4. Kahla A., Verheecke-Vaessen C., Delplino-Deelias M., Gutierrez Pozo M., Medina A., Magan N., Doohan F. Acclimatisation of *Fusarium langsethiae*, *F. poae* and *F. sporotrichioides* to elevated CO₂: Impact on fungal growth and mycotoxin production on oat-based media. *International Journal of Food Microbiology*, 2023, vol. 394, DOI: 110176. 10.1016/j.ijfoodmicro.2023.110176.
5. Loskutov I.G., Khlestkina E.K. Wheat, barley, and oat breeding for health benefit components in grain. *Plants*, 2021, vol. 10, iss. 1, p. 86. DOI: 10.3390/plants10010086.
6. Morcia C., Terzi V., Ghizzoni R., Carrara I., Gazzetti K. Looking for Fusarium resistance in oats: an update. *Agronomy*, 2024, vol. 14, iss. 3, p. 505. DOI: 10.3390/agronomy14030505.
7. Zhuikova O.A., Gradoboeva T.P., Batalova G.A. Effectiveness of infectious backgrounds in evaluating oat for resistance to fungal diseases. *Rossiiskaya sel'skokhozyaistvennaya nauka = Russian Agricultural Sciences*, 2020, no. 3, pp. 10–13. (In Russian). DOI: 10.31857/S2500262720030035.
8. Mielniczuk E., Wit M., Patkowska E., Cegielski M., Wakulinski W. Reaction of oat genotypes to Fusarium equiseti (Corda) Sacc. infection and mycotoxin concentrations in grain. *Agronomy*, 2022, vol. 12, p. 295. DOI: 10.3390/agronomy12020295.
9. Hautsalo J., Jauhiainen L., Hannukkala A., Manninen O., Veteläinen M., Pietilä L., Pelto-

REFERENCES

- niemi K., Jalli M. Resistance to Fusarium head blight in oats based on analyses of multiple field and greenhouse studies. *Foundation for Plant Pathology*, 2020, vol. 158, pp. 15–33. DOI: 10.1007/s10658-020-02039-0.
10. Zinatullina A.E., Nikonov V.I. Laboratory evaluation of regenerates of wheat hybrid combinations *in vitro* and *ex vitro* conditions. *Ekobiotekh = Ecobiotech*, 2021, no. 2 (4), pp. 81–88. (In Russian). DOI: 10.31163/2618-964X-2021-4-2-81-88.
11. Pathi K.M., Sprink T. From Petri dish to field: plant tissue culture and genetic engineering of oats for improved agricultural outcomes. *Plants*, 2023, vol. 12, Iss. 21, p. 3782. DOI: 10.3390/plants12213782.
12. Lugovtsova S.Yu., Stupko V.Yu., Neshumae-va N.A. Effect of culture filtrates of Fusarium fungi on oat callus cultures. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, no. 10 (53), pp. 15–22. (In Russian). DOI: 10.26898/0370-8799-2023-10-2.
13. Baimukhametova E.A., Kuluev B.R. Darkening of plant tissues during *in vitro* cultivation and methods for its prevention. *Biotechnology*, 2020, vol. 36, iss. 2, pp. 26–42. (In Russian) DOI: 10.21519/0234-2758-2020-36-2-26-42.
14. Shaunak I., Sharma R., Sharma P., Gupta M., Bhardwaj R.K. Developing resistance against soil-borne *Fusarium* pathogen causing tomato wilt through *in vitro* cell line selection. *Plant Cell, Tissue and Organ Culture*, 2023, vol. 153, pp. 91–104. DOI: 10.1007/s11240-023-02446-1.
15. Katanić Z., Mlinarić S., Katanić N., Ćosić J., Španić V. Photosynthetic efficiency in flag leaves and ears of winter wheat during Fusarium head blight infection. *Agronomy*, 2021, vol. 11, iss. 12, p. 2415. DOI: 10.3390/agronomy11122415.
16. Aucique-Pérez Carlos E., Ramos R. *Chlorophyll a Fluorescence: A method of biotic stress detection*. In book: *Challenges in plant disease detection and recent advancements*; Bahadur A., Ed.; IntechOpen: London, UK, 2024. DOI: 10.5772/intechopen.1004830.

ИНФОРМАЦИЯ ОБ АВТОРАХ

Луговцова Светлана Юрьевна, старший научный сотрудник; SPIN-код 4999-4861, ORCID 0000-0003-4185-9455

✉ **Ступко Валентина Юрьевна**, ведущий научный сотрудник, кандидат сельскохозяйственных наук; SPIN-код 9994-9840, ORCID 0000-0002-4430-2719; **адрес для переписки:** Россия, 660041, Красноярск, пр. Свободный, 66; e-mail: stupko@list.ru

Нешумаева Надежда Алексеевна, ведущий научный сотрудник, кандидат биологических наук; SPIN-код 5625-3519, ORCID 0000-0002-7314-9418

Герасимов Сергей Александрович, ведущий научный сотрудник, заведующий лабораторией, кандидат сельскохозяйственных наук; SPIN-код 1849-1717, ORCID 0000-0003-1273-3212

AUTHOR INFORMATION

Svetlana Yu. Lugovtsova, Senior Resercher; SPIN-code 4999-4861, ORCID 0000-0003-4185-9455

✉ **Valentina Yu. Stupko**, Lead Researcher, Candidate of Science in Agriculture; SPIN-code 9994-9840, ORCID 0000-0002-4430-2719; **address:** 66, Svobodny ave., Krasnoyarsk, 660041, Russia; e-mail: stupko@list.ru

Nadezhda A. Neshumaeva, Lead Researcher, Candidate of Science in Biology; SPIN-code 5625-3519, ORCID 0000-0002-7314-9418

Sergey A. Gerasimov, Lead Researcher, Laboratory Head, Candidate of Science in Agriculture; SPIN-code 1849-1717, ORCID 0000-0003-1273-3212

Дата поступления статьи / Received by the editors 14.08.2025
Дата принятия к публикации / Accepted for publication 21.10.2025
Дата публикации / Published 10.02.2026

Влияние средств интенсификации на выход семенной фракции у сортов картофеля сибирской селекции

✉ Мalyuga A.A.¹, Batov A.S.², Gureeva Yu.A.²

¹Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Новосибирская область, р.п. Краснообск, Россия

²Сибирский научно исследовательский институт растениеводства и селекции –
филиал Федерального исследовательского центра институт цитологии и генетики
Сибирского отделения Российской академии наук
Новосибирская область, р.п. Краснообск, Россия

✉ e-mail: anna_malyuga@mail.ru

Представлены результаты оценки эффективности применения различных средств интенсификации (минеральное удобрение $N_{40}P_{40}K_{80}$, химический инсекто-фунгицидный протравитель, а также препараты на основе гуматов Берес-8 и Реликт) при размножении исходного материала сортов картофеля сибирской селекции Юна, Лина, Златка в условиях лесостепи Новосибирского Приобья. Цель исследований заключалась в определении оптимальных сочетаний протравителей, гуминовых препаратов и минеральных удобрений для повышения продуктивности и выхода массы и количества клубней семенной фракции. Оптимальное соотношение массы и количества семенных клубней у сорта Юна (весовой процент 75,6, коэффициент размножения 7,0) получено при обработке посадочного материала Селест Топом (0,4 л/т) в сочетании с Бересом-8 (0,2 л/т) с дальнейшим опрыскиванием посадок Бересом-8 (0,2 л/га) в период бутонизации на фоне без минеральных удобрений. Для сорта Лина сочетание этих показателей было наилучшим (весовой процент 71,6, коэффициент размножения 10,2) при обработке посадочных клубней Селест Топом (0,2 л/т) в смеси с Реликтом (0,01 л/т) с последующим опрыскиванием растений Реликтом (0,2 л/га) без внесения минеральных удобрений. Для сорта Златка соотношение массы и количества семенных клубней было оптимальным (весовой процент 77,9, коэффициент размножения 10,8) при обработке семенного материала Селест Топом (0,2 л/т) в комплексе с Бересом-8 (0,2 л/т) и опрыскиванием посадок культуры Бересом-8 (0,2 л/га) с внесением минеральных удобрений. Полученные результаты подтвердили высокую эффективность интегрированного применения химических и биостимулирующих препаратов для повышения урожайности и семенной продуктивности картофеля, что может быть рекомендовано для оригинального и элитного семеноводства в условиях Сибири.

Ключевые слова: картофель, протравитель, гуматы, урожайность, семенная фракция, коэффициент размножения

The influence of intensification agents on the yield of seed fraction in Siberian potato varieties

✉ Malyuga A.A.¹, Batov A.S.², Gureeva Yu.A.²

¹Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk region, Russia

²Siberian Research Institute of Plant Production and Breeding – Branch of the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk region, Russia

✉ e-mail: anna_malyuga@mail.ru

The article presents the results of evaluating the effectiveness of using various intensification agents (mineral fertilizer $N_{40}P_{40}K_{80}$, chemical insecticide-fungicide seed dressing, as well as preparations based on humates Beres-8 and Relikt) in the propagation of the source material of the Siberian potato varieties Yuna, Lina, Zlatka in the forest-steppe conditions of the Novosibirsk Priobye. The purpose of the research was to determine the optimal combinations of seed dressings, humic preparations and mineral fertilizers to increase the productivity and yield of the mass and number of seed fraction tubers. The optimal ratio of the mass and quantity of seed tubers in the Yuna variety (weight percentage

75.6, multiplication factor 7.0) was obtained by treating the planting material with Celeste Top (0.4 l/t) in combination with Beres-8 (0.2 l/t) with subsequent spraying of the plantings with Beres-8 (0.2 l/ha) during the budding period without mineral fertilizers. For the Lina variety, the combination of these indicators was the best (weight percentage 71.6, multiplication factor 10.2) when treating planting tubers with Celeste Top (0.2 l/t) in a mixture with Relikt (0.01 l/t) followed by spraying the plants with Relikt (0.2 l/ha) without applying mineral fertilizers. For the Zlatka variety, the ratio of the mass and quantity of seed tubers was optimal (weight percentage 77.9, multiplication factor 10.8) when treating the seed material with Celeste Top (0.2 l/t) in combination with Beres-8 (0.2 l/t) and spraying the crop plantings with Beres-8 (0.2 l/ha) with the addition of mineral fertilizers. The obtained results confirmed the high efficiency of the integrated use of chemical and biostimulating preparations in increasing the yield and seed productivity of potatoes, which can be recommended for original and elite seed production in Siberian conditions.

Keywords: potato, seed dressing, humates, yield, seed fraction, multiplication factor

Для цитирования: Малюга А.А., Батов А.С., Гуреева Ю.А. Влияние средств интенсификации на выход семенной фракции у сортов картофеля сибирской селекции // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 34–47. <https://doi.org/10.26898/0370-8799-2026-1-4>

For citation: Malyuga A.A., Batov A.S., Gureeva Yu.A. The influence of intensification agents on the yield of seed fraction in Siberian potato varieties. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 34–47. <https://doi.org/10.26898/0370-8799-2026-1-4>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

INTRODUCTION

Potatoes are one of the key strategic food crops of the Russian Federation, occupying an important place in the structure of agro-industrial production. In the Siberian regions, they play a special role in ensuring food security, remaining one of the main food products for the population [1]. The crop's yield potential is largely limited by the natural and climatic conditions of the region, characterized by a short growing season, sharp temperature fluctuations, and an increased risk of disease infestation [2]. To improve the efficiency of potato production, it is necessary to develop seed production, primarily of the varieties created under the conditions of this region. Local varieties have increased adaptability, better tolerate temperature fluctuations and dry periods, which ensures yield stability [3].

Seed potato production occupies a special place in the potato-growing system, as potatoes are vegetatively propagated crops¹. A current

task of original potato seed production is the rapid multiplication of healthy initial material in the volumes necessary for conducting elite seed production, as well as the environmental safety of these crop cultivation technologies [4].

There is a need to create production technologies aimed at increasing the reproduction rate of the improved material. They should include various methods of intensification that affect the growth and development of the culture, such as plant protection agents, growth stimulants, fertilizers, and others [5].

Modern plant protection products are not only a way to combat diseases, but also an effective method to improve the quality indicators of the harvest. Pre-sowing treatment is a priority and one of the most important activities in the protection technology in potato seed production. Preparations intended for pre-planting treatment of the tubers (seed dressers, biopreparations, biologically active substances) provide compre-

¹Davidson R.D., Xie K.Y. Seed potato production // *The Potato: Botany, Production and Uses*. Wallingford, UK: CABI. 2014, pp. 115–132.

hensive protection against soil pathogens, dangerous pests, act as root system growth stimulators, and improve stress resistance [6, 7].

The use of intensification means has a positive effect on photosynthetic activity and nutrient uptake, which ultimately increases yield and improves the crop structure [8]. In potato seed production, not only the overall yield level is important, but also the output of seed fraction tubers, which determines the efficiency of reproducing healthy material. Optimizing tuber treatment schemes using seed dressers, humates, and biostimulants represents a promising direction for increasing the multiplication coefficient and the quality of seed material [9].

The reaction of potato varieties to various intensification methods can differ significantly. This is primarily due to the genetic nature of the varieties: intensive and extensive types are distinguished, as well as the forms belonging to different maturity groups [10]. The biological characteristics of each variety determine its responsiveness to growth stimulants, fertilizers, and protective agents. Therefore, it is important to select individual technological cultivation and seed production schemes that ensure the best realization of the variety's potential [11].

The purpose of the work is to develop the technologies for propagating the initial material of potato varieties of Siberian breeding of different maturity groups (Yuna, Lina, Zlatka), aimed at increasing the yield of high-quality seed fraction from the plants grown from the first field generation tubers, as well as at reducing the negative impact on the crop agrocenosis through the improvement of the use of modern chemical methods: plant growth stimulants, seed treatments, and mineral fertilizers and their integrated application.

MATERIAL AND METHODS

The subject of study was potato (*Solanum tuberosum* L.) represented by the Siberian breeding varieties Yuna (early variety), Lina (middle-early), and Zlatka (medium-maturing).

The methodological basis of the work was the system-alternative approach, implemented in a two-factor field experiment².

The research was conducted in 2022–2024 in the Novosibirsk region under soil and climatic conditions typical for the forest-steppe zone of Western Siberia. The soil cover of the research station is represented by drained leached chernozem of medium thickness. The depth of the humus horizon is about 40 cm. Agrochemical characteristics of the arable soil layer (0–30 cm) are: humus (according to Tyurin) – 5%, total nitrogen (according to Kjeldahl) – 0.34%, total phosphorus – 0.30%, available phosphorus and potassium (according to Chirikov) – 29 and 13 mg/100 g of soil respectively, pH = 6.7–6.8 units.

The climatic conditions are characterized by the following parameters. The duration of the frost-free period is 110–120 days per year. The growing season for cold-resistant plants is about 150 days, the sum of positive temperatures above 5 °C is 2080–2160 °C, above 10 °C – 1770–1860 °C (according to long-term average data). The spring period is the shortest, windiest, clearest, and driest of the year. Return frosts are typical at the end of April and May. The average date of the last frosts is May 20, as well as the last frosts on the ground, but they are also possible in the first ten-day period of June. On average, the transition through 0 °C occurs on April 15, through 5 °C – on April 28, through 10 °C – on May 15.

The research site is characterized by sufficient but unstable moisture, with an annual precipitation of 350–400 mm and a hydrothermal coefficient (according to Selyaninov) of 0.9–1.1. From May to September, 275 mm of precipitation usually falls, of which about 100 mm occurs in May–June. The maximum occurs in the summer months, July and August, and the minimum in February and March. During the growing season, precipitation often falls in the form of heavy rains, which reduces its effectiveness for plants.

²Kiryushin V.I. Methodological concept of the development of agriculture in Siberia // Zemledelie, 1989, N 12, pp. 7–14.

The frequency of years with moderately deficient, deficient, and sharply arid types of moisture in this area is 25%, 20%, and 10% of years, respectively. The frequency of droughts during this period is from 10 to 15% of years³.

Temperatures during the 2022 growing season were close to the long-term average. It should be noted that the third ten days of May and the second ten days of June were slightly warmer than usual. Precipitation during the current growing season was distributed extremely unevenly. In the third ten-day period of May, the first and second ten-day periods of July, and the first and third ten-day periods of August, moisture was insufficient, with precipitation amounts 16.3; 2.6; 26.0; 6.5 and 4.0 times less, respectively, than the long-term average. In other cases, precipitation amounts were close to the climatic norm (see Table 1).

The 2023 growing season was characterized by low precipitation and high temperatures. May was particularly humid, with precipitation in the third ten-day period 8.6 times lower

than the long-term average. Temperatures in the first ten-day period of June were 7.9°C above the long-term average, with precipitation in the second and third ten-day periods 2.6 and 50.0 times lower than normal, respectively. Overall, atmospheric moisture inflow for the month was 31.6 mm below the long-term average, or 2.2 times lower. In the second ten-day period of July, temperatures were 4.1°C above normal, while in the first and third ten-day periods, they were 1.9°C above normal. Overall, temperatures for the month were 2.6°C above normal. Average precipitation for the month was close to normal. In August, temperatures were close to the long-term average, with temperatures in the first and second ten-day periods being 2.9 and 4.2°C above normal, respectively, and in the third ten-day period, close to the long-term average. Precipitation for the month was 1.7 times above normal. In the first ten-day period, precipitation was 30.0 times below normal, while in the second and third ten-day periods, it was 3.3 and 2.0 times above normal.

Табл. 1. Метеоусловия вегетационного периода в годы исследований, АМС Огурцово Новосибирской области (2022–2024 гг.)

Table 1. Meteorological conditions of the growing season during the research years, Ogurtsovo AMS, Novosibirsk Region (2022–2024)

Indicator	Month, ten-day period									
	May	June			July			August		
	III	I	II	III	I	II	III	I	II	III
2022										
Air temperature, °C	19,0	12,0	19,5	20,2	18,5	18,1	20,0	18,8	15,2	15,7
Precipitation, mm	1,0	16,4	20,5	21,9	7,4	1,0	20,4	3,7	13,6	5,5
2023										
Air temperature, °C	15,2	23,3	17,7	16,0	21,0	23,0	20,8	20,8	14,8	17,7
Precipitation, mm	1,5	5,0	0,4	21,0	13,0	15,0	32,0	0,8	67,0	45,0
2024										
Air temperature, °C	10,3	14,3	19,3	24,6	20,3	22,1	22,3	20,6	18,6	16,1
Precipitation, mm	25,0	25,0	51,0	10,0	19,0	34,0	27,0	38,0	28,0	66,0
Long-time average annual										
Air temperature, °C	13,2	15,4	16,7	18,1	19,1	18,9	18,9	17,9	16,0	13,5
Precipitation, mm	13,0	13,0	20,0	25,0	19,0	26,0	27,0	24,0	20,0	22,0

³Voronina L.V., Gritsenko A.G. Climate and Ecology of the Novosibirsk Region. Novosibirsk: SSGA, 2011, 227 p.

Meteorological data for the 2024 growing season deviated significantly from long-term averages, particularly for moisture. Heavy rainfall, often of torrential character, occurred throughout the season. May, June, and August saw a significant excess of atmospheric moisture. Precipitation in May totaled 70 mm, while in June, it totaled 113 mm, exceeding the long-term average by 94.4% and 94.8%, respectively. In August, precipitation increased even further (133 mm), exceeding the long-term average (66 mm, or 201.5% of normal). In July, their number was within the normal range. Heavy rains accompanied by high temperatures created a stressful situation for potato development. The total amount of precipitation for the growing season amounted to 396 mm, exceeding the long-term average by 1.7 times. This growing season was classified as moderately waterlogged. The average daily air temperature exceeded the long-term average from May to August by 1.1, 2.8, 2.6, and 2.6 °C.

The experiment was conducted in a crop rotation of potato – green manured fallow (rape-seed) – potato. All technological operations in

the cultivation of crops, if they were not the subject of the study, were carried out according to recommendations⁴. The experimental design met the requirements of the field experiment methodology⁵ (see Table 2).

Each of the three studied potato varieties was placed at two levels of mineral nutrition: on the background of natural fertility and with mineral fertilizers N₄₀P₄₀ K₈₀. The effectiveness of potato protection with the seed treatment Celeste Top, SC, and preparations based on humates Beres-8 and Relikt was evaluated through pre-plant treatment of seed tubers with these compositions, as well as spraying the crop with humates during the growing season. The experiment was two-factorial: factor A – level of mineral nutrition, B – plant protection.

The experiment is repeated twice, with the number of plants in each repetition being 24. Planting density is 57.1 thousand plants/ha, with a spacing area of 0.25 × 0.7 m.

Crop care included pre-emergence harrowing, inter-row cultivation, and hilling. Weed control was carried out using the herbicides Boxer, EC

Табл. 2. Схема опыта (сорта картофеля Юна, Лина, Златка) (2022–2024 гг.)

Table 2. Experimental design (potato varieties Yuna, Lina, Zlatka) (2022–2024)

Level of mineral nutrition	Pre-planting treatment of tubers	Treatment during vegetation, 0.2 l/ha
Without fertilizers	Celeste Top (0,4 л/т)	–
	Celeste Top (0,4 l/t) + Beres -8 (0,2 l/t)	Beres -8
	Celeste Top (0,2 l/t) + Beres -8 (0,2 l/t)	»
	Celeste Top (0,4 l/t) + Relikt (0,01 l/t)	Relikt
	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	»
N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t)	–
	Celeste Top (0,4 l/t) + Beres -8 (0,2 l/t)	Beres -8
	Celeste Top (0,2 l/t) + Beres -8 (0,2 l/t)	»
	Celeste Top (0,4 l/t) + Relikt (0,01 l/t)	Relikt
	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	»

⁴Vegetable crops and potatoes in Siberia: recommendations / compiled by G.K. Mashyanova, E.G. Grinberg, T.V. Steinert. Novosibirsk: SB RAAS, 2010, pp. 496–507.

⁵Dospekhov B.A. Methodology of field experiment (with basics of statistical processing of research results): textbook for universities. Moscow, 2012, 351 p.

(prosulfocarb, 800 g/l) at a rate of 3 L/ha and Fusilade Super, SC (fluazifop-P-butyl, 125 g/l)⁶.

The removal of tops was carried out by mechanized mowing with KIR. The harvesting of experimental plots was carried out using a two-row mounted potato digger (KTN-2V). Potato yield and the fractional composition of the new harvest were determined according to generally accepted methods at the appropriate times⁷.

The calculation of the reproduction coefficient was carried out according to the standard methodology⁸.

The results were processed using the Snedecor application software package⁹.

RESULTS AND DISCUSSION

One of the key indicators of the effectiveness of using intensification means is crop yield. Increasing plant productivity reflects the combined effect of nutrition, protection, and growth stimulation factors, and also serves as the main criterion when evaluating cultivation technologies. Potato productivity directly determines the economic efficiency of production and is a basic indicator when choosing optimal treatment schemes and levels of mineral nutrition [12].

Research has established that the use of intensification means for cultivating Siberian-bred potato varieties has increased crop productivity (see Table 3), as well as the yield of the seed fraction (see Table 4).

Yuna. On average, for the factor "mineral nutrition of plants", a significant increase in the gross yield of potato tubers was noted in the case of its optimization. In this case, the increase on average amounted to 3.5 t/ha (or 28.0%).

On average, in terms of the "protection" factor, all variants with humates showed a significant increase in crop yield compared to treating seed tubers with pure Celeste Top (dose 0.4 l/t).

The highest potato productivity was observed in the variant of treating seed tubers with Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha), in this case the yield increase was 5.8 t/ha (49.1%).

Analysis of the averages showed that a complex of factors allowed obtaining a reliable yield increase in the Yuna variety in all experimental variants (except for the seed tuber treatment – Celeste Top (0.4 l/t) + Beres-8 (0.2 l/t) + Beres-8 (0.2 l/ha)) ranging from 1.1 to 9.4 t/ha (from 9.7 to 83.2%). The maximum yield increase was observed in the variant of planting tuber treatment – Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha), which amounted to 83.2%.

Application of mineral fertilizers to the Yuna variety, on average according to the "mineral nutrition" factor, reduced the seed fraction yield by 9.1%. On average, according to the "protection" factor, the highest yield of the medium fraction was observed in the Celeste Top (0.4 l/t) + Beres-8 (0.2 l/t) + Beres-8 (0.2 l/ha) variant, and its increase compared to the pure seed treatment agent (dose 0.4 l/t) used for treating seed tubers was 2.7%.

The analysis of averages showed that a combination of factors allowed the maximum increase in the seed fraction of the Yuna variety against the background of natural fertility in the Celeste Top (0.4 l/t) + Beres-8 (0.2 l/t) + Beres-8 (0.2 l/ha) treatment by 11.9%.

The calculation of the reproduction coefficient showed that for the Yuna variety it reaches the highest value when the crop is grown with mineral fertilizers and seed tubers are treated with Celeste Top (application rate 0.2 l/t) mixed with Beres-8 humates (application rate 0.2 l/t) or Relikt (application rate 0.01 l/t), as well as when plants are treated during vegetation with Beres-8 (0.2 l/ha) or Relikt (application rate 0.2 l/ha) (see the figure).

⁶State catalog of pesticides and agrochemicals as of April 11, 2022. Website of the Ministry of Agriculture of the Russian Federation. URL: <https://docviewer.yandex.ru/view/1130000058938082/> (date of reference: 01.03.2022).

⁷Research methodology on potato cultivation. Moscow, 1967, 263 p.

⁸StudFiles. Determination of biological yield and reproduction rate. URL: <https://studfile.net/preview/2981976/page:16/>.

⁹Sorokin O.D. Applied statistics on the computer. Novosibirsk, 2012, 282 p.

Табл. 3. Влияние средств интенсификации на продуктивность сортов картофеля (2022–2024 гг.)
Table 3. The influence of intensification means on the productivity of potato varieties (2022–2024)

Level of mineral nutrition	Treatment option		Yield, t/ha	Yield increase		Averages by factor	
	Tubers	Plants*		t/ha	%	Protection	Level of mineral nutrition
Yuna							
Natural fertility background	CT 0,4 (control)	–	11,3	–	–	11,8	12,5
	CT 0,4 + B 0,2	B 0,2	11,9	0,6	5,3	13,6	
	CT 0,2 + B 0,2	B 0,2	12,5	1,2	10,6	14,1	
	CT 0,4 + R 0,01	R 0,2	12,4	1,1	9,7	14,0	
	CT 0,2 + R 0,01	R 0,2	14,5	3,2	28,3	17,6	
N ₄₀ P ₄₀ R ₈₀	CT 0,4	–	12,4	1,1	9,7		16,0
	CT 0,4 + B 0,2	B 0,2	15,4	4,1	36,3		
	CT 0,2 + B 0,2	B 0,2	15,7	4,4	38,9		
	CT 0,4 + R 0,01	R 0,2	15,7	4,4	38,9		
	CT 0,2 + R 0,01	R 0,2	20,7	9,4	83,2		
LSD _{0,5} average quotients			1,1				
LSD _{0,5} by factors						0,7	0,5
Lina							
Natural fertility background	CT 0,4 (control)	–	20,4	–	–	22,1	22,4
	CT 0,4 + B 0,2	B 0,2	23,5	3,1	15,2	24,3	
	CT 0,2 + B 0,2	B 0,2	21,5	1,1	5,4	23,1	
	CT 0,4 + R 0,01	R 0,2	22,9	2,5	12,2	24,1	
	CT 0,2 + R 0,01	R 0,2	23,7	3,3	16,2	25,7	
N ₄₀ P ₄₀ R ₈₀	CT 0,4	–	23,9	3,5	17,2		25,4
	CT 0,4 + B 0,2	B 0,2	25,1	4,7	23,0		
	CT 0,2 + B 0,2	B 0,2	24,7	4,3	21,1		
	CT 0,4 + R 0,01	R 0,2	25,4	5,0	24,5		
	CT 0,2 + R 0,01	R 0,2	27,8	7,4	36,3		
LSD _{0,5} average quotients			1,1				
LSD _{0,5} by factors						0,8	0,5
Zlatka							
Natural fertility background	CT 0,4 (control)	–	15,6	–	–	19,0	18,7
	CT 0,4 + B 0,2	B 0,2	19,1	3,5	22,4	21,6	
	CT 0,2 + B 0,2	B 0,2	19,0	3,4	21,8	21,2	
	CT 0,4 + R 0,01	R 0,2	19,0	3,4	21,8	20,3	
	CT 0,2 + R 0,01	R 0,2	20,7	5,1	32,7	20,4	
N ₄₀ P ₄₀ R ₈₀	CT 0,4	–	22,5	6,9	44,2		22,4
	CT 0,4 + B 0,2	B 0,2	24,1	8,5	54,5		
	CT 0,2 + B 0,2	B 0,2	23,5	7,9	50,6		
	CT 0,4 + R 0,01	R 0,2	21,7	6,1	39,1		
	CT 0,2 + R 0,01	R 0,2	20,2	4,6	29,5		
LSD _{0,5} average quotients			1,2				
LSD _{0,5} by factors						0,8	0,5

Here and in Table 4:

* The plants were treated once during the budding phase:

CT 0,4 – Celeste Top (the consumption rate of the preparation is 0,4 l/t);

CT 0,4 + B 0,2 – Celeste Top (the consumption rate of the preparation is 0,4 l/t) + Beres -8 (the consumption rate of the preparation is 0,2 l/t);

CT 0,2 + B 0,2 – Celeste Top (the consumption rate of the preparation is 0,2 l/t) + Beres 8 (the consumption rate of the preparation is 0,2 l/t);

CT 0,4 + R 0,01 – Celeste Top (the consumption rate of the preparation is 0,4 l/t) + Relikt (the consumption rate of the preparation is 0,01 l/t);

CT 0,2 + R 0,01 – Celeste Top (the consumption rate of the preparation is 0,2 l/t) + Relikt (the consumption rate of the preparation is 0,01 l/t);

B 0,2 – Beres -8 (the consumption rate of the preparation is 0,2 l/ha);

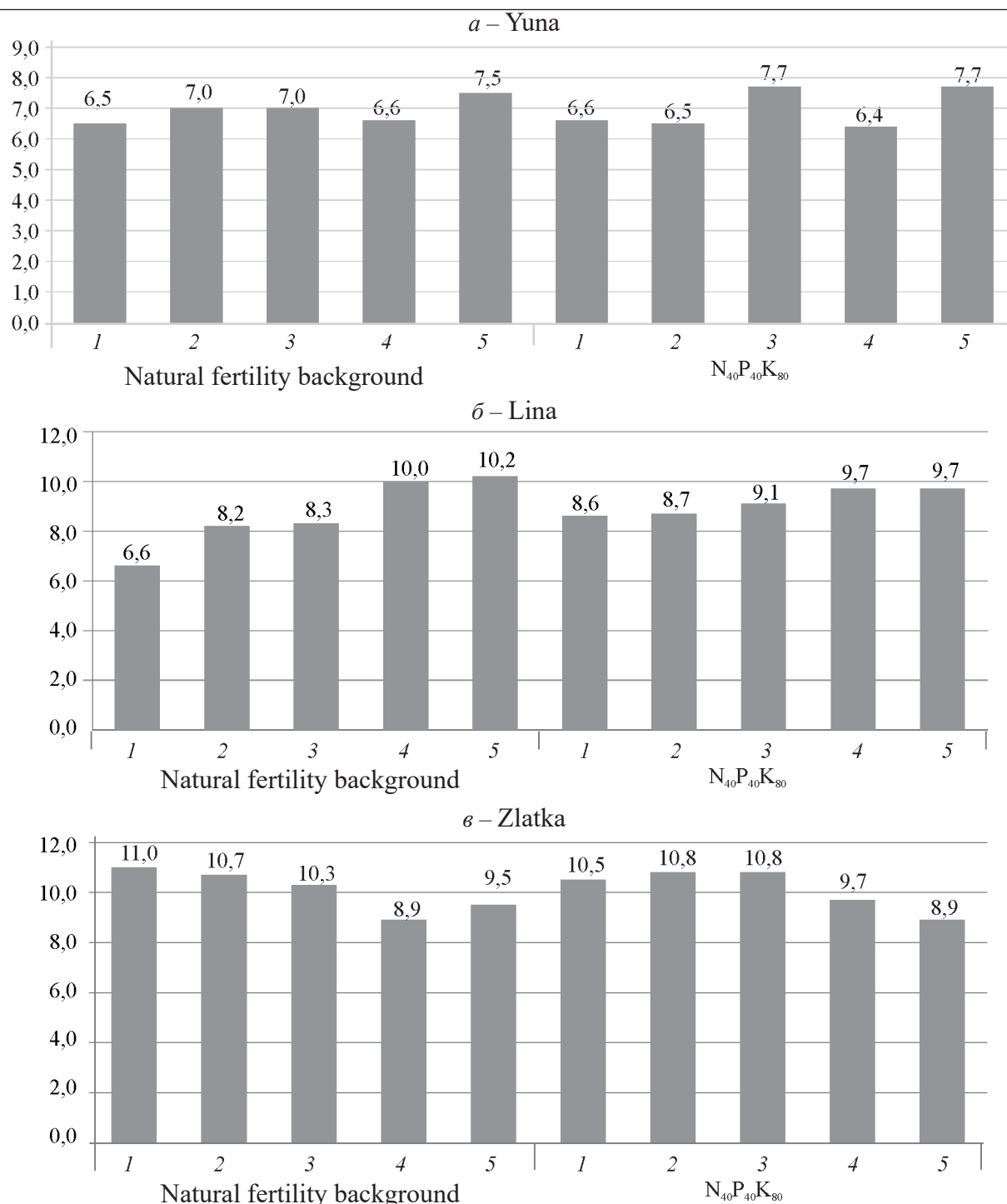
P 0,2 – Relikt (the consumption rate of the preparation is 0,2 l/ha)

Табл. 4. Влияние средств интенсификации на выход семенной фракции, весовой % (2022–2024 гг.)
Table 4. The influence of intensification means on the yield of seed fraction, weight % (2022–2024)

Mineral nutrition level	Treatment option		Quantity of seed fraction	Increase (+), decrease (-) in the amount of the seed fraction	Average by factor	
	Tubers	Plants*			Protection	Mineral nutrition level
Yuna						
Natural fertility background	CT 0,4 (control)	–	63,7	–	64,3	67,7
	CT 0,4 + B 0,2	B 0,2	75,6	+11,9	67,0	
	CT 0,2 + B 0,2	B 0,2	69,5	+5,8	64,7	
	CT 0,4 + R 0,01	R 0,2	62,3	–1,4	57,0	
	CT 0,2 + R 0,01	R 0,2	67,6	+3,9	62,6	
N ₄₀ P ₄₀ R ₈₀	CT 0,4	–	65,0	+1,3		58,6
	CT 0,4 + B 0,2	B 0,2	58,5	–5,2		
	CT 0,2 + B 0,2	B 0,2	60,0	–3,7		
	CT 0,4 + R 0,01	R 0,2	51,7	–12,0		
	CT 0,2 + R 0,01	R 0,2	57,6	–6,1		
Lina						
Natural fertility background	CT 0,4 (control)	–	56,8	–	59,7	63,8
	CT 0,4 + B 0,2	B 0,2	62,6	+5,8	62,5	
	CT 0,2 + B 0,2	B 0,2	65,8	+9,0	65,0	
	CT 0,4 + R 0,01	R 0,2	62,3	+5,5	68,7	
	CT 0,2 + R 0,01	R 0,2	71,6	+14,8	72,5	
N ₄₀ P ₄₀ R ₈₀	CT 0,4	–	62,7	+5,9		67,6
	CT 0,4 + B 0,2	B 0,2	62,4	+5,6		
	CT 0,2 + B 0,2	B 0,2	64,2	+27,7		
	CT 0,4 + R 0,01	R 0,2	75,2	+18,4		
	CT 0,2 + R 0,01	R 0,2	73,4	+31,7		
Zlatka						
Natural fertility background	CT 0,4 (control)	–	73,1	–	73,9	72,1
	CT 0,4 + B 0,2	B 0,2	72,8	–0,3	71,9	
	CT 0,2 + B 0,2	B 0,2	72,7	–0,4	75,3	
	CT 0,4 + R 0,01	R 0,2	65,8	–7,3	71,3	
	CT 0,2 + R 0,01	R 0,2	76,2	+3,1	77,1	
N ₄₀ P ₄₀ R ₈₀	CT 0,4	–	74,7	+1,6		75,7
	CT 0,4 + B 0,2	B 0,2	71,0	–2,1		
	CT 0,2 + B 0,2	B 0,2	77,9	+4,8		
	CT 0,4 + R 0,01	R 0,2	76,9	+3,8		
	CT 0,2 + R 0,01	R 0,2	78,1	+5,0		

Lina. On average, for the factor “mineral nutrition of plants”, a significant increase in the gross yield of potato tubers was noted in case of its optimization. The average increase amounted to 3.0 t/ha (or 13.4%). On average, for the factor “protection”, there was no sharp difference in productivity among the variants. The significant increase in yield ranged from 1.0 to 3.6 t/ha, but the highest potato productivity, as with the Yuna variety, was noted in the variant of seed tuber treatment with Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha); in this case, the yield increase amounted to 3.6 t/ha (16.3%).

Analysis of the averages showed that the combination of factors allowed for a reliable increase in yield of the Lina variety in all experimental options from 1.1 to 7.4 t/ha (from 5.4 to 36.3%). The maximum yield increase was noted in the variant with the treatment of seed tubers with Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha), which amounted to 36.3%.
The application of mineral fertilizers to the Lina variety, on average according to the “mineral nutrition” factor, increased the yield of the seed fraction by 3.8%. On average, according to



Влияние уровня минерального питания и обработки картофеля протравителем и гуматами на коэффициент размножения:

a – Юна; *б* – Лина; *в* – Златка (2022–2024 гг.): 1 – СТ 0,4 – Селест Топ (норма расхода препарата 0,4 л/т) – на фоне естественного плодородия данный вариант являлся контролем; 2 – СТ 0,4 + Б 0,2 + Б 0,2 – Селест Топ (0,4 л/т) + Берес-8 (0,2 л/т) + Берес-8 (0,2 л/га); 3 – СТ 0,2 + Б 0,2 + Б 0,2 – Селест Топ (0,2 л/т) + Берес-8 (0,2 л/т) + Берес-8 (0,2 л/га); 4 – СТ 0,4 + Р 0,01 + Р 0,2 – Селест Топ (0,4 л/т) + Реликт (0,01 л/т) + Реликт (0,2 л/га); 5 – СТ 0,2 + Р 0,01 + Р 0,2 – Селест Топ (0,2 л/т) + Реликт (0,01 л/т) + Реликт (0,2 л/га)

The influence of mineral nutrition level and potato treatment with seed dressing and humates on the multiplication coefficient:

a – Yuna; *б* – Lina; *в* – Zlatka (2022–2024): 1 – СТ 0.4 – Celeste Top (consumption rate of the drug 0.4 l/t) – against the background of natural fertility, this option was the control; 2 – СТ 0.4 + Б 0.2 + Б 0.2 – Celeste Top (0.4 l/t) + Beres-8 (0.2 l/t) + Beres-8 (0.2 l/ha); 3 – СТ 0.2 + Б 0.2 + Б 0.2 – Celeste Top (0.2 l/t) + Beres-8 (0.2 l/t) + Beres-8 (0.2 l/ha); 4 – СТ 0.4 + Р 0.01 + Р 0.2 – Celeste Top (0.4 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha); 5 – СТ 0.2 + Р 0.01 + Р 0.2 – Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha)

the “protection” factor, the highest yield of the medium fraction was observed in the Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha) variant, and its increase compared to pure Celeste Top (rate 0.4 l/t), used for treating seed tubers, was 12.8%.

Analysis of the averages showed that a combination of factors allowed the maximum increase in the seed fraction in the Lina variety when optimizing mineral nutrition in the Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha) variant, amounting to 31.7%.

The calculation of the reproduction coefficient showed that the highest value for the Lina variety is achieved when cultivating the crop on the background of natural fertility and using Celeste Top for treating seed tubers (application rate 0.2 l/t) in a mixture with the Relikt humate (application rate 0.01 l/t), as well as treating plants during vegetation with Relikt (application rate 0.2 l/ha) (see the figure).

Zlatka. On average, for the factor “mineral nutrition of plants”, a significant increase in the gross yield of potato tubers was noted in the case of its optimization. The increase averaged 3.7 t/ha (or 19.8%). On average, with respect to the “protection” factor, the variants differed little in productivity, with a significant yield increase ranging from 1.3 to 2.6 t/ha. The highest productivity of the Lina potato variety was noted in the variant of treating seed tubers – Celeste Top (0.4 l/t) + Beres-8 (0.2 l/t) + Beres-8 (0.2 l/ha); in this case, the yield increase was 2.6 t/ha (13.7%).

Analysis of the averages showed that the combination of factors made it possible to achieve a reliable yield increase in the Zlatka variety in all experimental variants from 3.4 to 8.5 t/ha (from 21.8 to 54.5%). The maximum yield increase was observed in the treatment variant of seed tubers – Celeste Top (0.4 l/t) + Beres-8 (0.2 l/t) + Beres-8 (0.2 l/ha), which amounted to 54.5%.

The application of mineral fertilizers to the Zlatka variety, on average according to the “mineral nutrition” factor, increased the yield of the

seed fraction by 3.6%. On average, according to the “protection” factor, the highest yield of the medium fraction was observed in the Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha) option, and its increase compared to the pure seed dressing agent (rate 0.4 l/t) used for treating seed tubers was 3.2%.

Analysis of the averages showed that a combination of factors allowed obtaining the maximum increase in the seed fraction of the Zlatka variety with the optimization of mineral nutrition in the Celeste Top (0.2 l/t) + Relikt (0.01 l/t) + Relikt (0.2 l/ha) option, amounting to 5.0%.

The calculation of the reproduction coefficient showed that it reaches its highest value for the Zlatka variety when the crop is grown on the background of natural fertility and Celeste Top (consumption rate 0.4 l/t) is used for treating seed tubers in pure form (see the figure).

Ranking of such traits as the weight percentage of the seed fraction and the reproduction coefficient made it possible to identify cultivation options for the varieties that allow obtaining the optimal ratio of the number and mass of seed tubers (see Table 5).

This statistical method showed that the best option for the Yuna variety, allowing to achieve an optimal ratio of quantity and mass of seed tubers, is its cultivation without the use of mineral fertilizers, as well as the treatment of planting material with a mixture of Celeste Top (0.4 l/t) and Beres-8 (0.2 l/t) followed by spraying with Beres-8 (0.2 l/t).

In this case, it can be seen that the yield of the average fraction in weight equivalent is maximal (75.6%) (see Table 4), and the multiplication coefficient (7.0) is slightly lower than the maximum (7.7) noted for this variety in the experiment (see the figure).

For the Lina variety, the optimal mass-to-tuber ratio was found in the treatment variant of the planting material Celeste Top (0.2 l/t) in combination with Relikt (0.01 l/t), followed by cultivation of the crop on the background of natural soil fertility and treatment of the plantings during

Табл. 5. Ранжирование признаков (весовой процент семенной фракции, коэффициент размножения) для различных сортов картофеля (2022–2024 гг.)

Table 5. Ranking of traits (weight percentage of seed fraction, multiplication coefficient) for different potato varieties (2022–2024)

Location of the object	Mineral nutrition level	Treatment option		Sum of ranks
		tubers	plants, 0,2 l/ha	
Yuna				
The group of "best" objects				
1	NFB*	Celeste Top (0,4 l/t) + Beres -8 (0,2 l/t)	Beres -8	20,5
2	NFB	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	Relikt	20,0
3	NFB	Celeste Top (0,2 l/t) + Beres -8 (0,2 l/t)	Beres -8	19,5
The group of "average" objects				
4	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,2 l/t) + Beres -8 (0,2 l/t)	Beres -8	15,5
5	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t)	–	15,5
6	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	Relikt	13,5
7	NFB	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	»	11,5
8	NFB	Celeste Top (0,4 l/t) (control)	–	10,5
The group of "worst" objects				
9	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t) + Beres -8 (0,2 l/t)	Beres -8	6,5
10	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t) + Relikt (0,01 l/t)	Relikt	2,0
Lina				
The group of "best" objects				
1	NFB	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	Relikt	22,0
2	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t) + Relikt (0,01 l/t)	»	21,5
3	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	»	20,5
The group of "average" objects				
4	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,2 l/t) + Beres -8 (0,2 l/t)	Beres -8	16,0
5	NFB	Celeste Top (0,4 l/t) + Relikt (0,01 l/t)	Relikt	15,0
6	NFB	Celeste Top (0,2 l/t) + Beres -8 (0,2 l/t)	Beres -8	14,0
7	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t)	–	13,0
8	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t) + Beres -8 (0,2 l/t)	Beres -8	12,0
9	NFB	Celeste Top (0,4 l/t) + Beres -8 (0,2 l/t)	»	10,0
The group of "worst" objects				
10	NFB	Celeste Top (0,4 l/t) (control)	–	4,0
Zlatka				
The group of "best" objects				
1	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,2 l/t) + Beres -8 (0,2 l/t)	Beres -8	19,5
2	NFB	Celeste Top (0,4 l/t) (control)	–	17,0
The group of "average" objects				
3	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t) + Relikt (0,01 l/t)	Relikt	14,0
4	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t)	–	14,0
5	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	Relikt	13,5
6	NFB	Celeste Top (0,2 l/t) + Relikt (0,01 l/t)	»	12,0
7	NFB	Celeste Top (0,4 l/t) + Beres -8 (0,2 l/t)	Beres -8	11,0
8	N ₄₀ P ₄₀ K ₈₀	Celeste Top (0,4 l/t) + Beres -8 (0,2 l/t)	»	10,5
The group of "worst" objects				
9	NFB	Celeste Top (0,2 l/t) + Beres-8 (0,2 l/t)	Beres -8	8,0
10	NFB	Celeste Top (0,4 l/t) + Relikt (0,01 l/t)	Relikt	2,5

Note: NFB – natural fertility background.

vegetation with Relikt (0.2 l/ha). In this case, it is seen that the yield of the medium fraction in weight equivalent (71.6%) and the reproduction coefficient (10.2) are maximal (see Table 4, the figure) for this variety in the experiment.

For the Zlatka variety, among all the studied options, ranking revealed that using mineral fertilizer for growing this variety, treating the tubers with Celeste Top (0.2 l/t) in combination with Beres-8 (0.2 l/t), as well as treating the plants during the growing season with Beres-8 (0.2 l/ha), allows obtaining the optimal ratio of the quantity and mass of seed tubers. In this case, the yield of the middle fraction in weight equivalent is 77.9%, which is slightly less than the maximum (78.1%) (see Table 4), and the multiplication factor (10.8) is also slightly lower than the maximum (11.0) noted for this variety in the experiment (see the figure).

CONCLUSIONS

1. To achieve the highest yield of seed tubers for the Yuna variety in terms of weight, it should be cultivated on the basis of natural fertility using Celeste Top (0.4 l/t) for seed tuber treatment in combination with Beres-8 humate (0.2 l/t) and treating plants during the budding period with Beres-8 humate (0.2 l/ha). In this case, the output of the seed fraction increased by 11.9%. To increase the number of seed tubers in numerical terms, the crop should be grown with mineral fertilizers and the use of Celeste Top (application rate 0.2 l/t) to treat the seed tubers in combination with Beres-8 humates (0.2 l/t) or Relikt (0.01 l/t), as well as treating the plants during the growing season with Beres-8 (0.2 l/ha) or Relikt (0.2 l/ha), respectively. The reproduction coefficient in these cases is 7.7, in the control – 6.5. The optimal ratio of quantity and mass of seed tubers for the Yuna variety was observed when cultivating it without the use of mineral fertilizers, as well as when treating the planting material with a mixture of Celeste Top (0.4 l/t) and Beres-8 (0.2 l/t) followed by spraying with Beres-8 (0.2 l/t). In this case, the yield of the av-

erage fraction in weight equivalent is maximum (75.6%), and the reproduction coefficient (7.0) is slightly lower than the maximum (7.7).

2. For the maximum realization of the productivity of the Lina variety, it is necessary to treat the planting tubers with Celeste Top (application rate 0.2 L/t) in a mixture with the humic preparation Relikt (application rate 0.01 L/t), followed by treatment of the plantings during the vegetative period at the budding stage with Relikt (application rate 0.2 L/ha). In this case, the increase in gross yield amounted to 36.3%. To achieve the highest yield of seed tubers of the Lina variety in terms of weight, it should be cultivated with mineral fertilizers, using Celeste Top (0.2 l/t) for seed tuber treatment in combination with Relikt humate (0.01 l/t) and treating the plants during the budding period with Relikt (0.2 l/ha). In this case, the yield of the seed fraction increased by 31.7%. To increase the number of seed tubers in numerical terms, the crop should be cultivated on the basis of natural fertility and the use of Celeste Top for seed tuber treatment (application rate 0.2 l/t) in a mixture with Relikt humate (application rate 0.01 l/t), as well as the treatment of plants during vegetation with Relikt (application rate 0.2 l/ha). The reproduction rate in these cases is 10.2, in the control – 6.6. For the Lina variety, the optimal mass-to-tuber ratio was found in the treatment option with Celeste Top (0.2 l/t) in combination with Relikt (0.01 l/t) for seed material, followed by crop cultivation under natural fertility conditions and treatment of the plantings during the growing season with Relikt (0.2 l/ha). The yield of the medium fraction in weight equivalent was 71.6%, the reproduction rate was 10.2, which was the maximum for this variety in the experiment.

3. For the maximum realization of the productivity of the Zlatka variety, it is necessary to treat the planting tubers with Celeste Top (applicant rate 0.2 l/t) in a mixture with the humic preparation Beres-8 (applicant rate 0.2 l/t), followed by treatment of the plantings during vegetation at the budding period with Beres-8 (applicant rate

0.2 l/ha). In this case, the increase in gross yield was 54.5%. To obtain the highest yield of seed tubers of the Zlatka variety in weight terms, it should be grown on a background with mineral fertilizers using Celeste Top (0.2 l/t) for seed tuber treatment in combination with Relict humate (0.01 l/t) and treating plants during the budding period with Relict (0.2 l/ha). In this case, the yield of the seed fraction increased by 5.0%. To increase the number of seed tubers in numerical terms, the crop should be grown on the background of natural fertility and using only Celeste Top (application rate 0.4 l/t) for seed tuber treatment. The reproduction rate in these cases is 11.0. For the Zlatka variety, it was found that using mineral fertilizer to grow this variety, treating tubers with Celeste Top (0.2 l/t) in combination with Beres-8 (0.2 l/t), as well as treating plants during the growing season with Beres-8 (0.2 l/ha), allows achieving an optimal ratio of the quantity and weight of seed tubers. The yield of the average fraction in weight equivalent was 77.9%, which is slightly below the maximum (78.1%), and the reproduction rate (10.8) is also slightly lower than the maximum (11.0).

СПИСОК ЛИТЕРАТУРЫ

1. Шанина Е.П., Оберюхтин Д.А., Черницкий А.Е. Картофель: новый взгляд на традиционный пищевой продукт и его употребление в виде сока (обзор) // Сельскохозяйственная биология. 2024. Т. 59. № 1. С. 22–38. DOI: 10.15389/agrobiology.2024/1/22rus.
2. Иващенко А.Д., Хасбиуллина О.И. Оценка коллекционных сортообразцов картофеля на скороспелость и продуктивность в условиях Камчатского края // Агронаука. 2024. Т. 2. № 2. С. 49–58. DOI: 10.24412/2949-2211-2024-2-2-49-58.
3. George T.S., Taylor M.A., Dodd I.C., White P.J. Climate change and consequences for potato production: a review of tolerance to emerging abiotic stress // Potato Research. 2017. Vol. 60. N 3. P. 239–268. DOI: 10.1007/s11540-018-9366-3.
4. Bertschinger L., Bühler L., Dupuis B., Daffy B., Gessler C., Forbes C.A., Keller E.R., Scheidegger U.C., Struik P.C. Incomplete infection of secondarily infected potato plants – an environment dependent underestimated mechanism in

- plant virology // Frontiers in Plant Science. 2017. Vol. 8. P. 74. DOI: 10.3389/fpls.2017.00074.
5. Awati R., Bhattacharya A., Char B. Rapid multiplication technique for production of high-quality seed potato (*Solanum tuberosum* L.) tubers // Journal of Applied Biology & Biotechnology. 2019. Vol. 7. N 1. P. 1–5. DOI: 10.7324/JABB.2019.70101.
 6. Долженко В.И., Лантисев А.Б. Современный ассортимент средств защиты растений: биологическая эффективность и безопасность // Плодородие. 2021. № 3 (120). С. 71–75. DOI: 10.25680/S19948603.2021.120.13.
 7. Васильева С.В., Зейрук В.Н., Деревягина М.К., Белов Г.Л. Роль предпосадочной обработки клубней в борьбе с болезнями картофеля // Земледелие. 2018. № 5. С. 37–40. DOI: 10.24411/0044-3913-2018-10510.
 8. Мельничук Д.И., Старовойтов М.Н., Рылко В.А. Эффективность приемов интенсификации производства картофеля на связных почвах северо-востока Беларуси // Картофелеводство. 2022. Т. 22. № 1. С. 102–123.
 9. Черемисин А.И., Кумпан В.Н. Применение биопрепаратов комплексного действия и биоудобрений в оригинальном семеноводстве картофеля // Вестник Омского ГАУ. 2017. № 1 (25). С. 28–34.
 10. Глаз Н.В., Васильев А.А., Дергулева Т.Т., Мушинский А.А. Оценка экологической пластичности среднеранних и среднеспелых сортов картофеля // Дальневосточный аграрный вестник. 2019. № 1 (49). С. 10–19.
 11. Темерева И.В. Физиологические и агрохимические характеристики различных сортов картофеля при возделывании на лугово-черноземной почве // Вестник Омского ГАУ. 2016. № 2 (22). С. 50–55.
 12. Xu F., Meng A., Liu Y., Li J., Wu N. Effects of New Special Formula Fertilizer on Potato Growth, Yield, and Fertilizer Utilization Efficiency // Plants. 2025. N 14. P. 627. DOI: 10.3390/plants14040627.

REFERENCES

1. Shanina E.P., Oberyukhtin D.A., Chernitskii A.E. Potato juice vs. traditional potato use – a new insight (review). *Sel'skokhozyaistvennaya biologiya = Agricultural Biology*, 2024, vol. 59, no. 1, pp. 22–38. (In Russian). DOI: 10.15389/agrobiology.2024/1/22rus.
2. Ivashchenko A.D., Khasbiullina O.I. Evaluation of collectible potato varieties for earliness

- and productivity in the Kamchatka Territory. *Agronauka = Agrosience*, 2024, vol. 2, no. 2, pp. 49–58. (In Russian). DOI: 10.24412/2949-2211-2024-2-2-49-58.
3. George T.S., Taylor M.A., Dodd I.C., White P.J. Climate change and consequences for potato production: a review of tolerance to emerging abiotic stress. *Potato Research*, 2017, vol. 60, no. 3, pp. 239–268. DOI: 10.1007/s11540-018-9366-3.
 4. Bertschinger L., Bühler L., Dupuis B., Daffy B., Gessler C., Forbes C.A., Keller E.R., Scheidegger U.C., Struik P.C. Incomplete infection of secondarily infected potato plants – an environment dependent underestimated mechanism in plant virology. *Frontiers in Plant Science*, 2017, vol. 8, p. 74. DOI: 10.3389/fpls.2017.00074.
 5. Awati R., Bhattacharya A., Char B. Rapid multiplication technique for production of high-quality seed potato (*Solanum tuberosum* L.) tubers. *Journal of Applied Biology & Biotechnology*, 2019, vol. 7, no. 1, pp. 1–5. DOI: 10.7324/JABB.2019.70101.
 6. Dolzhenko V.I., Laptev A.B. Modern range of plant protection means: biological efficiency and safety. *Plodorodie = Plodorodie*, 2021, no. 3 (120), pp. 71–75. (In Russian). DOI: 10.25680/S19948603.2021.120.13.
 7. Vasil'eva S.V., Zeiruk V.N., Derevyagina M.K., Belov G.L. Role of pre-sowing treatment of tubers in the control of potato diseases. *Zemledelie = Zemledelie*, 2018, no. 5, pp. 37–40. (In Russian). DOI: 10.24411/0044-3913-2018-10510.
 8. Mel'nichuk D.I., Starovoitov M.N., Rylko V.A. Various efficiency methods of potato production on heavy soils in the North East of Belarus. *Kartofelevodstvo = Potato Growing*, 2022, vol. 22, no. 1, pp. 102–123. (In Russian).
 9. Cheremisin A.I., Kumpan V.N. Application of biological products of complex action and biofertilizers in original seed farming of potatoes. *Vestnik Omskogo GAU = Vestnik of Omsk SAU*, 2017, no. 1 (25), pp. 28–34. (In Russian).
 10. Glaz N.V., Vasil'ev A.A., Dergileva T.T., Mushinskii A.A. Middle-early and mid-ripening varieties of potato: environmental assessment of flexibility. *Dal'nevostochnyi agrarnyi vestnik = Far Eastern Agricultural Journal*, 2019, no. 1 (49), pp. 10–19. (In Russian).
 11. Temereva I.V. Physiological and agrochemical characteristics of different varieties of potato under cultivation on meadow-chernozem soil. *Vestnik Omskogo GAU = Vestnik of Omsk SAU*, 2016, no. 2 (22), pp. 50–55. (In Russian).
 12. Xu F., Meng A., Liu Y., Li J., Wu N. Effects of New Special Formula Fertilizer on Potato Growth, Yield, and Fertilizer Utilization Efficiency. *Plants*, 2025, no. 14, p. 627. DOI: 10.3390/plants14040627.

ИНФОРМАЦИЯ ОБ АВТОРАХ

✉ **Малюга Анна Анатольевна**, главный научный сотрудник, доктор сельскохозяйственных наук; SPIN-код 1018-5075, ORCID 0000-0001-9729-2668; **адрес для переписки:** Россия, 630501, Новосибирская область, Новосибирский район, р.п. Краснообск, СФНЦА РАН; e-mail: anna_malyuga@mail.ru

Батов Александр Сергеевич, младший научный сотрудник; SPIN-код 7636-5732, ORCID 0000-0002-6624-8178

Гуреева Юлия Александровна, младший научный сотрудник; SPIN-код 7770-2204, ORCID 0000-0003-4981-7890

AUTHOR INFORMATION

✉ **Anna A. Malyuga**, Head Researcher, Doctor of Science in Agriculture; SPIN-code 1018-5075, ORCID 0000-0001-9729-2668; **address:** SFSCA RAS, Krasnoobsk, Novosibirsk District, Novosibirsk Region, 630501, Russia; e-mail: anna_malyuga@mail.ru.

Aleksandr S. Batov, Junior Researcher; SPIN-code 7636-5732 ORCID 0000-0002-6624-8178

Yulia A. Gureeva, Junior Researcher; SPIN-code 7770-2204 ORCID 0000-0003-4981-7890

Дата поступления статьи / Received by the editors 07.11.2025
Дата принятия к публикации / Accepted for publication 21.12.2025
Дата публикации / Published 10.02.2026

Оценка себестоимости производства посадочного материала чеснока стрелкующегося (*Allium sativum* L.) с использованием технологии *in vitro*

✉ Азопкова М.А.

Всероссийский научно-исследовательский институт овощеводства –
филиал Федерального научного центра овощеводства
Московская область, д. Верея, Россия

✉ e-mail: tixanish@mail.ru

В рамках исследования выполнен сравнительный анализ себестоимости получения оздоровленного посадочного материала чеснока озимого с использованием классической технологии (из воздушных луковичек) и метода *in vitro*. Представлены затраты на разных этапах получения посадочного материала. При использовании классической технологии общие затраты составляют 368 чел. ч и 258,94 тыс. р., расчетная себестоимость одной луковички чеснока доходит до 26 р. При этом основной статьей затрат является заработная плата. Первый этап технологии *in vitro* (введение в культуру) занимает 3,74% затрат, в денежном эквиваленте – 28,83 тыс. р. Этапы микроразмножения, а также укоренения и подращивания растений *in vitro* по длительности и объему затрат находятся на одном уровне. Их доля в структуре затрат составляет 17% (132,85 и 134,65 тыс. р. соответственно). Себестоимость одного растения чеснока *in vitro* – 8,86 и 10,20 р. соответственно. Основными статьями расходов служат заработная плата и материалы (в среднем по 45%). Наиболее затратным этапом является адаптация растений к условиям *ex vitro*: длится более 7 мес, в структуре затрат его доля составляет 61,81%, себестоимость одного растения составляет 31,76 р. В целом затраты на получение посадочного материала с использованием метода *in vitro* составляют 899,72 тыс. р. Себестоимость одной луковички – 89,95 р., что на 64 р. дороже по сравнению с классической технологией. Хотя высокотехнологичные и наукоемкие методы оздоровления посадочного материала чеснока стрелкующегося существенно повышают его себестоимость, однако являются более эффективными и могут рассматриваться как долгосрочные инвестиции в развитие чесноководства в России.

Ключевые слова: себестоимость, чеснок, оздоровленный посадочный материал, культура *in vitro*, воздушные луковички

Estimation of the production cost of the planting material of bolting garlic (*Allium sativum* L.) using *in vitro* technology

✉ Azopkova M.A.

All-Russian Scientific Research Institute of Vegetable Growing –
Branch of the Federal Scientific Center of Vegetable Growing
Vereya village, Moscow region, Russia

✉ e-mail: tixanish@mail.ru

The study included a comparative analysis of the cost of obtaining improved winter garlic planting material using the classical technology (from aerial bulbs) and the *in vitro* method. The costs at different stages of obtaining the planting material are presented. When using the classical technology, total costs amount to 368 man-hours and 258.94 thousand rubles, the estimated cost of one bulb of garlic reaches 26 rubles. The main cost item is the wages. The first stage of the *in vitro* technology (introduction to culture) accounts for 3.74% of costs, in monetary terms – 28.83 thousand rubles. The stages of micropropagation, as well as rooting and growing plants *in vitro*, are at the same level in terms of duration and cost. Their share in the cost structure accounts for 17% (132.85 and 134.65 thousand rubles, respectively). The cost of one *in vitro* garlic plant is 8.86 and 10.20 rubles, respectively. The main expense items are wages and materials (45% each on average). The most expensive stage is the adaptation of plants to *ex vitro* conditions: it lasts more than 7 months, its share in the cost structure is 61.81%, the cost of one plant is 31.76 rubles. In total, the costs of obtaining the planting material using

the *in vitro* method amount to 899.72 thousand rubles. The cost of one bulb is 89.95 rubles, which is 64 rubles more expensive than the classic technology. Although high-tech and science-intensive methods for improving the planting material of bolting garlic significantly increase its cost, they are more effective and can be considered as a long-term investment in the development of garlic growing in Russia.

Keywords: cost price, garlic, improved planting material, *in vitro* culture, air bulbs

Для цитирования: Азопкова М.А. Оценка себестоимости производства посадочного материала чеснока стрелкующегося (*Allium sativum* L.) с использованием технологии *in vitro* // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 48–54. <https://doi.org/10.26898/0370-8799-2026-1-5>

For citation: Azopkova M.A. Estimation of the production cost of the planting material of bolting garlic (*Allium sativum* L.) using *in vitro* technology. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 48–54. <https://doi.org/10.26898/0370-8799-2026-1-5>

Конфликт интересов

Автор заявляет об отсутствии конфликта интересов.

Conflict of interest

The author declares no conflict of interest.

INTRODUCTION

The government, within the framework of the Program of Fundamental Scientific Research in the Russian Federation for the long-term period (2021–2030), allocated about 2 billion rubles for the creation of new highly productive forms of cultivated plants that are resistant to adverse abiotic and biotic environmental factors. This indicates the state's interest in using scientific achievements to ensure the country's food security under conditions of economic isolation. In this regard, modern biotechnological methods are becoming in demand not only in science but also in the production of agricultural products.

According to data from the Food and Agriculture Organization of the United Nations (FAO), the total demand for garlic is about 300 thousand tons per year, while actual production of this vegetable crop across all types of farms in 2020 amounted to 190 thousand tons. In Russia, 18.5 thousand hectares are planted with garlic. According to Rosstat, in 2023 the total gross garlic harvest amounted to 1,712.9 thousand centners [1]. Garlic occupies a special place in human nutrition. In addition, its role as a medicinal plant is increasingly growing.

Garlic can be propagated by cloves, aerial bulbs, and single-clove bulbs [2–5]. Due to the vegetative method of propagation, this valuable vegetable crop is susceptible to numerous dis-

eases [6–9]. The use of infected starting material leads to a loss of bulb mass by 12.3%, a reduction in the number of cloves by 40.2%, and a decrease in yield up to 60%. At the same time, new varieties created by the method of clonal selection are initially at risk of degeneration [3, 10]. Therefore, the issue of renewing varieties and obtaining healthy planting material is particularly pressing.

For example, in Russia, in order to solve this problem in potato cultivation, which also reproduces through vegetative organs, a technology for obtaining pathogen-free planting material using the *in vitro* method has been developed and widely implemented. According to open sources, the price of one potato microtuber obtained in this way can range from 150 to 1500 rubles.

The use of biotechnological methods is also possible in garlic breeding and seed production [11–15].

In order to implement the technology for improving the health of garlic planting material, it is necessary to conduct an economic analysis.

The purpose of the work is a comparative analysis of costs and the calculation of the cost of obtaining improved planting material of winter garlic (*Allium sativum* L.) using the classical technology (from aerial bulbs) and the *in vitro* method.

MATERIAL AND METHODS

Calculation of the cost of the improved winter garlic planting material was carried out in the laboratory of the All-Russian Scientific Research Institute of Vegetable Growing based on the previously developed methods^{1, 2}.

The following initial data were used to calculate the costs of obtaining the planting material in *in vitro* culture: specialist's salary with benefits – 100 thousand rubles, cost of 1 kW·h – 8.5 rubles.

Donor plants were grown on beds with a total area of 15 m² at a plant density of 40 plants/m² to simultaneously obtain 350 garlic inflorescences suitable for introduction into culture.

All work on obtaining the planting material from airborne bulbs was carried out in the experimental plot using manual labor. The calculated area at the first stage was 15 m², at the second – 300, at the third – 50 m².

RESULTS AND DISCUSSION

Obtaining garlic planting material from aerial bulbs involves a complex set of activities. In general, this method involves the sequential production of aerial bulbs, as well as single- and multi-clove bulbs. The total costs for implementing this method amount to 368 man-hours and 258.94 thousand rubles (see Table 1). The most labor-intensive process is the production of single-clove bulbs. Labor costs at this stage amount to 184 man-hours, and monetary costs are 123.42 thousand rubles. The main cost item is the salary.

At the same time, the cost of one garlic bulb, obtained using the classical scheme of planting material health improvement, averaged 25.9 rubles.

Obtaining garlic planting material using biotechnological methods consists of three stages: growing donor plants, the biotechnological

Табл. 1. Затраты на получение оздоровленного посадочного материала

Table 1. The cost of obtaining an improved planting material

Stage	Duration, months	Expenses						
		labor		materi- als	electricity		other	total
		mhrs	thous. ru- bles	thous. rubles	kW · h	thous. rubles	thous. rubles	thous. rubles
In vitro culture								
Donor plant cultivation	10	24	12,0	1,58	0	0	3,0	16,58
Biotechnological	10,5	440	261,5	339,82	19 930	169,4	11,0	781,72
Cultivation of the first field generation	10	140	70,0	21,42	0	0	10,0	101,42
Total	30,5	604	343,5	362,82	19 930	169,4	24,0	899,72
Aerial bulbs								
Obtaining aerial bulbs	10	44	22,0	2,10	0	0	10,0	34,10
Obtaining single-clove bulbs	10	184	92,0	21,42	0	0	10,0	123,42
Obtaining multi-clove bulbs	10	140	70,0	21,42	0	0	10,0	101,42
Total	30	368	184,0	44,94	0	0	30,0	258,94

¹Polyakov A.V., Azopkova M.A., Muravyova I.V. Obtaining *in vitro* planting material of winter garlic (*Allium sativum* L.): methodological recommendations. Moscow, 2018, 18 p.

²Polyakov A.V., Alekseeva T.V. Obtaining planting material of winter garlic (*Allium sativum* L.) from aerial bulbs in the Non-Black Earth zone of the Russian Federation: methodological recommendations. Moscow, 2018, 16 p.

stage, and growing the first field generation (see Table 1).

Growing donor plants includes preparing the soil for planting, cutting the beds, preparing the planting material, planting, caring for the plants during the growing season, as well as preventive treatment against diseases and pests. The duration of the stage is 10 months. Labor costs at this stage amount to 24 person-hours, and monetary costs – 16.58 thousand rubles.

The biotechnological stage is carried out under the laboratory conditions. It consists of the preparation of the plant material, *in vitro* cultivation (introduction into *in vitro*; micropropagation; rooting and growth of plants *in vitro*), adaptation of plants to *ex vitro* conditions, and their growth. The biotechnological stage lasts on average 11 months, including the period from introduction into culture to adaptation to *ex vitro* conditions, which takes 4 months, adaptation to *ex vitro* conditions and growth of plants up to single-clove bulbs, and storage in a cold chamber – 7 months (see Table 2).

The first stage of *in vitro* cultivation is the introduction into the culture. The effectiveness of this stage determines all subsequent work. In the overall cost structure, it accounts for only 3.74%, which is 28.83 thousand rubles in monetary terms.

Micropropagation and *in vitro* rooting of plants are similar in duration and in their share of the cost structure. At the micropropagation stage,

one passage from a single garlic inflorescence can produce 30 well-formed plants *in vitro* [12]. Thus, 350 inflorescences are sufficient to produce 11,000 plants *in vitro*. The share of these stages in the overall cost structure is 17% (132.85 and 134.65 thousand rubles, respectively). The cost of one plant is 8.86 and 10.20 rubles.

At the same time, the main expense items are salaries and materials, which account for an average of 45% of costs each.

The adaptation of garlic plants to *ex vitro* conditions is the costliest stage, accounting for 61.81% of the total costs. At this stage, the *in vitro* plants are grown to a single-clove bulb, followed by storage in refrigeration chambers until planting in the soil. The cost of one plant is 31.76 rubles.

Electricity costs include payment for electricity consumed by the lighting system, laminar box, split system, drying cabinets, autoclaves, distillers, and refrigerated chamber for vernalization of single-toothed bulbs. Electricity costs at the *ex vitro* plant growing stage are the highest compared to other stages and amount to 147.90 thousand rubles.

Material costs include the cost of dishes, chemical reagents, insulating materials, disinfectants, containers, and soil. It should be noted that during the experiment for plant adaptation, Jiffy peat tablets with a diameter of 24 mm were used, which increased the material costs by 184 thousand rubles.

Табл. 2. Затраты на получение 10 тыс. растений методом *in vitro*

Table 2. Costs of producing 10,000 plants using the *in vitro* method

Stage	Duration, months	Costs, thous.rubles			
		total	labor	electricity	materials
Introduction into <i>in vitro</i>	1	28,83	13,0	2,2	13,63
Micropropagation	1,5	132,85	62,75	8,75	61,35
Rooting and growing plants <i>in vitro</i>	1,5	134,65	62,75	10,55	61,35
Adaptation of plants to <i>ex vitro</i> conditions, growing, storage in a cold chamber	7	474,39	123,0	147,90	203,49
Total	11	770,72	261,5	169,4	339,82

The total costs of obtaining winter garlic plants in *in vitro* culture amount to 770.72 thousand rubles, the cost of one plant is 77 rubles.

The final stage in obtaining the planting material by the *in vitro* culture method is the cultivation of the first field generation. The duration of this stage is 10 months (see Table 1). The obtained adapted plants are planted in beds, and care for the plantings is carried out according to the technology for growing winter garlic from a single-clove bulb.

In total, the costs of obtaining the planting material using the *in vitro* method amount to 899.72 thousand rubles. The cost of one bulb of the first field generation is 89.95 rubles, which is 64 rubles more expensive compared to the conventional technology.

CONCLUSION

Since winter garlic is an exclusively vegetatively propagated plant, complete elimination of infections from the planting material using traditional methods is impossible. The use of high-tech and knowledge-intensive methods for the purification of the planting material significantly increases its cost.

As a result of the work carried out, it was established that the cost of the planting material obtained using the *in vitro* method is 3.5 times higher than the cost of bulbs obtained by the classical method.

It is possible to obtain the planting material for an area of 1 hectare from the bulbs of the first field generation, after two years of cultivation in open ground with compliance with all agronomic standards. Such material is free from phytopathogens, and the costs of obtaining it can be considered long-term investments in the development of garlic growing in Russia.

СПИСОК ЛИТЕРАТУРЫ

1. Сурихина Т.Н., Азопкова М.А. Аналитический обзор производства чеснока в России // Рисоводство. 2024. Т. 23. № 2 (63). С. 85–91. DOI: 10.33775/1684-2464-2024-63-2-85-91.
2. Солдатенко А.В., Пивоваров В.Ф., Пышина О.Н., Гуркина Л.К., Пинчук Е.В. Селекция и семеноводство овощных культур – на инновационный путь развития // Овощи России. 2023. № 1. С. 5–13. DOI: 10.18619/2072-9146-2023-1-5-13.
3. Поляков А.В., Алексеева Т.В. Производство чеснока озимого *Allium sativum* L. из воздушных луковичек: монография. М., 2022. 118 с.
4. Сузан В.Г., Литвиненко Н.В., Грехова И.В., Середин Т.М., Ниматулаев Н.М. Размножение чеснока озимого воздушными луковичками // Овощи России. 2021. № 3. С. 72–75. DOI: 10.18619/2072-9146-2021-3-72-75.
5. Середин Т.М., Агафонов А.Ф., Герасимова Л.И., Солдатенко А.В., Кривенков Л.В. Селекция чеснока озимого на качество продукции: монография. Омск, 2020. 115 с.
6. Dugan F.M., Lupien S.L., Hellier B.C. Infection by *Fusarium proliferatum* in aerial garlic bulbils is strongly reduced compared to rates in seed cloves when both originate from infected bulbs // Crop Protection. 2019. N 116. P. 43–48. DOI: 10.1016/j.cropro.2018.10.006.
7. Дуаките С., Поляков А.В., Стахеев А.А., Алексеева Т.В., Завриев С.К., Said R.R. Видовой состав грибов рода *Fusarium* Link на культуре чеснока в условиях Московской области // Сельскохозяйственная биология. 2022. Т. 57. № 1. С. 151–157. DOI: 10.15389/agrobiology.2022.1.151rus.
8. Filyushin M.A., Anisimova O.K., Kochieva E.Z., Shchennikova A.V. Genome-wide identification and expression of chitinase class I genes in garlic (*Allium sativum* L.) cultivars resistant and susceptible to *Fusarium proliferatum* // Plants. 2021. N 10 (4). P. 720. DOI: 10.3390/plants10040720.
9. Mondani L., Chiusa G., Battilani P. Chemical and biological control of *Fusarium species* involved in garlic dry rot at early crop stages // European Journal of Plant Pathology. 2021. N 160. P. 575–587. DOI: 10.1007/s10658-021-02265-0.
10. Филюшин М.А., Данилова О.А., Середин Т.М. Идентификация патогенных грибов в луковичах чеснока при хранении и в корневой сфере в период роста растений // Овощи России. 2021. № 3. С. 105–109. DOI: 10.18619/2072-9146-2021-3-105-109.

11. Karn R., Ranjan J.K., Ranjan P., Das B., Attri B.L. In vitro regeneration in long-day garlic (*Allium sativum*) // Current Horticulture. 2022. N 10 (1). P. 37–40. DOI: 10.15666/aeer/2204_29412957.
12. Азопкова М.А., Середин Т.М., Муравьева И.В., Жаркова С.В. Применение метода *in vitro* для получения оздоровленного посадочного материала чеснока озимого // Вестник Алтайского государственного аграрного университета. 2023. № 3 (221). С. 11–15. DOI: 10.53083/1996-4277-2023-221-3-11-15.
13. Tirado B., Gómez Rodríguez V.M., Cruz-Cárdenas C.I., Zelaya-Molina L.X., Ramírez-Vega H., Sandoval-Cancino G. In vitro Conservation of Mexican Garlic Varieties by Minimal Growth // Plants (Basel). 2023. N 12 (23). P. 3929. DOI: 10.3390/plants12233929.
14. Greedharry P., Boodhram K.I.D., Koyelas C. In vitro Propagation of Garlic (*Allium sativum* L.) from Meristem Culture // Current Agriculture Research Journal. 2024. Vol. 12. N 2. P. 623–638. DOI: 10.12944/CARJ.12.2.10.
15. Hailu M.M., Kahsay T.N., Sony S.S. Garlic Micro-propagation and Polyploidy Induction *in vitro* by Colchicine // Plant Breeding and Biotechnology. 2021. Vol. 9. P. 19. DOI: 10.9787/PBB.2021.9.1.1.
5. Seredin T.M., Agafonov A.F., Gerasimova L.I., Soldatenko A.V., Krivenkov L.V. Breeding winter garlic for product quality. Omsk, 2020, 115 p. (In Russian).
6. Dugan F.M., Lupien S.L., Hellier B.C. Infection by *Fusarium proliferatum* in aerial garlic bulbils is strongly reduced compared to rates in seed cloves when both originate from infected bulbs. *Crop Protection*, 2019, no. 116, pp. 43–48. DOI: 10.1016/j.cropro.2018.10.006.
7. Diakite S., Polyakov A.V., Stakheev A.A., Alekseeva T.V., Zavriev S.K., Said R.R. Species composition of fungi of the genus *Fusarium* Link on garlic plants in Moscow region. *Sel'skokhozyaistvennaya biologiya = Agricultural biology*, 2022, vol. 57, no. 1, pp. 151–157. (In Russian). DOI: 10.15389/agrobiology.2022.1.151rus.
8. Filyushin M.A., Anisimova O.K., Kochieva E.Z., Shchennikova A.V. Genome-wide identification and expression of chitinase class I genes in garlic (*Allium sativum* L.) cultivars resistant and susceptible to *Fusarium proliferatum*. *Plants*, 2021, no. 10 (4), p. 720. DOI: 10.3390/plants10040720.
9. Mondani L., Chiusa G., Battilani P. Chemical and biological control of *Fusarium* species involved in garlic dry rot at early crop stages. *European Journal of Plant Pathology*, 2021, no. 160, pp. 575–587. DOI: 10.1007/s10658-021-02265-0.
10. Filyushin M.A., Danilova O.A., Seredin T.M. Identification of pathogenic fungi in garlic bulbs during storage and in the root zone during plant growth. *Ovoshchi Rossii = Vegetable crops of Russia*, 2021, no. 3, pp. 105–109. (In Russian). DOI: 10.18619/2072-9146-2021-3-105-109.
11. Karn R., Ranjan J.K., Ranjan P., Das B., Attri B.L. In vitro regeneration in long-day garlic (*Allium sativum*). *Current Horticulture*, 2022, no. 10 (1), pp. 37–40. DOI: 10.15666/aeer/2204_29412957.
12. Azopkova M.A., Seredin T.M., Murav'eva I.V., Zharkova S.V. Application of *in vitro* method to obtain clean planting material of winter garlic. *Vestnik Altaiskogo gosudarstvennogo agrarnogo universiteta = Bulletin of Altai State Agricultural University*, 2023, no. 3 (221), pp. 11–15. (In Russian). DOI: 10.53083/1996-4277-2023-221-3-11-15.

REFERENCES

1. Surikhina T.N., Azopkova M.A. Analytical review of garlic production in Russia. *Risovodstvo = Rice Growing*, 2024, vol. 23, no. 2 (63), pp. 85–91. (In Russian). DOI: 10.33775/1684-2464-2024-63-2-85-91.
2. Soldatenko A.V., Pivovarov V.F., Pyshnaya O.N., Gurkina L.K., Pinchuk E.V. Selection and seed production of vegetable crops – on an innovative path of development. *Ovoshchi Rossii = Vegetable crops of Russia*, 2023, no. 1, pp. 5–13. (In Russian). DOI: 10.18619/2072-9146-2023-1-5-13.
3. Polyakov A.V., Alekseeva T.V. *Production of winter garlic Allium sativum L. from aerial bulbs*. Moscow, 2022, 118 p. (In Russian).
4. Susan V.G., Litvinenko N.V., Grekhova I.V., Seredin T.M., Nimatulaev N.M. Reproduction of winter garlic air bulbs. *Ovoshchi Rossii = Vegetable crops of Russia*, 2021, no. 3, pp. 72–75. (In Russian). DOI: 10.18619/2072-9146-2021-3-72-75.

13. Tirado B., Gómez Rodríguez V.M., Cruz-Cárdenas C.I., Zelaya-Molina L.X., Ramírez-Vega H., Sandoval-Cancino G. In vitro Conservation of Mexican Garlic Varieties by Minimal Growth. *Plants (Basel)*, 2023, no. 12 (23), p. 3929. DOI: 10.3390/plants12233929.
14. Greedharry P., Boodhram K.I.D., Koyelas C. In vitro Propagation of Garlic (*Allium sativum* L.) from Meristem Culture. *Current Agriculture Research Journal*, 2024, vol. 12, no. 2, pp. 623–638. DOI: 10.12944/CARJ.12.2.10.
15. Hailu M.M., Kahsay T.N., Sony S.S. Garlic Micro-propagation and Polyploidy Induction in vitro by Colchicine. *Plant Breeding and Biotechnology*, 2021, vol. 9, p. 19. DOI: 10.9787/PBB.2021.9.1.1.

ИНФОРМАЦИЯ ОБ АВТОРЕ

✉ **Азопкова Марина Александровна**, научный сотрудник, кандидат сельскохозяйственных наук; SPIN-код 7828-0945, ORCID 0000-0002-9351-1701; **адрес для переписки:** Россия, 140153, Московская область, д. Верея, стр-е 500; e-mail: tixanish@mail.ru

AUTHOR INFORMATION

✉ **Marina A. Azopkova**, Researcher, Candidate of Science in Agriculture; SPIN-code 7828-0945, ORCID 0000-0002-9351-1701; **address:** build. 500, Vereya village, Moscow Region, 140153, Russia; e-mail: tixanish@mail.ru

Дата поступления статьи / Received by the editors 04.09.2025
Дата принятия к публикации / Accepted for publication 31.10.2025
Дата публикации / Published 10.02.2026

Фенологическое развитие и урожайность ромашки аптечной и календулы лекарственной в зависимости от сроков посева в Забайкалье

✉ Андреева О.Т.

Научно-исследовательский институт ветеринарии Восточной Сибири – филиал
Сибирского федерального научного центра агrobiотехнологий Российской академии наук
Чита, Россия

✉ e-mail: frau.olgaa2015@yandex.ru

В статье на основании трехлетних (2020–2022) полевых опытов и лабораторных исследований изложены результаты изучения процесса формирования агрофитоценозов ценных лекарственных растений – ромашки аптечной (*Matricaria chamomilla*) и календулы лекарственной (*Calendula officinalis* L.) – при разных сроках посева в лесостепной зоне Забайкальского края. Исследование проводили на опытном поле Научно-исследовательского института ветеринарии Восточной Сибири. Почва опытного участка лугово-черноземная мучнисто-карбонатная, по гранулометрическому составу – легкий суглинок. Цель работы – оценка влияния сроков посева (II декада мая, II декада июня, II декада июля) на продолжительность межфазных периодов развития растений, линейный рост, облиственность, полевую всхожесть, сохранность растений и урожайность лекарственного сырья. Полученные данные свидетельствуют о том, что благодаря различным срокам посева в зависимости от почвенно-климатических условий региона можно получать различную урожайность изучаемых лекарственных культур. Наибольшая урожайность лекарственного сырья сформировалась при посеве 15 мая и 15 июня: урожайность сырой массы ромашки аптечной составила 8,20–9,60 т/га, сухой массы – 1,37–1,49 т/га, семян – 0,15–0,16 т/га, у календулы лекарственной – 9,80–10,30; 1,80–1,87; 0,40–0,41 т/га соответственно. К моменту уборки высота растений ромашки аптечной доходила до 89–95 см, облиственность – до 57–58%, календулы лекарственной – 82–84 см и 52–55% соответственно. Отмечено, что лекарственные растения свободны от болезней и вредителей, их посевы устойчивы к полеганию и засухе в условиях Забайкалья.

Ключевые слова: лекарственные растения, ромашка аптечная, календула лекарственная, сроки посева, межфазные периоды, развитие растений, урожайность, адаптивность

Phenological development and productivity of wild chamomile and calendula officinalis depending on the sowing time in Transbaikalia

✉ Andreeva O.T.

Scientific Research Institute of Veterinary Science of Eastern Siberia – Branch of the
Siberian Federal Scientific Centre of Agro-Biotechnologies of the Russian Academy of Sciences
Chita, Russia

✉ e-mail: frau.olgaa2015@yandex.ru

The article presents the results of a study on the formation of agrophytocenoses of valuable medicinal plants – wild chamomile (*Matricaria chamomilla*) and calendula officinalis (*Calendula officinalis* L.) – at different sowing times in the forest-steppe zone of the Trans-Baikal Territory, based on three years (2020–2022) of field experiments and laboratory research. The study was conducted on the experimental field of the Scientific Research Institute of Veterinary Science of Eastern Siberia. The soil of the experimental plot was meadow-chnozem floury-carbonate, light loam in granulometric composition. The purpose of the work was to study the effect of the sowing dates (second ten days of May, second ten days of June, second ten days of July) on the duration of interphase periods of plant development, linear growth, foliage, field germination, plant survival, and yield of medicinal raw materials. The obtained data indicate that, thanks to different sowing times depending on the soil and climatic conditions of the region, it is possible to obtain different yields of the studied medicinal crops. The highest yield of medicinal raw materials was achieved when sowing on May 15 and June 15: the yield of the raw mass of wild chamomile was 8.20–9.60 t/ha, dry mass – 1.37–1.49 t/ha, seeds – 0.15–0.16 t/ha, and for calendula officinalis – 9.80–10.30; 1.80–1.87; 0.40–0.41 t/ha, respectively. By

the harvest time, the wild chamomile plants reached 89–95 cm in height, with a foliage coverage of 57–58%, while the calendula officinalis plants reached 82–84 cm and 52–55%, respectively. These medicinal plants were noted to be free of diseases and pests, and their crops were resistant to lodging and drought in the conditions of Transbaikalia.

Keywords: medicinal plants, wild chamomile, calendula officinalis, sowing dates, interphase periods, plant development, yield, adaptability

Для цитирования: Андреева О.Т. Фенологическое развитие и урожайность ромашки аптечной и календулы лекарственной в зависимости от сроков посева в Забайкалье // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 55–63. <https://doi.org/10.26898/0370-8799-2026-1-6>

For citation: Andreeva O.T. Phenological development and productivity of wild chamomile and calendula officinalis depending on the sowing time in Transbaikalia. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 55–63. <https://doi.org/10.26898/0370-8799-2026-1-6>

Конфликт интересов

Автор заявляет об отсутствии конфликта интересов.

Conflict of interest

The author declares no conflict of interest.

INTRODUCTION

At present, medicinal plants play a significant role in the production of pharmaceuticals, since about half of all medicines used in modern world medicine are of natural origin, obtained from products processed from medicinal plant raw materials. The distinctive feature of medicinal plants and preparations based on them is that their range of action is very wide, because plants naturally contain a whole complex of various substances, each of which not only has a specific effect on the body but also enhances the action of other biologically active substances. The therapeutic spectrum of action of the preparations based on certain plants is quite significant. Examples of such plants include calendula officinalis, wild chamomile, Ural licorice, and others. Medicinal plants and preparations made from them have a mild therapeutic effect, lower toxicity, and minimal side effects compared to substances obtained synthetically.

The use of medicinal plants has its roots in the distant past. Many of them have undergone centuries of testing and are an invaluable resource for modern medicine. Thanks to the combination of the historical experience of the peoples of the world and the results of scientists' work, a unique arsenal of medicinal plant preparations

has been created, which is in great demand both in Russia and in other countries. Eco-products from medicinal plants are used in the production of medical and veterinary drugs, in the food industry, perfumery, and cosmetology. Medicinal plants are widespread in all geographic zones of our country, with a large number growing in Transbaikalia, Western and Eastern Siberia. Currently, the domestic pharmaceutical industry's needs for medicinal raw materials are not fully met, with imports accounting for up to 80%¹ [1–3].

In recent years, there has been a sharp turn towards the use of medicinal plants for treatment, which has been facilitated by an increased level of knowledge about medicinal plants and the stability of the effects obtained. In government program documents, the Government of the Russian Federation has set the crucial task of providing the country's population with highly effective domestic herbal medicines². Therefore, the revival and development of medicinal plant cultivation in the Russian Federation at the present stage and in the future constitute an important and relevant task of great national economic significance.

Promising sources of medicinal products are wild chamomile (*Matricaria chamomilla*) and

¹Telyatyev V.V. Healing treasures of Eastern Siberia. Irkutsk, 1976, 445 p.

²Order of the Ministry of Industry and Trade of the Russian Federation dated October 23, 2009 No. 965 "On approval of the strategy for the development of the pharmaceutical industry of the Russian Federation for the period up to 2020" // GARANT.RU: information and legal portal. URL: <https://www.garant.ru/products/ipo/prime/doc/4089282/>.

calendula officinalis (*Calendula officinalis* L.).

Calendula officinalis is an annual herbaceous plant of the Asteraceae family. The flowers of calendula contain a whole complex of biologically active substances. For example, carotenoids help reduce inflammation and have anti-cancer effects. Sterols contribute to the improvement of the cardiovascular system and remove excess cholesterol. Triterpenoids stabilize blood sugar levels and tone the immune system. Essential oils support immunity and have an antibiotic effect. Coumarins maintain the elasticity of blood vessels and reduce the chance of blood clot formation. Lactone has an anti-tumor effect [4–7].

Wild chamomile is an annual herbaceous plant of the Aster family. The flowers, stems, and leaves of chamomile contain many essential oils, coumarins, polysaccharides, flavonoids, organic acids, and vitamins of various groups. Chamomile helps with stomach ulcers, acute and chronic inflammations of the intestinal mucosa, gastritis, colitis, constipation, and neuralgic pain. Valuable components in medicinal chamomile are glycosides, flavonoids, and a type of ether – chamazulene, which is used for the treatment of bronchial asthma, rheumatism, allergic gastritis and colitis, and burns from X-rays. Chamomile flower infusion has anti-inflammatory, hemostatic, antiseptic, analgesic, antispasmodic, and diaphoretic effects, enhances and quickens breathing, dilates the cerebral vessels, and stimulates appetite. Ready-made medicinal forms: Romazulan, Alorom, Arfazetin, Rotokan, Kamilosid [8–10].

The content of biologically active substances in various organs of medicinal plants largely depends on the growing conditions, the vegetative period, the mass, and the size of these organs. Within the complex of technological methods of cultivating medicinal crops, the sowing dates are of great importance. Sowing dates affect the yield and quality of the produce to the extent that they coincide with favorable conditions (in terms of moisture and temperature) during the period of plant growth, development, and harvest formation. The technological method that most influences the formation and quality of the

harvest is the use of different sowing dates. By adjusting sowing dates, it is possible to reduce the plants' dependence on adverse environmental factors and achieve a high yield of high-quality medicinal raw materials. The yield and quality of medicinal raw materials are the basis for the effective use of medicinal crops in production [11, 12].

The sowing dates influence on the yield of medicinal calendula and chamomile in the Trans-Baikal region has not been previously studied. Therefore, research to determine the optimal sowing dates for these medicinal plants is timely, relevant, and has both scientific and practical significance.

The purpose of the study is to determine the optimal sowing periods for chamomile and medicinal calendula, which allow for consistently obtaining high yields of medicinal raw materials and full-fledged seeds under the conditions of Transbaikalia.

MATERIAL AND METHODS

The study was conducted in the forest-steppe zone of the Trans-Baikal Territory, in the fields of the Research Institute of Veterinary Science of Eastern Siberia. The soil of the site is meadow-chnozem, floury-carbonate, with a loamy texture according to granulometric composition. The content of organic matter in the arable layer is 3.67%, total nitrogen is 0.31%. The availability of assimilable forms of phosphorus is low, and of potassium is medium. The reaction of the soil solution of the arable horizon is slightly acidic (pH of the water extract 5.9), of the sub-arable horizon – neutral (pH = 6.3). The area of the sowing plot is 20 m², of the accounting plot – 10 m². The plot arrangement is sequential, the shape is rectangular, with fourfold replication.

Mineral fertilizers were applied at a rate of N₆₀P₆₀K₆₀ for pre-sowing cultivation. Sowing was carried out after fallow in three stages (second ten-day period of May, second ten-day period of June, second ten-day period of July). Wild chamomile seeds were sown at a rate of 4 kg/ha, and calendula officinalis seeds at a rate of 10 kg/ha. Wild chamomile seeds were embedded to

a depth of 0.5–1.0 cm, and calendula officinalis seeds were embedded to a depth of 2.0–3.0 cm. When sowing, the seeds were mixed with granulated superphosphate (at a ratio of 1:5) to ensure uniform seeding. The medicinal plant material was collected four times during the growing season (every 8–10 days) when sowing on May 15 and June 15, and once when sowing on July 15. Records and observations were conducted according to the methodological guidelines³⁻⁸.

The climate in Transbaikalia is sharply continental, with cold winters and hot summers, with little snow. Average annual precipitation is 330–380 mm, with most (85–90%) falling in the summer, and the maximum from July to August. Overall, the climate is characterized by variable moisture levels. The sum of temperatures above 10°C during the summer months ranges from 1500–1800°C, with a high average daily temperature in July (19.1°C). The frost-free period lasts for 90–110 days.

A distinctive feature of the Transbaikalian Territory's climate is its long sunshine hours. In this regard, the region surpasses even the southern regions of Russia. The average sunshine hour in Chita is 6.4 hours per day. The abundance of warmth and light in the summer and the long duration of direct sunlight are extremely favorable factors for the cultivation of many crops. These plants, fully utilizing the region's bioclimatic resources (moisture, nutrients, and solar energy), have time to mature before the onset of autumn frosts. If all agricultural practices are followed, they can produce a fairly high yield of medicinal plants and seeds.

The study period (2020–2022) was characterized by a sufficient level of moisture and heat supply. In 2020, 320 mm of precipitation fell from April to September, in 2021 – 349 mm, in 2022 – 406 mm, which exceeds the long-term average (276 mm) by 44, 73, and 130 mm. The

average temperature of the growing seasons exceeded the long-term average (11.2 °C) by 0.7, 0.9, and 1.9 °C. The hydrothermal coefficient (HTC) averaged: 1.0 in May, 1.2 in June, 2.6 in July, 1.1 in August, and 2.4 in September. May, June, and August were characterized as sufficiently wet, while July and September were excessively wet. Overall, the established weather conditions ensured the timely appearance of seedlings, good plant development, and the formation of high yields of medicinal raw materials and seeds. It was noted that the studied crops in the forest-steppe conditions of the Trans-Baikal region are resistant to pests and diseases, lodging, and drought.

RESULTS AND DISCUSSION

The study revealed that the growth of wild chamomile and calendula officinalis plants at the beginning and throughout the phenological phases was strongly influenced by weather conditions (temperature and soil moisture), sowing date, and the biological characteristics of the plants. Active plant development was observed with precipitation and optimal temperature conditions (20–23 °C).

The average daily air temperature during the sowing-to-emergence interphase period during sowing in the second ten-day period of May was 8.8–9.0 °C, in the second ten-day period of June – 16.2–16.5 °C, in the second ten-day period of July – 20.6–21.3 °C. The productive moisture in the arable soil layer was 31.2–32.1; 36.4–36.6; 38.3–39.0 mm, respectively. Soil temperature at the seed depth varied between sowing dates: 7.2–8.3°C on May 15, 11.9–12.5°C on June 15, and 19.5–20.1°C on July 15. All of this significantly influenced soil warming and differences in seedling emergence times. When sowing in the second ten-day period of May, seedlings

³Methodological guidelines for conducting field experiments with fodder crops. Moscow, 1983, 197 p.

⁴Experimental work in crop production. Moscow, 1982, 190 p.

⁵Dospekhov B.A. Methodology of field experiment (with basics of statistical processing of the research results). Moscow, 1985, 357 p.

⁶Methodology of state variety testing of agricultural crops. Moscow, 1985, 267 p.

⁷Instructions for zonal agrochemical laboratories on the analysis of feed and plants. Moscow: Kolos, 1968, 56 p.

⁸GOST 34221–2017. Seeds of medicinal and aromatic plants. Varietal and sowing qualities. General technical conditions. Moscow: Standartinform, 2017, 23 p.

emerged 23–24 days after sowing, 5–6 days earlier in the second ten-day period of June, and 15–16 days earlier in the second ten-day period of July (see Table 1).

For wild chamomile, the germination-budding period lasted from 33 to 38 days, while for calendula officinalis it was 30–35 days. The germination-flowering period lasted 52–54 days for wild chamomile and 47–50 days for calendula officinalis when sown in May and June. Moreover, this period was shorter by 2–3 days when sown in June. In July crops, the full flowering phase occurred in only 40% of wild chamomile plants and 60% of calendula officinalis plants. In wild chamomile and calendula officinalis agrocenoses, seed ripening was observed only when sown in May and June, with the periods lasting 82–86 and 72–75 days, respectively.

An important element of the agrophytocenosis is the number of plants per unit area. Field germination rates varied across experimental variants depending on sowing time. The most favorable conditions for heat and moisture were observed during sowing in the second ten-day period of July, due to precipitation and optimal average daily temperatures during germination and subsequent vegetation. High plant survival rates were noted—96–98% (see Table 2).

In wild chamomile crops, field germination was 57–70%, and in calendula officinalis, 69–78%. This indicator increased from early sowing (May 15) to later ones (by 4–6% when sowing

on June 15 and by 9–13% when sowing on July 15). Plant survival was quite high in all experimental variants (93–98%). The standing density at harvest for chamomile was 31–39 pcs/m², and for calendula officinalis, 61–73 pcs/m².

Weed infestation in spring crops during the germination period (with one cultivation) was high (96–109 weeds/m²). When sowing on June 15 (with two pre-sowing cultivations), weed infestation rates decreased slightly (73–75 weeds/m²). Less weedy were the July crops, where two pre-sowing cultivations were carried out (30–33 weeds/m²). By the end of the growing season, as a result of clearing and harrowing, weed infestation in all variants decreased to 2–7 weeds/m².

Important parameters influencing the productivity of the grass stand are the height and foliage of the plants. In the sowings carried out on May 15 and June 15, the height of the plants was the greatest by the time of harvesting: wild chamomile – 89–95 cm, calendula officinalis – 82–84 cm, which is higher than in the sowings carried out on July 15 by 51–61 and 38–40 cm, respectively. The foliage coverage was 57–59 and 52–55%. With the late sowing date (July 15), the plant height was the smallest and amounted to 34–44 cm, while the foliage coverage was high (62–65%) (see Table 3).

When assessing the response to drought using a method based on yellowing of basal leaves and loss of turgor, it was noted that all the studied crops are drought-resistant (5 points).

Табл. 1. Межфазные периоды ромашки аптечной и календулы лекарственной, дни (среднее за 2020–2022 гг.)

Table 1. Interphase periods of wild chamomile and calendula officinalis, days (average for 2020–2022)

Culture	Sowing – seedlings	Seedlings – budding	Seedlings – flowering	Seedlings – seed ripening
<i>Sowing on May 15</i>				
Wild camomile	23	33	54	82
Calendula officinalis	24	30	50	72
<i>Sowing on June 15</i>				
Wild camomile	18	34	52	86
Calendula officinalis	18	32	47	75
<i>Sowing on July 15</i>				
Wild camomile	8	38	50	–
Calendula officinalis	8	35	44	–

Табл. 2. Густота стояния, полевая всхожесть, сохранность и засоренность посевов ромашки аптечной и календулы лекарственной (среднее за 2020–2022 гг.)

Table 2. Plant density, field germination, survival and weed infestation of wild chamomile and calendula officinalis crops (average for 2020–2022)

Culture	Sowing time	Plant density, pcs./m ²		Field germination, %	Viability, %	Weed infestation, pcs./m ²	
		during the sprouting period	before harvesting			during the sprouting period	by the end of the growing season
Wild chamomile	May 15	33	31	57	93	109	7
	June 15	36	34	63	94	73	5
	July 15	41	39	70	96	33	3
Calendula officinalis	May 15	64	61	69	95	96	5
	June 15	69	66	73	96	75	4
	July 15	74	73	78	98	30	2

Important indicators of the yield structure of medicinal raw materials of the studied crops are the plant density per unit area and the weight of inflorescences. In wild chamomile, in sowing carried out on May 15, with a plant density of 31 pcs/m², the fresh weight of inflorescences was 820 g/m²; in sowing carried out on June 15, the values of these indicators were 34 pcs/m² and 960 g/m²; in sowing carried out on July 15 – 39 pcs/m² (of which flowering – 16 pcs/m², or 40%) and 277 g/m². For calendula officinalis, the presented indicators were 61 pcs/m² and 980 g/m²; 66 pcs/m² and 1030 g/m²; 73 pcs/m² (of which flowering – 44 pcs/m², or 60%) and 383 g/m², respectively. The diameter of the flowering heads of wild chamomile, depending on the declared sowing dates, was 3.9; 3.7; 2.9 cm, for calendula officinalis – 7.6; 7.3; 5.7 cm.

It was found that, under the prevailing growing season conditions, wild chamomile and calendula officinalis achieved maximum produc-

tivity when sown on May 15 and June 15: fresh weight of 8.20–9.60 and 9.80–10.30 t/ha, dry weight of 1.37–1.49 and 1.80–1.87 t/ha, thousand-seed weight of 0.089–0.090 and 13.9–14.0 g, and seed yield of 0.15–0.16 and 0.40–0.41 t/ha, respectively (see Table 4).

In the sowings carried out on July 15, a decrease in the yield of medicinal raw materials was observed: for wild chamomile, the raw mass decreased by 5.43–6.83 t/ha (66.2–77.1%), the dry mass – by 0.95–1.11 t/ha (69.3–74.5%), for calendula officinalis, the raw mass decreased by 5.97–6.47 t/ha (60.9–62.8%), the dry mass – by 1.20–1.27 t/ha (66.7–67.9%). Seeds in the July sowings of wild chamomile and calendula officinalis did not form.

On average, over the years of study, the highest yield of medicinal raw materials of wild chamomile was obtained at a plant density of 31–34 plants/m², and calendula officinalis – 61–66 plants/m². A close positive correlation was noted between the yield and plant height ($r = 0,87$).

Табл. 3. Высота и облиственность растений ромашки аптечной и календулы лекарственной (среднее за 2020–2022 гг.)

Table 3. Height and foliage of medicinal plants of wild chamomile and calendula officinalis (average for 2020–2022)

Culture	Height, cm			Foliage, %		
	May 15	June 15	July 15	May 15	June 15	July 15
Wild chamomile	89	95	34	57	59	65
Calendula officinalis	82	84	44	52	55	62

Табл. 4. Урожайность лекарственного сырья и семян ромашки аптечной и календулы лекарственной (среднее за 2020–2022 гг.)

Table 4. Yields of medicinal raw materials and seeds of wild chamomile and calendula officinalis (average for 2020–2022)

Culture	Sowing time	Yield, t/ha			Weight of 1000 seeds, g
		raw mass	dry mass	seeds	
Wild chamomile	May 15	8,20	1,37	0,16	0,090
	June 15	9,60	1,49	0,15	0,089
	July 15	2,77	0,38	–	–
LSD ₀₅		1,41	0,16		
Calendula officinalis	May 15	9,80	1,80	0,41	14,00
	June 15	10,30	1,87	0,40	13,90
	July 15	3,83	0,60	–	–
LSD ₀₅		0,89	0,15		

CONCLUSIONS

1. The natural and climatic conditions of the Trans-Baikal Territory correspond to the biological requirements of wild chamomile and calendula officinalis and, if optimal agricultural cultivation methods are observed, allow for the formation of high yields of medicinal raw materials and seeds.

2. Based on the results of the study, it was established that the optimal time for sowing wild chamomile and calendula officinalis in the forest-steppe zone of the Trans-Baikal Territory is the period from May 15 to June 15. When sowing during the specified period, the highest yield of medicinal raw materials and seeds was recorded: for wild chamomile, raw mass is 8.20–9.60 t / ha, dry mass - 1.37–1.49 t / ha, seeds - 0.15–0.16 t / ha, for calendula officinalis - 9.80–10.30; 1.80–1.87; 0.40–0.41 t / ha, respectively.

3. The duration of the transitional phases of medicinal plants at the specified sowing times was:

– for wild chamomile: from sowing to seedlings – 18–23 days, from seedlings to budding – 33–34 days, from seedlings to flowering – 52–54 days, from seedlings to seed maturation – 82–86 days;

– for calendula officinalis – 18–24; 20–22; 47–50 and 72–75 days respectively.

4. By the time of harvest, the height of wild chamomile plants was 89–95 cm, foliage – 57–

59%, calendula officinalis – 82–84 cm and 52–55% respectively.

5. It has been found that wild chamomile and Calendula officinalis are resistant to drought and lodging, as well as to diseases and pests in the forest-steppe zone of Transbaikalia.

СПИСОК ЛИТЕРАТУРЫ

1. Аникина А.Ю., Басалаева И.В., Бушковская Л.М., Быкова О.В., Грязнов М.Ю. Лекарственные и эфиромасличные культуры: особенности возделывания на территории Российской Федерации: монография. М., 2021. 256 с.
2. Цицилин А.Н. Необходимость и важность применения САСР в России при получении лекарственного сырья // Фармация. 2018. Т. 67. № 4. С. 13–17.
3. Кайшев В.Г., Лукин Н.Д., Серегин С.Н., Корниенко А.В. Рынок инулина в России: возможности развития сырьевой базы и необходимые ресурсы для создания современного отечественного производства // Пищевая промышленность. 2018. № 5. С. 8–17.
4. Кошелева Е.Д., Орлова Е.Е. Влияние условий выращивания на проявление декоративных признаков календулы лекарственной (*Calendula officinalis* L.) в условиях г. Москвы // Вестник ландшафтной архитектуры. 2022. № 29. С. 36–41.
5. Кузьменко И.Н., Колясникова Н.Л. Особенности семенной продуктивности *Calendula*

- officinalis* L. (Asteraceae) в Предуралье // Известия высших учебных заведений. Поволжский регион. Естественные науки. 2021. № 3. С. 45–55.
6. Кузьменко И.Н., Колясникова Н.Л. Фертильность и особенности формирования соцветий календулы лекарственной (*Calendula officinalis* L.) в условиях Предуралья // Пермский аграрный вестник. 2020. № 1. С. 45–51.
7. Гущина В.А. Сырьевая продуктивность календулы лекарственной в лесостепи Среднего Поволжья // Нива Поволжья. 2021. № 4. С. 65–73.
8. Загозулько Е.Ю., Ожигова М.Г. Подходы к стандартизации цветков ромашки аптечной (*Chamomillae recutita flores*) в российской и зарубежных фармакопеях // Фармация и фармакология. 2017. Т. 5. № 2. С. 135–149.
9. Олимова Н.Т., Сафаров А.К. Рост, развитие и продуктивность ромашки аптечной в условиях культуры // Вестник магистратуры. 2022. № 4-4 (127). С. 9–10.
10. Такаева М.А., Астарханова Т.С. Особенности технологии возделывания ромашки аптечной на черноземах обыкновенных Чеченской Республики // Известия Дагестанского государственного аграрного университета. 2023. № 2. С. 22–30.
11. Андреева О.Т. Влияние сроков посева на фенологическое развитие и урожайность лекарственных культур в Забайкалье // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 11. С. 23–31.
12. Савельева Л.Н., Бондарчук М.Л. Влияние фитобиотических препаратов на морфохимические показатели крови телят при диспепсии // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 5. С. 98–104.
1. Anikina A.Yu., Basalaeva I.V., Bushkovskaya L.M., Bykova O.V., Gryaznov M.Yu. *Medicinal and essential oil crops: features of cultivation in the territory of the Russian Federation*. Moscow, 2021, 256 p. (In Russian).
2. Tsitsilin A.N. The need and importance of applying GACP for crude drugs in Russia. *Pharmatsiya = Pharmacy*, 2018, vol. 67, no. 4, pp. 13–17. (In Russian).
3. Kaishev V.G., Lukin N.D., Seregin S.N., Kornienko A.V. Inulin market in Russia: possibilities of raw materials base development and necessary resources for creation of modern domestic production. *Pishchevaya promyshlennost' = Food Industry*, 2018, no. 5, pp. 8–17. (In Russian).
4. Kosheleva E.D., Orlova E.E. The influence of growing conditions on the manifestation of ornamental features of *Calendula officinalis* L. in Moscow. *Vestnik landshavtnoy arkhitektury = Bulletin of Landscape Architecture*, 2022, no. 29, pp. 36–41. (In Russian).
5. Kuzmenko I.N., Kolyasnikova N.L. The features of seed productivity of *Calendula officinalis* L. (Asteraceae) in the Preduralye region. *Izvestiya vysshikh uchebnykh zavedenij. Povolzhskij region. Estestvennye nauki = University proceedings. Volga region. Natural sciences*, 2021, no. 3, pp. 45–55. (In Russian).
6. Kuzmenko I.N., Kolyasnikova N.L. Fertility and peculiarities of formation of inflorescences of *Calendula officinalis* L. in the conditions of the Predurals. *Permskiy agrarniy vestnik = Perm Agrarian Journal*, 2020, no. 1, pp. 45–51. (In Russian).
7. Gushchina V.A. Raw material productivity of calendula officinalis in the forest-steppe of the Middle Volga region. *Niva Povolzh'ya = Volga Region Farmland*, 2021, no. 4, pp. 65–73. (In Russian).
8. Zagozulko E.Yu., Ozhigova M.G. Approaches to the standardization of chamomile flowers (*Chamomillae recutita flores*) in the Russian and foreign pharmacopoeias. *Pharmatsiya i farmakologiya = Pharmacy and Pharmacology*, 2017, vol. 5, no. 2, pp. 135–149. (In Russian).
9. Olimova N.T., Safarov A.K. Growth, development and productivity of chamomile under cultural conditions. *Vestnik magistratury = The Magistrate's Bulletin*, 2022, no. 4-4 (127), pp. 9–10. (In Russian).
10. Takaeva M.A., Astarkhanova T.S. Features of the technology of cultivation of chamomile on the common chernozem of the Chechen Republic. *Izvestiya Dagestanskogo GAU = Daghestan GAU Proceedings*, 2023, no. 2, pp. 22–30. (In Russian).
11. Andreeva O.T. Influence of sowing dates on the phenological development and yield of medicinal crops in Transbaikalia. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 11, pp. 23–31. (In Russian).
12. Savelyeva L.N., Bondarchuk M.L. The effect of phyto-biotic preparations on morphochemical blood parameters of calves with dyspepsia. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2022, vol. 52, no. 5, pp. 98–104. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРЕ

✉ **Андреева Ольга Терентьевна**, ведущий научный сотрудник, кандидат сельскохозяйственных наук, старший научный сотрудник; SPIN-код 4314-5028; **адрес для переписки:** Россия, 672010, Чита, ул. Кирова, 49, а/я 470; e-mail: frau.olgaa2015@yandex.ru

AUTHOR INFORMATION

✉ **Olga T. Andreeva**, Lead Researcher, Candidate of Science in Agriculture, Senior Researcher; SPIN-code 4314-5028; **address:** PO BOX 470, 49, Kirova St., Chita, 672010, Russia; e-mail: frau.olgaa2015@yandex.ru

Дата поступления статьи / Received by the editors 23.09.2025

Дата принятия к публикации / Accepted for publication 26.11.2025

Дата публикации / Published 10.02.2026



Сезонная динамика лёта доминирующих чешуекрылых вредителей в современных садах

✉ Васильченко А.В., Прах С.В., Подгорная М.Е.

Северо-Кавказский федеральный научный центр садоводства, виноградарства, виноделия
Краснодар, Россия

✉ e-mail: anfisaVV@yandex.ru

Под влиянием ряда факторов в плодовых агроценозах происходят изменения, проявляющиеся в естественных эволюционных процессах динамики видового и количественного состава фитофагов, их вредоносности и биологии развития. Наибольшее влияние на формирование комплексов насекомых-вредителей оказывают сдвиги в климатической системе, нарастание темпов глобального потепления, увеличение волн экстремально высоких температур и их повторяемость, рост количества опасных метеорологических явлений. Мониторинг многолетних плодовых насаждений показывает изменения в формировании и особенностях развития комплекса чешуекрылых. Ежегодно в течение всего вегетационного сезона в садовых агроценозах Краснодарского края отмечаются следующие симпатричные виды: яблонная (*Cydia pomonella* L.), сливовая (*Grapholitha funebrana* Mats.) и восточная плодожорка (*Grapholita molesta* Busck) из семейства Tortricidae, а также двуполосая огневка-плодожорка (*Euzophera bigella* Zeller) из семейства Pyralidae, обитающие в агроценозе на протяжении всей вегетации. Установлено, что разный температурный режим и относительная влажность воздуха в весенний период влияют на характер динамики вылета особей перезимовавшего поколения. Особенность в лёте *C. pomonella*, *G. funebrana*, *G. molesta* – многочисленные пики, что свидетельствует о неравномерном выходе особей в агроценозе сада в начале вегетации. В результате мониторинга плодовых насаждений отмечено существенное различие (по зонам садоводства и годам) в сроках вылета бабочек перезимовавшего поколения – разница составляет от 5 до 12 дней. Выявлено, что неустойчивая весенняя погода способствует неравномерному и растянутому вылету имаго перезимовавшего поколения. Продление вегетационного периода на месяц в 2023 и 2024 гг. увеличило продолжительность лёта чешуекрылых фитофагов. Изучение сезонной динамики лёта чешуекрылых вредителей показало, что в Краснодарском крае доминирующие виды развиваются в нескольких генерациях: *C. pomonella* и *G. funebrana* – по три поколения, *E. bigella* – четыре, *G. molesta* – пять.

Ключевые слова: чешуекрылые, доминирующие вредители, плодовые насаждения, температурный режим, генерация

Seasonal flight dynamics of dominant Lepidoptera pests in modern gardens

✉ Vasilchenko A.V., Prach S.V., Podgornaya M.E.

North Caucasian Federal Scientific Center of Horticulture, Viticulture, Wine-making
Krasnodar, Russia

✉ e-mail: anfisaVV@yandex.ru

Under the influence of a number of factors, changes occur in fruit agroecosystems that manifest themselves in the natural evolutionary processes of the dynamics of the species and quantitative composition of phytophages, their harmfulness and developmental biology. The greatest impact on the formation of the complexes of harmful species is exerted by the shifts in the climate system, an increase in global warming, an increase in the waves of extremely high temperatures and their recurrence, and an increase in dangerous meteorological phenomena. Monitoring of perennial plantations shows changes in the formation and development features of the Lepidoptera complex. Every year, during the entire

growing season, sympatric species are observed in the garden agrocenoses of the Krasnodar Territory: apple *Cydia pomonella* L., plum *Grapholitha funebrana* Mats., oriental codling moth *Grapholitha molesta* Busck (fam. Tortricidae) and the double-banded pyralid moth *Euzophera bigella* Zeller (fam. Pyralidae), which live in the cenosis throughout the growing season. It has been established that different temperature conditions and relative air humidity in the spring period influence the nature of the dynamics of the emergence of individuals of the overwintered generation. A distinctive feature in the flight of *C. pomonella*, *G. funebrana*, *G. molesta* is numerous peaks, which indicates an uneven yield of individuals in the agrocenosis of the orchard at the beginning of the growing season. As a result of monitoring fruit plantations, significant differences have been noted (across horticultural zones and years) in the timing of the emergence of butterflies of the overwintered generation – the difference ranges from 5 to 12 days. It has been revealed that the spring period unstable weather contributes to uneven and extended the emergence of the imago of the overwintered generation. The extension of the growing season by a month in 2023 and 2024 increased the flight duration of Lepidoptera phytophages. A study of the seasonal flight dynamics of Lepidoptera pests showed that dominant species develop in several generations in the Krasnodar Territory: *C. pomonella* and *G. funebrana* have three generations each, *E. bigella* has four, and *G. molesta* has five.

Keywords: Lepidoptera, dominant pests, fruit and berry plantations, temperature conditions, generation

Для цитирования: Васильченко А.В., Прах С.В., Подгорная М.Е. Сезонная динамика лёта доминирующих чешуекрылых вредителей в современных садах // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 64–71. <https://doi.org/10.26898/0370-8799-2026-1-7>

For citation: Vasilchenko A.V., Prach S.V., Podgornaya M.E. Seasonal flight dynamics of dominant Lepidoptera pests in modern gardens. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 64–71. <https://doi.org/10.26898/0370-8799-2026-1-7>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

Благодарность

Работа выполнена при поддержке Министерства науки и высшего образования Российской Федерации в рамках государственного задания ФГБНУ «Северо-Кавказский федеральный научный центр садоводства, виноградарства, виноделия» (тема № 0498-2023-0005).

Авторы благодарят рецензентов за их вклад в экспертную оценку работы.

Acknowledgements

The work was carried out with the support of the Ministry of Science and Higher Education of the Russian Federation within the framework of the state assignment of the FSBSI "North Caucasian Federal Scientific Center of Horticulture, Viticulture, Wine-making" (theme No. 0498-2023-0005).

The authors thank the reviewers for their contribution to the peer review of the work.

INTRODUCTION

One of the aspects determining the transformation of the structure of insect pest complexes is the change in the main climate parameters. According to Roshydromet, since the late 1970s, there has been an unprecedented disruption of the climate balance¹. The last two years have been marked as the warmest in the Southern Federal District in the entire history of observations. In 2024, new daily maximum temperatures were recorded in the Krasnodar Territory. The summer

average monthly temperatures, as well as November and December, were extremely warm. The average annual air temperature anomaly in the spring of 2023 was +1.77 °C, in the autumn of the same year it reached +2.38 °C, and in the summer of 2024 it was +2.07 °C. There is also a noted increase in average monthly temperatures in the region from May to September by 2.4 °C [1].

In this regard, the duration of the growing periods ($T > 5$ °C) and active growing periods ($T > 10$ °C) exceeded the long-term average (on

¹Climate Change: Information Bulletin / Roshydromet, No. 112. URL: www.global-climate-change.ru.

average by 11 and 15 days, respectively), which resulted in the extension of the growing season by a month².

Over the past decade, the frequency of extreme weather conditions recording has increased³: prolonged thaws at the beginning and middle of winter, return frosts in spring, heavy precipitation, hail, dry and hot weather in July – August with relative humidity on certain days below 30% combined with extremely high temperatures (36,8–38,2 °C).

Air temperature and precipitation significantly affect the physiology, spatial distribution, and biological characteristics of phytophagous organisms: in particular, the timing of organism appearance and their development rates^{4,5} [2, 3]. Over longer periods, the temperature regime affects the seasonality and evolutionary responses of insects^{6, 7}. Short-term daily temperature fluctuations affect the activity and survival of individuals, which has a decisive impact on the dynamics of the flight intensity of Lepidoptera. Insects' response to extreme temperatures over a short period of time may be an important factor in population development and, consequently, in abundance and geographical distribution over longer time periods (see footnote 6) [4, 5].

Reactions of the type to extreme temperatures are recorded in phenological modeling of the consequences of climate change [6–8]. Changes in the dynamics of phytophage development appear after prior exposure to sublethal temperatures and, possibly, in anticipation of extreme environmental conditions [9], allowing insects to survive in conditions that may be lethal or significantly reduce population numbers. Individu-

als unable to increase thermal tolerance through rapid plastic responses exhibit higher mortality during subsequent exposure to extreme temperatures [10].

The purpose of the study is to investigate the seasonal dynamics of flight and the developmental characteristics of dominant pest species of the order Lepidoptera in fruit plantations in the territory of the Krasnodar Territory under the influence of biotic, abiotic, and anthropogenic factors.

MATERIAL AND METHODS

The research was conducted in 2023 and 2024 in industrial orchards located in the Black Sea, Prikubanskaya Central, and Prikubanskaya Floodplain gardening zones of the Krasnodar Territory.

Objects of study are the agroecosystems of apple, plum, and cherry plum, as well as lepidopteran pests (representatives of the order Lepidoptera).

In the course of work, the method of phytosanitary monitoring was applied according to the generally accepted standard methods. The dynamics and intensity of the flight of lepidopteran pests were determined using 'Delta' pheromone traps (OOO 'Pheromone', Russia). During the spring period, counts of overwintering caterpillars and lepidopteran pupae were carried out. From the flowering phase, the onset and dynamics of butterfly flight were recorded by setting up pheromone traps. During fruit growth, the damage to harvested fruits and fallen fruits, the presence of carpophagous insects, and the species and age composition of the insects were monitored⁸⁻¹⁰.

²Report on the climate characteristics in the territory of the Russian Federation for 2023 / Roshydromet, Moscow, 2024, 104 p.

³Third assessment report on climate change and its impacts on the Russian Federation. general Summary / Roshydromet. St. Petersburg, 2022, 124 p.

⁴Crozier L. Winter warming facilitates range expansion: cold tolerance of the butterfly *Atalopedes campestris* // *Oecologia*. 2003, N 135 (4), p. 648.

⁵Rosenzweig C., Iglesias A., Yang X.B., Epstein P.R., Chivian E. Climate change and extreme weather events // *Global Change & Human Health*, 2001, N 2 (2), pp. 90–104.

⁶Bale J.S. Insects and low temperatures: from molecular biology to distributions and abundance // *Philosophical Transactions of the Royal Society B*, 2002, N 357, pp. 849–862.

⁷Chown S.L., Nicholson S.W. *Insect Physiological Ecology: Mechanisms and Patterns*, New York, 2004, 237 p.

⁸Phytosanitary and toxicological monitoring in orchards and berry fields. Krasnodar, 2002, 57 p.

⁹Methodological and analytical support for horticultural research. Krasnodar, 2010, 300 p.

¹⁰Experimental methods and guidelines of the North Caucasian Zonal Research Institute of Horticulture and Viticulture. Krasnodar, 2002, pp. 143–176.

RESULTS AND DISCUSSION

Annually, throughout the entire growing season, the following sympatric species are observed in the garden agrocenoses of the Krasnodar Territory: codling moth (*Cydia pomonella* L.), plum moth (*Grapholitha funebrana* Mats.) and oriental codling moth (*Grapholitha molesta* Busck) from the family Tortricidae, as well as double-banded pyralid seedworm (*Euzophera bigella* Zeller) from the family Pyralidae. The study of the development of the lepidopteran complex showed that these species are dominant, characterized by high abundance and harmfulness (see Fig. 1).

Double-banded pyralid seedworm has been recorded in the Krasnodar Territory since the late 1990s, and since the 2000s it has been damaging pome and stone fruit crops; in apple orchards, it is the most numerous and harmful species. Without protective measures, fruit damage can reach 60% or more.

Oriental codling moth is a quarantine species whose adaptive properties have allowed it to expand its range and become a cosmopolitan, damaging a wide range of crops. In the Krasnodar Territory, *G. molesta* causes significant damage to stone fruit crops – peach, plum, cherry plum, and in the second half of the growing season, damage to apple fruits is observed (1–2%).

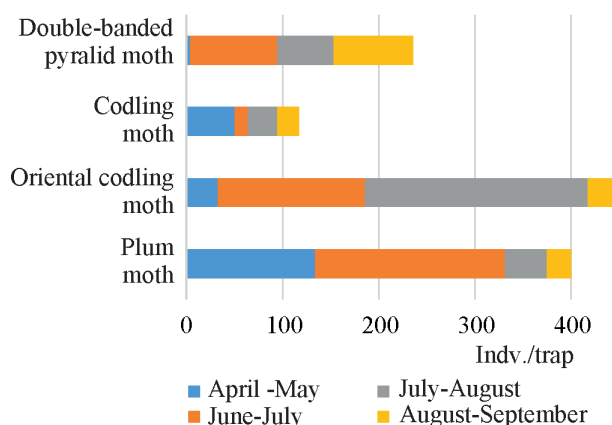


Рис. 1. Численность чешуекрылых вредителей на территории Прикубанской зоны садоводства в 2023 г.

Fig. 1. The number of the Lepidoptera pests in the Prikubanskaya horticultural zone in 2023

Plum moth is a flexible species, quite numerous in the region. Most common and harmful on stone fruit crops.

In the apple agrocenosis, the codling moth continues to remain a dangerous and economically significant pest. In recent years, the development of the species has been greatly influenced by biotic stress factors, which is manifested in fluctuations in the number and harmfulness of the insect.

Pheromone monitoring of dominant species showed changes at the onset of flight of the overwintered generation and the subsequent development of phytophages during the growing season. It was established that different temperature regimes and relative air humidity in the spring period affect the dynamics of the flight of individuals of the overwintered generation. The beginning of imago flight, depending on the gardening zone, varies in timing (from 5 to 12 days) and in the sum of effective temperatures (SET).

In 2023, a prolonged spring with periodic drops in temperature and heavy rains caused shifts in the timing of flight, the start of egg-laying, and larval emergence. The flight of *C. pomonella* butterflies of the overwintered generation was observed when the SET reached 101–123 °C, with the main flight occurring when this value reached 120–140 °C and above (see Fig. 2, a).

In recent years, this period (April – the first half of May) in the region has been characterized by unstable weather, temperature fluctuations from 25 °C to significant drops with returning frosts, and frequent and heavy precipitation. Such conditions lead to a decrease and complete cessation of flight and, as a result, uneven and prolonged ontogenesis.

The 2024 growing season began with a shortage of precipitation and several rises in air temperature up to 30°C in April, which triggered an earlier flight of butterflies of the overwintered generation; however, the drop in temperature to below zero and periodic precipitation in the first ten-day period of May during the flowering phenophase interrupted the flight (see Fig. 2, b).

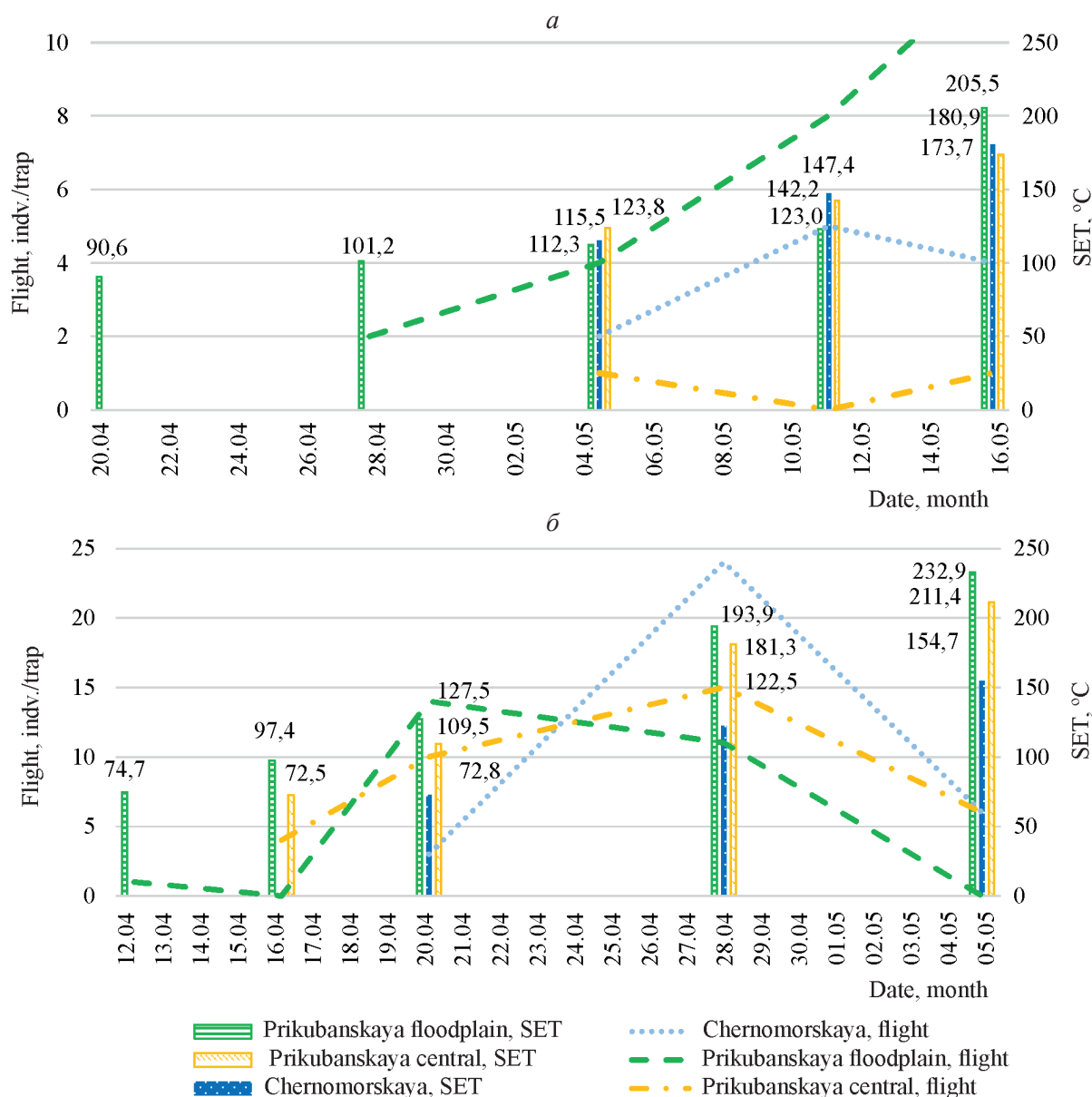


Рис. 2. Динамика начала лёта *C. pomonella* перезимовавшего поколения по зонам садоводства в 2023 (а) и 2024 гг. (б)

Fig. 2. Dynamics of the beginning of the flight of *C. pomonella* of the overwintered generation by gardening zones 2023 (a) and 2024 (b)

A similar situation is observed with the emergence of the plum moth, but with differences in the timing of emergence and the SET indicators: over several years, the appearance of the first individuals is recorded when the SET reaches 40–50 °C, and the main flight occurs at the SET above 75 °C [11].

A prolonged period of precipitation and lower temperatures in 2023 caused stress on the development of *C. pomonella*, *G. funebrana*, and

G. molesta, which in the season was manifested by a low number of individuals caught in traps, a large number of peaks, extended flight, and overlapping generations (see Fig. 3).

Dry July and August with elevated temperature backgrounds are becoming the norm for the region. In 2023, the extremely high air temperatures noted after a prolonged period of precipitation, acting as a stress factor, triggered aestivation in up to 60% of the *C. pomonella* population (see Fig. 4).

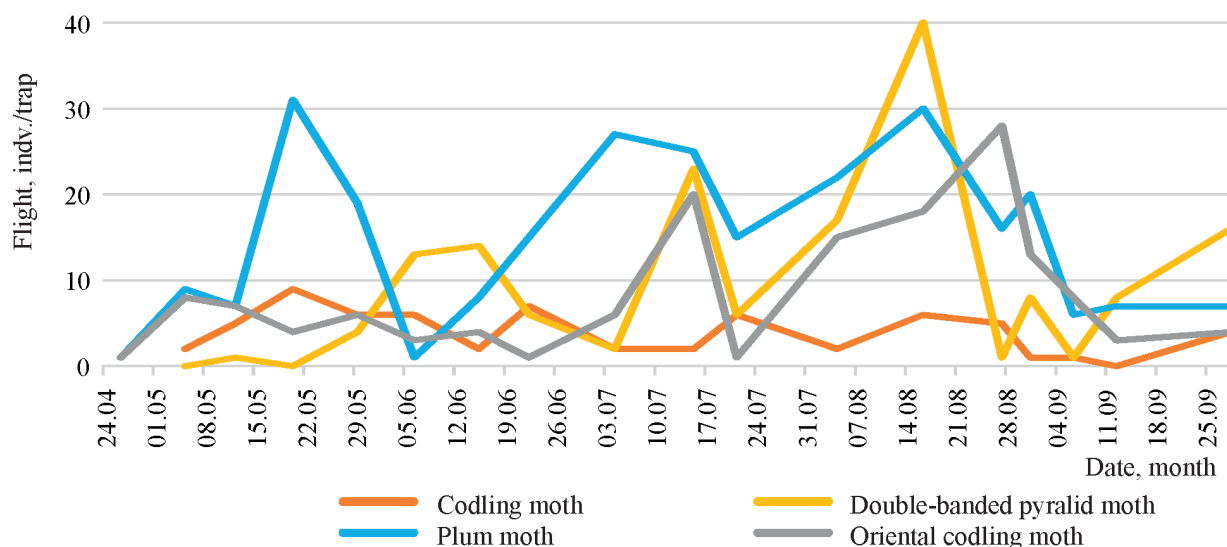


Рис. 3. Динамика лёта доминирующих чешуекрылых на территории Прикубанской плавневой зоны садоводства в 2023 г.

Fig. 3. Flight dynamics of the dominant Lepidoptera in the Prikubanskaya floodland horticultural zone in 2023

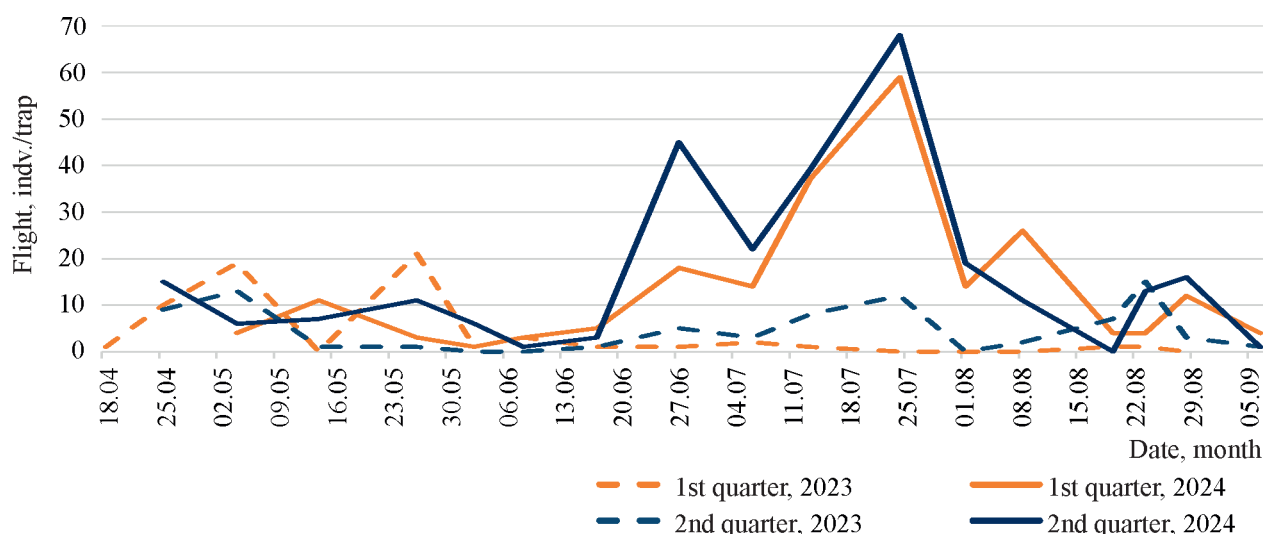


Рис. 4. Динамика лёта *C. pomonella* на территории Прикубанской центральной зоны садоводства (ЗАО «Лорис») в 2023 и 2024 гг.

Fig. 4. Flight dynamics of the *C. pomonella* on the territory of the Prikubanskaya central horticultural zone (ZAO "Loris") in 2023 and 2024

The 2024 growing season was characterized by elevated temperatures and a deficit of precipitation. The prolonged dry period with high temperatures and hazardous natural phenomena (hot dry winds, atmospheric drought), which set in from the third ten-day period of May, caused a mass emergence of *C. pomonella* individuals from estivation in the second ten-day period of June. From June to September, no distinctions

between the first and second summer generations were observed (see Fig. 4).

A distinctive feature of this period in the development of *C. pomonella*, *G. funebrana*, and *G. molesta* was the overlap of the flight of individuals emerging from estivation and the main flight of the phytophagous insects. At the same time, as a result of monitoring fruit crops, an overlap of all stages of ontogenesis was recorded.

The extension of the growing season by a month and the drop in temperatures to abnormal levels in September 2023 stimulated the resumption of lepidopteran flight. For the region, this is a dangerous period, characterized by high harmfulness of *C. pomonella*, *G. molesta*, and *E. bigella*, which damage apple fruits. In 2024, these species completed their development at the end of September.

One of the responses of living organisms to climate warming is an increase in the number of multivoltine species. Such a reaction has been observed in the plum moth – three full generations have been recorded over the past ten years [11]. The oriental codling moth in the region develops in five generations. The codling moth exhibits three full generations (for the development of one generation, the sum of effective temperatures should be 570–650 °C), and the double-banded pyralid seedworm has four generations (with a sum of effective temperatures of 450–470 °C).

CONCLUSIONS

1. It has been determined that the following carpophagous species are among those constantly recorded in the territory of the Krasnodar Territory: codling moth, plum moth, oriental codling moth and double-banded pyralid seedworm, living in the garden throughout the entire season.

2. A significant difference has been noted (by gardening zones and years) in the timing of the flight of butterflies of the overwintered generation (from 5 to 12 days).

3. It has been found that unstable weather during the spring period contributes to an uneven and prolonged emergence of imagoes of the overwintered generation and further ontogenesis.

4. It has been established that in the region the dominant species of lepidopteran pests are multivoltine: *C. pomonella* and *G. funebrana* – for three generations, *E. bigella* – four, *G. molesta* – five.

СПИСОК ЛИТЕРАТУРЫ

1. Черкезова С.Р. Влияние абиотических и антропогенных факторов на энтомо-акароценоз плодовых культур // Плодоводство и виноградарство Юга России. 2018. № 53 (5). С. 153–

165. DOI: 10.30679/2219-5335-2018-5-53-153-165.

2. Wolfe D.W., Ziska L., Petzold C., Seaman A., Hayhoe L.C. Projected change in climate thresholds in the Northeastern U.S.: Implications for crops, pests, livestock, and farmers // Mitigation and Adaptation Strategies for Global Change. 2008. N 13. P. 5–6. DOI: 10.1007/s11027-007-9125-2.
3. Trnka M., Muška F., Semerádová D., Dubrovský M., Kocmánková E., Žalud Z. European Corn Borer life stage model: Regional estimates of pest development and spatial distribution under present and future climate // Ecological Modelling. 2007. Vol. 207. Iss. 2-4. P. 61–84. DOI: 10.1016/j.ecolmodel.2007.04.014.
4. Chown S.L., Terblanche J.S. Physiological diversity in insects: ecological and evolutionary contexts // Advances in Insect Physiology. 2007. Vol. 33. P. 50–152. DOI: 10.1016/S0065-2806(06)33002-0.
5. Hoffmann A.A. Physiological climatic limits in Drosophila: patterns and implications // Journal of Experimental Biology. 2010. Vol. 213. P. 870–880. DOI: 10.1242/jeb.037630.
6. Estay S.A., Lima M., Labra F.A. Predicting insect pest status under climate change scenarios: combining experimental data and population dynamics modeling // Journal of Applied Entomology. 2009. Vol. 133. P. 491–499. DOI: 10.1111/j.1439-0418.2008.01380.x.
7. Lima E.A.B.F., Ferreira C.P., Godoy W.A.C. Ecological modelling and pest population management: a possible and necessary connection in a changing world // Neotropical Entomology. 2009. Vol. 38. P. 699–707. DOI: 10.1590/S1519-566X2009000600001.
8. Hazell S.P., Neve B.P., Groutides C., Groutides C., Douglas A.E., Blackburn T.M., Bale J.S. Hyperthermic aphids: insights into behaviour and mortality // Journal of Insect Physiology. 2010. Vol. 56. Iss. 2. P. 123–131. DOI: 10.1016/j.jinsphys.2009.08.022.
9. Terblanche J.S., Deere J.A., Clusella-Trullas S., Janion C., Chown S.L. Critical thermal limits depend on methodological context // Proceedings of the Royal Society B, Biological Sciences. 2007. Vol. 274. P. 2935–2943. DOI: 10.1098/rspb.2007.0985.
10. Terblanche J.S., Clusella-Trullas S., Deere J.A., Chown S.L. Thermal tolerance in a south-east African population of tsetse fly *Glossina pallidipes* (Diptera: Glossinidae): implications for forecasting climate change impacts // Journal of Insect Physiology. 2008. Vol. 54. Iss. 2. P. 14–127. DOI: 10.1016/j.jinsphys.2007.08.007.
11. Васильченко А.В., Прах С.В., Подгорная М.Е. Изучение особенностей развития сливовой плодовой Grapholita funebrana Tr.

(Lepidoptera: Tortricidae) в изменяющихся климатических условиях Краснодарского края // Известия Тимирязевской сельскохозяйственной академии. 2023. № 2. С. 55–65. DOI: 10.26897/0021-342X-2023-2-55-65.

REFERENCES

1. Cherkezova S.R. Influence of abiotic and anthropogenic factors on the entomo-akarocenosis of fruit crops. *Plodovodstvo i vinogradarstvo Yuga Rossii = Fruit growing and viticulture of South Russia*, 2018, no. 53 (5), pp. 153–165. (In Russian). DOI: 10.30679/2219-5335-2018-5-53-153-165.
2. Wolfe D.W., Ziska L., Petzold C., Seaman A., Hayhoe L.C. Projected change in climate thresholds in the Northeastern U.S.: Implications for crops, pests, livestock, and farmers. *Mitigation and Adaptation Strategies for Global Change*, 2008, no. 13, pp. 5–6. DOI: 10.1007/s11027-007-9125-2.
3. Trnka M., Muška F., Semerádová D., Dubrovský M., Kocmánková E., Žalud Z. European Corn Borer life stage model: Regional estimates of pest development and spatial distribution under present and future climate. *Ecological Modelling*, 2007, vol. 207, iss. 2-4, pp. 61–84. DOI: 10.1016/j.ecolmodel.2007.04.014.
4. Chown S.L., Terblanche J.S. Physiological diversity in insects: ecological and evolutionary contexts. *Advances in Insect Physiology*, 2007, vol. 33, pp. 50–152. DOI: 10.1016/S0065-2806(06)33002-0.
5. Hoffmann A.A. Physiological climatic limits in *Drosophila*: patterns and implications. *Journal of Experimental Biology*, 2010, vol. 213, pp. 870–880. DOI: 10.1242/jeb.037630.
6. Estay S.A., Lima M., Labra F.A. Predicting insect pest status under climate change scenarios: combining experimental data and population dynamics modeling. *Journal of Applied Entomology*, 2009, vol. 133, pp. 491–499. DOI: 10.1111/j.1439-0418.2008.01380.x.
7. Lima E.A.B.F., Ferreira C.P., Godoy W.A.C. Ecological modelling and pest population management: a possible and necessary connection in a changing world. *Neotropical Entomology*, 2009, vol. 38, pp. 699–707. DOI: 10.1590/S1519-566X2009000600001.
8. Hazell S.P., Neve B.P., Grootides C., Grootides C., Douglas A.E., Blackburn T.M., Bale J.S. Hyperthermic aphids: insights into behaviour and mortality. *Journal of Insect Physiology*, 2010, vol. 56, iss. 2, pp. 123–131. DOI: 10.1016/j.jinsphys.2009.08.022.
9. Terblanche J.S., Deere J.A., Clusella-Trullas S., Janion C., Chown S.L. Critical thermal limits depend on methodological context. *Proceedings of the Royal Society B, Biological Sciences*, 2007, vol. 274, pp. 2935–2943. DOI: 10.1098/rspb.2007.0985.
10. Terblanche J.S., Clusella-Trullas S., Deere J.A., Chown S.L. Thermal tolerance in a south-east African population of tsetse fly *Glossina pallidipes* (Diptera: Glossinidae): implications for forecasting climate change impacts. *Journal of Insect Physiology*, 2008, vol. 54, iss. 2, pp. 14–127. DOI: 10.1016/j.jinsphys.2007.08.007.
11. Vasilchenko A.V., Prakh S.V., Podgornaya M.E. Study of the development of the plum moth features *Grapholita funebrana* Tr. (Lepidoptera: Tortricidae) in changing climatic conditions of the Krasnodar territory. *Izvestiya Timiryazevskoy sel'skokhozyaystvennoy akademii = Izvestiya of Timiryazev Agricultural Academy*, 2023, no. 2, pp. 55–65. (In Russian). DOI: 10.26897/0021-342X-2023-2-55-65.

ИНФОРМАЦИЯ ОБ АВТОРАХ

✉ **Васильченко Анфиса Витальевна**, младший научный сотрудник; SPIN-код 6853-1941, ORCID 0000-0001-7680-7511; **адрес для переписки:** Россия, 350901, Краснодар, ул. 40-летия Победы, 39; e-mail: anfisaVV@yandex.ru

Прах Светлана Владимировна, старший научный сотрудник, кандидат биологических наук; SPIN-код 3652-3020, ORCID 0000-0001-6416-3798

Подгорная Марина Ефимовна, заведующая лабораторией, кандидат биологических наук; SPIN-код 6686-9037, ORCID 0000-0002-2268-1279

AUTHOR INFORMATION

✉ **Anfisa V. Vasilchenko**, Junior Researcher; SPIN-code 6853-1941, ORCID 0000-0001-7680-7511; **address:** 39, 40-letiya Pobedy St., Krasnodar, 350901, Russia; e-mail: anfisaVV@yandex.ru

Svetlana V. Prach, Senior Researcher, Candidate of Science in Biology; SPIN-code 3652-3020, ORCID 0000-0001-6416-3798

Marina E. Podgornaya, Laboratory Head, Candidate of Science in Biology; SPIN-code 6686-9037, ORCID 0000-0002-2268-1279

Дата поступления статьи / Received by the editors 04.08.2025
Дата принятия к публикации / Accepted for publication 31.10.2025
Дата публикации / Published 10.02.2026

Распространение *Cephalophilon nepalense* (Polygonaceae) и *Rorippa sylvestris* (Brassicaceae) в агроценозах юга Приморского края

Федина Л.А., (✉)Маркова Т.О., Маслов М.В.

Федеральный научный центр биоразнообразия наземной биоты Восточной Азии
Дальневосточного отделения Российской академии наук
Владивосток, Россия
(✉)e-mail: martania@mail.ru

В статье приведены сведения о сорных растениях семейства Гречишные (Polygonaceae Juss.) и Капустовые (Brassicaceae Burnett) – головокочетник непальский (*Cephalophilon nepalense* (Meissn.) Tzvel.) и жерушник лесной (*Rorippa sylvestris* (L.) Bess.). Цель исследования – обобщить современные данные о распространении указанных видов растений в агроценозах Приморского края. Полевые исследования выполнены в 2018–2024 гг. на территории городских и сельских поселений. Использован метод маршрутного обследования, проанализированы литературные данные, информация из интернет-ресурсов. Проведен анализ гербарных образцов *C. nepalense* и *R. sylvestris* (VLA, VBG, MW, MHA, LE), отобранных на территории российского Дальнего Востока. Осуществлены фенологические наблюдения, произведены сбор и определение гербарного материала, фотографирование объектов из мест произрастания. Гербарные образцы переданы в региональные фонды: Федеральный научный центр биоразнообразия наземной биоты Восточной Азии ДВО РАН (VLA), Ботанический сад-институт ДВО РАН (VBG). Согласно полученным данным, *C. nepalense* и *R. sylvestris* в настоящее время прочно вошли в группу сорных и заселили агроценозы юга Приморского края, в том числе огородные участки. *C. nepalense* в числе некоторых других растений семейства Polygonaceae обнаружен в большинстве административно-территориальных районов региона и активно расселяется по антропогенно трансформированным участкам. Предлагаем внести этот вид в список сорных растений Приморского края. *R. sylvestris* стал обычным видом на огородных участках частных хозяйств.

Ключевые слова: *Cephalophilon nepalense*, *Rorippa sylvestris*, сорные растения, агроценозы, Уссурийский городской округ, Приморский край

Distribution of *Cephalophilon nepalense* (Polygonaceae) and *Rorippa sylvestris* (Brassicaceae) in agrocenoses of the south of the Primorsky Territory

Fedina L.A., (✉)Markova T.O., Maslov M.V.

Federal Scientific Center of the East Asia Terrestrial Biodiversity of the Far Eastern Branch of the Russian Academy of Sciences
Vladivostok, Russia
(✉)e-mail: martania@mail.ru

Information is provided on the weeds of the Buckwheat (Polygonaceae Juss.) and Cabbage (Brassicaceae Burnett) families – persicaria nepalensis (*Cephalophilon nepalense* (Meissn.) Tzvel.) and yellow field cress (*Rorippa sylvestris* (L.) Bess.). The purpose of the study is to summarize modern data on the distribution of the indicated plant species in the agrocenoses of the Primorsky Territory. Field research was conducted between 2018 and 2024 in urban and rural settlements. A route survey method was used, and literature and online information were analyzed. The analysis of herbarium specimens of *C. nepalense* and *R. sylvestris* (VLA, VBG, MW, MHA, LE) collected in the Russian Far East was carried out. Phenological observations were carried out, herbarium material was collected and identified, and objects from the vegetation areas were photographed. Herbarium specimens were transferred to the regional funds: the Federal Scientific Center of the East Asia Terrestrial Biodiversity of the Far Eastern Branch of the Russian Academy of Sciences (VLA), and the Botanical Garden-Institute of the Far Eastern Branch of the Russian Academy of Sciences (VBG). According to the data obtained, *C. nepalense* and *R. sylvestris* have now firmly entered the group of weeds and have populated ag-

rocenoses in the south of the Primorsky Territory, including vegetable gardens. *C. nepalense*, along with several other plants in the Polygonaceae family, is found in most administrative districts of the region and is actively spreading through anthropogenically transformed areas. We propose adding this species to the list of weeds of the Primorsky Territory. *R. sylvestris* has become a common species in private garden plots.

Keywords: *Cephalophilon nepalense*, *Rorippa sylvestris*, weeds, agrocenoses, Ussuriysk urban district, Primorsky Territory

Для цитирования: Федина Л.А., Маркова Т.О., Маслов М.В. Распространение *Cephalophilon nepalense* (Polygonaceae) и *Rorippa sylvestris* (Brassicaceae) в агроценозах юга Приморского края // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 72–78. <https://doi.org/10.26898/0370-8799-2026-1-8>

For citation: Fedina L.A., Markova T.O., Maslov M.V. Distribution of *Cephalophilon nepalense* (Polygonaceae) and *Rorippa sylvestris* (Brassicaceae) in agrocenoses of the south of the Primorsky Territory. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 72–78. <https://doi.org/10.26898/0370-8799-2026-1-8>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

Благодарность

Работа выполнена в рамках государственного задания Министерства науки и высшего образования Российской Федерации (тема № 124012200183-8).

Acknowledgements

The research was carried out within the state assignment of the Ministry of Science and Higher Education of the Russian Federation (theme No. 124012200183-8).

INTRODUCTION

According to the existing classification, weeds are considered to be wild plants that grow alongside cultivated plants and thrive in agrocenoses (in summer cottages, gardens, and vegetable plots). Weeds reduce the yield of cultivated plants: they create a moisture deficit, actively consume nutrients from the soil, shade seedlings, have a mechanical impact, and create favorable conditions for pest reproduction.

Weeds have traditionally been the subject of observations, and in order to combat them in crops and plantings of agricultural crops, it is necessary to identify the species and know their biological characteristics [1–7]. Considering that weeds are capable of moving from one plant community to another, there is a need to monitor

them both in the fields and in other types of agrocenoses. It is known that the systematic composition and abundance of weeds depend not only on ecological factors but also on crop cultivation technologies, the extent of chemical protection use, the area of disturbed lands, and the presence of uncultivated lands, which become sources of the spread of harmful and invasive species. To date, the results of studies on the flora of weeds in the south of the Russian Far East have been summarized and published. The most aggressive of them are quarantine objects¹⁻⁴ [8–12].

The intrusion of many plant species into specially protected natural areas causes great concern. Among these is the persicaria nepalensis (*Cephalophilon nepalense* (Meissn.) Tzvel., family Polygonaceae), which was first discovered in the Ussuriysk Urban District (UUD)

¹Nikitin V.V. Geographical distribution of the most important weed plants of the USSR and their dynamics // Botanical Journal, 1979, vol. 64, N 7, pp. 943–949.

²Buch T.G., Kachura N.N., Shvydkaya V.D., Andreeva E.R. Weeds of the Primorskii Territory and their control. Vladivostok: Dalnevostochnoe Publishing House, 1981, 250 p.

³Nechaeva T.I. New data on the adventive flora of Vladivostok // Bulletin of the Main Botanical Garden, 1981, Iss. 121, pp. 54–55.

⁴Vinogradova Y.K., Antonova L.A., Darman G.F., Devyatova E.A., Kotenko O.V., Kudryavtseva E.P., Lesik (Aistova) E.V., Marchuk E.A., Nikolin E.G., Prokopenko S.V., Rubtsova T.A., Khoreva M.G., Chernyagina O.A., Chubar E.A., Sheiko V.V., Krestov P.V. Black Book of the Flora of the Far East: invasive plant species in the ecosystems of the Far Eastern Federal District. Moscow, 2021, 510 p.

on the territory of the V.L. Komarov Ussuriysk State Nature Reserve in 2008^{5,6}. The first data on the persicaria nepalensis (as a weed were published in a popular guide to the flora of the Far East⁷. Data on the yellow field cress (*Rorippa sylvestris* (L.) Bess., family Brassicaceae) as a weed plant in the agroecosystems of the Primorsky Territory is reported by us for the first time.

The aim of the study is to summarize current data on the distribution of *C. nepalense* and *R. sylvestris* in agroecosystems of the Primorsky Territory.

MATERIAL AND METHODS

Field studies were carried out in 2018–2024 in the Primorsky Territory: Gorno-Tayezhnoye village (43°41'37" N; 132°08'32" E), Kamenushka village (43°37'36" N; 132°14'49" E), Kaimanovka village (43°38'29" N; 132°15'19" E), Zarechnoye village (43°41'07" N; 132°06'34" E), the arboretum of the Gorno-Tayezhnaya station of the Far Eastern Branch of the Russian Academy of Sciences (43°41'37" N; 132°09'10" E), Ussuri State Nature Reserve (43°39'13" N; 132°25'12" E) (see Fig. 1).

The route survey method was used, literary data and information from Internet resources were analyzed. The analysis of herbarium specimens of *C. nepalense* and *R. sylvestris* was carried out, collected in the territory of the Russian Far East (Primorsky Territory): Kavalеровsky District, Kavaleroovo village (44°16'14" N; 135°03'17" E); Shkotovsky District, Anisimovka village (43°10'20" N; 132°45'22" E), Novonezhino village (43°13'21" N; 132°35'47" E); Partizansky District, Sergeevka village (43°20'35" N; 133°21'15" E); Vladivostok Urban Okrug, Vladivostok (43°06'54" N; 131°53'07" E); Russky Island (43°01'01" N; 131°54'23" E); Nakhodka Ur-

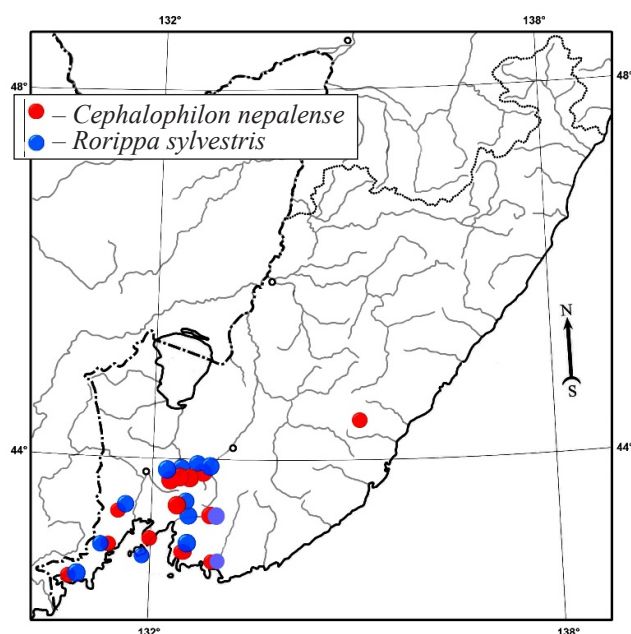


Рис. 1. Местонахождения *C. nepalense* и *R. sylvestris* в агроценозах на территории Приморского края

Fig. 1. Locations of *C. nepalense* and *R. sylvestris* in agroecosystems in the Primorsky Territory

ban Okrug, Nakhodka (42°49'00" N; 132°53'00" E); Khasansky District, Mramornaya settlement (43°19'67" N; 131°26'31" E); Krabbe Peninsula (42°38'00" N; 130°52'00" E); ZATO Fokino, the outskirts of the village of Fokino (42°58'22" N; 132°24'31" E); Kedrovaya Pad Nature Reserve (43°06'18" N; 131°30'45" E). The herbarium of the VLA (Federal Scientific Center of the East Asia Terrestrial Biodiversity of the Far Eastern Branch of the Russian Academy of Sciences), VBG (Botanical Garden-Institute, Far Eastern Branch of the Russian Academy of Sciences), MW (Moscow State University), MHA (N.V. Tsitsin Main Botanical Garden, Russian Academy of Sciences), and LE (V.L. Komarov Botanical Institute, Russian Academy of Sciences) was used. The nomenclature and volume of taxa

⁵Fedina L.A. Floristic discoveries in the Ussurisky Reserve of the Far Eastern Branch of the Russian Academy of Sciences // Bulletin of the Krasnoyarsk State Agrarian University, 2012, N 12, pp. 37–40.

⁶Fedina L.A. Additions to the flora of the Ussurisky Nature Reserve (Primorsky Territory) over ten Years (2007–2016) // Komarov Readings, 2017, Iss. 65, pp. 55–59.

⁷Vorobyov D.P., Voroshilov V.N., Gorovoy P.G., Shreter A.T. Guide to the plants of Primorye and Priamurye. M.; L.: Nauka, 1966, 490 p.

are given according to the following publications: "Vascular Plants of the Soviet Far East"^{8,9} and "Illustrated Flora of the Primorsky Territory (Russian Far East)"¹⁰.

Collection and identification of herbarium material were carried out, photographing of objects from their habitats. Herbarium specimens were transferred to regional funds (VLA, VBGI).

RESULTS AND DISCUSSION

Persicaria nepalensis –

Cephalophilon nepalense (Meissn.) Tzvel.

Brief description. Annual and biennial grass up to 40 (50) cm tall, taprooted monocarpic. Stems are erect, ascending, or prostrate, slightly fleshy. Inflorescences are terminal, consisting of 15–30 flowers, with upper leaves close to their base, with glandular hairs, head-shaped. Leaf blades lanceolate-ovate or ovate, 1–5 cm long, 0.8–2.5 cm wide, tapering at the apex, finely tuberculate along the edge (see footnote 7).

Distribution and ecology. Pan-Asian (East-Southeast Asian) species. In the Russian Federation, it has been recorded only in the south of the Far East (see notes 8, 9). It is noted for the Kurilsky Nature Reserve, where it is often found on river gravel beds, wet meadows, and roadsides. Kunashir Island – introduced species¹¹. Meadow-floodplain (near-channel) type.

Typical habitats for *C. nepalense* are sands and pebbles of riverbeds and lake valleys. It can grow as a weed in settlements, along roads and trails. It was recorded in the Kedrovaya Pad Nature Reserve (Khasansky District) in the 1980s. In 1998, it was found in the same district on the Krabbe Peninsula, in 2000 – in the agroценоses of Mramornaya village, and later it was noted in the cities of Vladivostok and Nakhodka (VBGI)¹² [13, 14].

Persicaria nepalensis was discovered in the Ussurisky Nature Reserve in 2008 (see footnotes 5, 6). According to our observations, this ornamental honey plant became a common weed in the yards of private households in the villages of the Ussuriysk Urban District from 2000 to 2020. On the iNaturalist platform, *C. nepalense* has been recorded in the UUD territory – in the villages of Gorno-Tayezhnoye (2019) and Kamenushka (2021). In 2023 and 2024, this plant was widely noted by us in garden plots in the villages of Kamenushka, Kaimanovka, Zarechnoye, Gorno-Tayezhnoye, and was found in the arboretum of the Gornotayezhnaya station of the Far Eastern Branch of the Russian Academy of Sciences (see Fig. 2). *Persicaria nepalensis* blooms from July to September and bears fruit from August to September (October).

Yellow field cress –

Rorippa sylvestris (L.) Bess.

Brief description. Annual and biennial grass up to 50 cm tall, taprooted stolon-forming monocarpic plant. Laminas are pinnately-parted or



Рис. 2. *C. nepalense* на огородном участке (с. Каймановка, Уссурийский городской округ). Фото М.В. Маслова

Fig. 2. *C. nepalense* on a garden plot (Kaymanovka, Ussuriysk urban district). Photo by M.V. Maslov

⁸Vascular plants of the Soviet Far East: in 10 vols. / Chief editor S.S. Kharkevich. Leningrad: Nauka, 1988, vol. 3, 420 p.

⁹Vascular plants of the Soviet Far East: in 10 vols. / ed. S.S. Kharkevich. Leningrad: Nauka, 1989, vol. 4, 380 p.

¹⁰Kozhevnikov A.E., Kozhevnikova Z.V., Kwak M., Lee B.Y. Illustrated flora of the Primorsky Territory (Russian Far East). Incheon, 2019, 1124 p.

¹¹Barkalov V.Yu., Eremenko N.A. Flora of the Kuril Nature Reserve and the Malye Kurily Sanctuary (Sakhalin Region). Vladivostok: Dalnauka, 2003, 285 p.

¹²Dmitrieva E.A., Chernomyrdina I.N. Species diversity of adventitious plants in Vladivostok and analysis of their life forms // Modern scientific research: current issues, achievements and innovations: collection of articles of the XII International scientific-practical conference (Penza, June 5, 2020). Penza: Science and Education, 2020, pp. 29–35.



Рис. 3. *R. sylvestris* в агроценозах Приморского края (Уссурийский городской округ):
a – садовый участок (с. Каймановка); *б* – междурядья на картофельном поле (с. Каменушка). Фото М.В. Маслова
Fig. 3. *R. sylvestris* in agrocenoses of the Primorsky Territory (Ussuriysk urban district):
a – garden plot (Kaimanovka); *б* – row spacing in a potato field (Kamenushka). Photo by M.V. Maslov

dissected, the upper ones are sessile, sometimes with little ears at the base, the lower ones are on petioles. Leaf segments are lanceolate, often dentated or lobed, the upper ones are linear and often entire. Flowers are 6–18 mm long, 1.0–1.5 mm wide, have pedicels, and are collected in terminal inflorescences (see footnote 7).

Distribution and ecology. Eurasian-Mediterranean rare introduced species (see footnote 8).

Listed for the Kedrovaya Pad Nature Reserve in 2002¹³ (VBGI, herbarium No. 164142). The appearance of this decorative, medicinal, and honey-bearing plant in the gardens of residents of the Primorsky Territory (Vladivostok, settlements of the Khasansky and Shkotovsky districts) was recorded in 1997–2002 (VBGI).

According to our data, the first reports of the discovery of *R. sylvestris* in potato plantations and other vegetable crops in the UUD territory were obtained in 2020. In 2023 and 2024, yellow field cress was observed by us not only in agricultural crop plantings but also in single numbers in roadside ditches in the villages of

Kamenuška, Kaimanovka, Zarechnoe, and Gorno-Tayozhnoye (see Fig. 3). The plant flowers from June to August, and fruits from August to September.

CONCLUSION

According to the obtained data, by 2024 *C. nepalense* and *R. sylvestris* (an epecophyte), classified as vascular plants, have firmly entered the group of weeds and have inhabited the agrocenoses of the southern Primorsky Territory, including garden plots. At present, *C. nepalense*, along with some other plants of the Polygonaceae family, has been found in most administrative-territorial districts of the region and is actively spreading in anthropogenically transformed areas. We propose to include this species in the list of weeds of the Primorsky Territory. *R. sylvestris* has become a common species in the garden plots of private households. Ruderal habitats may become a permanent source of field contamination, so for protection against weeds, their edge treatment is necessary.

¹³Korkishko R.I. Vascular plants of the Kedrovaya Pad Nature Reserve // Flora and fauna of nature reserves. Moscow, 2000, 84 p.

СПИСОК ЛИТЕРАТУРЫ

1. Лунева Н.Н. Прогноз распространения доминирующих видов сорных растений на сегетальных и рудеральных местообитаниях в агроклиматических районах Липецкой области // Агропромышленные технологии Центральной России. 2020. Вып. 2 (16). С. 84–97. DOI: 10.24888/2541-7835-2020-16-84-97.
2. Третьякова А.С., Баранова О.Г., Лунева Н.Н., Терехина Т.А., Ямалов С.М., Лебедева М.В., Хасанова Г.Р., Груданов Н.Ю. Сегетальная флора некоторых регионов России: характеристика таксономической структуры // Труды по прикладной ботанике, генетике и селекции. 2020. № 181 (2). С. 123–133. DOI: 10.30901/2227-8834-2020-2-123-133.
3. Михайлова С.И., Эбель Т.В., Шереметова С.А., Эбель А.П. Сорные растения в агроценозах и зернопродукции Кемеровской области // Вестник Красноярского государственного аграрного университета. 2022. № 6. С. 58–64. DOI: 10.36718/1819-4036-2022-6-58-64.
4. Мальшикин Н.Г. Оценка видового состава растений рудеральных и сегетальных местообитаний Аромашевского района Тюменской области // Вестник Красноярского государственного аграрного университета. 2022. № 2. С. 29–34. DOI: 10.36718/1819-4036-2022-2-29-34.
5. Гребенников А.М. Влияние гречишных сидеральных агросообществ на агрофизические свойства почвенных ресурсов Черноземной зоны // Агрохимия. 2023. № 4. С. 32–38. DOI: 10.31857/S000218812304004X.
6. Сенатор С.А., Виноградова Ю.К. Инвазионные растения России: результаты инвентаризации, особенности распространения и вопросы управления // Успехи современной биологии. 2023. Т. 143. № 4. С. 393–402. DOI: 10.31857/50042132423040099.
7. Лунева Н.Н., Закота Т.Ю. Активность сорных растений в посевах полевых культур степной зоны Краснодарского края // Сибирский вестник сельскохозяйственной науки. 2024. Т. 54. № 7. С. 45–56.
8. Fedina L.A., Kuprin A.V., Ogorodnikov E.M. *Tussilago farfara* (Asteraceae) in the south of the Far East of Russia // Russian Journal of Biological Invasions. 2021. Vol. 11. N 1. P. 88–91. DOI: 10.1134/S2075111720010038.
9. Федина Л.А., Малышева С.К. Распространение адвентивных видов *Galinsoga parviflora* и *G. quadriradiata* (Asteraceae) на юге Дальнего Востока // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 4. С. 57–63. DOI: 10.26898/0370-8799-2023-4-6.
10. Fedina L.A., Malysheva S.K., Repin E.N. About the Finding of *Lobelia inflata* L. (Lobeliaceae) and new locations of alien plant species in Primorsky krai // Russian Journal of Biological Invasions. 2024. Vol. 15. N 4. P. 670–678. DOI: 10.1134/S2075111724700528.
11. Федина Л.А., Маркова Т.О., Маслов М.В. Оценка видового состава сорных растений семейства Капустовые (Brassicaceae) рудеральных и сегетальных местообитаний Уссурийского городского округа Приморского края // Сибирский вестник сельскохозяйственной науки. 2024. Т. 54. № 5. С. 49–55. DOI: 10.26898/0370-8799-2024-5-4.
12. Дорофеев В.И., Маркова Т.О., Маслов М.В., Шмаков А.И. *Rorippa astyla* и *Rorippa neogradensis* (Cruciferae) – новые для флоры России нотовиды // Turczaninowia. 2024. Т. 27. № 4. С. 182–185. DOI: 10.14258/turczaninowia.27.4.21.
13. Прокопенко С.В. Находки адвентивных растений в Приморском крае // Бюллетень Московского общества испытателей природы. Отдел биологический. 2024. Т. 129. № 3. С. 85–86. DOI: 10.55959/MSU0027-1403-BB-2024-129-3-85-86.
14. Прокопенко С.В., Кудрявцева Е.П. Инвазионные виды растений Приморского края: дополнения и изменения к изданию «Черная книга флоры Дальнего Востока» (2021) // Комаровские чтения. 2023. Вып. 71. С. 7–69.

REFERENCES

1. Luneva N.N. Forecast of the distribution of dominant weed species in segetal and ruderal habitats in agroclimatic areas of the Lipetsk region. *Agropromyshlennye tekhnologii central'noj Rossii = Agro-industrial technologies of central Russia*, 2020, vol. 2 (16), pp. 84–97. (In Russian). DOI: 10.24888/2541-7835-2020-16-84-97.
2. Tretyakova A.S., Baranova O.G., Luneva N.N., Terekhina T.A., Yamalov S.M., Lebedeva M.V., Khasanova G.R., Grudanov N.Yu. Segetal flora of some regions of Russia: characteristics of the taxonomic structure. *Trudy po prikladnoj botanike, genetike i selekcii = Proceedings on applied botany, genetics and breeding*, 2020, no. 181 (2), pp. 123–133. (In Russian). DOI: 10.30901/2227-8834-2020-2-123-133.
3. Mikhailova S.I., Ebel T.V., Sheremetova S.A., Ebel A.P. Weeds in agrocenoses and grain pro-

- ducts of the Kemerovo region. *Vestnik Krasnoyarskogo gosudarstvennogo agrarnogo universiteta* = *Bulletin of KrasSAU*, 2022, no. 6, pp. 58–64. (In Russian). DOI: 10.36718/1819-4036-2022-6-58-64.
4. Malyshev N.G. Plants species composition evaluation in ruderal and segetal habitats of the Armashevsky district of the Tyumen region. *Vestnik Krasnoyarskogo gosudarstvennogo agrarnogo universiteta* = *Bulletin of KrasSAU*, 2022, no. 2, pp. 29–34. (In Russian). DOI: 10.36718/1819-4036-2022-2-29-34.
 5. Grebennikov A.M. Influence of buckwheat sideral agricultural communities on the agrophysical properties of soil resources of the Chernozem Zone. *Agrokhimiya* = *Agricultural Chemistry*, 2023, no. 4, pp. 32–38. (In Russian). DOI: 10.31857/S000218812304004X.
 6. Senator S.A., Vinogradova Yu.K. Invasive plants of Russia: inventory results, distribution features and management issues. *Uspekhi sovremennoy biologii* = *Advances in current biology*, 2023, vol. 143, no. 4, pp. 393–402. (In Russian). DOI: 10.31857/50042132423040099.
 7. Luneva N.N., Zakota T.Yu. Activity of weed plants in field crops in the steppe zone of the Krasnodar territory. *Sibirskij vestnik sel'skhozayajstvennoj nauki* = *Siberian Herald of Agricultural Science*, 2024, vol. 54, no. 7, pp. 45–56. (In Russian). DOI: 26898/0370-8799-2024-7-5.
 8. Fedina L.A., Kuprin A.V., Ogorodnikov E.M. *Tussilago farfara* (Asteraceae) in the south of the Far East of Russia. *Russian Journal of Biological Invasions*, 2021, vol. 11, no. 1, pp. 88–91. DOI: 10.1134/S2075111720010038.
 9. Fedina L.A., Malysheva S.K. Distribution of the adventive species *Galinsoga parviflora* and *G. quadriradiata* (Asteraceae) in the south of the Far East. *Sibirskij vestnik sel'skhozayajstvennoj nauki* = *Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 4, pp. 57–63. (In Russian). DOI: 10.26898/0370-8799-2023-4-6.
 10. Fedina L.A., Malysheva S.K., Repin E.N. About the Finding of *Lobelia inflata* L. (Lobeliaceae) and new locations of alien plant species in Primorsky krai. *Russian Journal of Biological Invasions*, 2024, vol. 15, no. 4, pp. 670–678. DOI: 10.1134/S2075111724700528.
 11. Fedina L.A., Markova T.O., Maslov M.V. Assessment of weed species composition of Cabbage family plants (Brassicaceae) of ruderal and segetal habitats of the Ussuriysk urban district of the Primorsky Territory. *Sibirskij vestnik sel'skhozayajstvennoj nauki* = *Siberian Herald of Agricultural Science*, 2024, vol. 54, no. 5, pp. 49–55. (In Russian). DOI: 10.26898/0370-8799-2024-5-4.
 12. Dorofeyev V.I., Markova T.O., Maslov M.V., Shmakov A.I. *Rorippa astyla* and *Rorippa neogradensis* (Cruciferae) are new nothospecies for the Russian flora. *Turczaninowia* = *Turczaninowia*, 2024, vol. 27, no. 4, pp. 182–185. (In Russian). DOI: 10.14258/turczaninowia.27.4.21.
 13. Prokopenko S.V. Records of alien plants in Primorsky Krai. *Byulleten' Moskovskogo obshchestva ispytatelej prirody. Otdel biologicheskij* = *Bulletin of Moscow Society of Naturalists. Biological series*, 2024, vol. 129, no. 3, pp. 85–86. (In Russian). DOI: 10.55959/MSU0027-1403-BB-2024-129-3-85-86.
 14. Prokopenko S.V., Kudryavtseva E.P. Invasive plant species of the Primorye Territory: addenda and corrigenda to «Black Book of flora of the Far East» (2021). *Komarovskie chteniya* = *V. L. Komarov Memorial Lectures*, 2023, iss. 71, pp. 7–69. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРАХ

Федина Любовь Александровна, старший научный сотрудник, кандидат биологических наук; SPIN-код 7988-6456

✉ **Маркова Татьяна Олеговна**, старший научный сотрудник, кандидат биологических наук; SPIN-код 7826-9502; **адрес для переписки:** Россия, 690022, Владивосток, пр. 100-летия Владивостока, 159; e-mail: martania@mail.ru

Маслов Михаил Вениаминович, старший научный сотрудник, кандидат биологических наук; SPIN-код 2706-2420

AUTHOR INFORMATION

Luibov A. Fedina, Senior Researcher, Candidate of Science in Biology; SPIN-code 7988-6456

✉ **Tatyana O. Markova**, Senior Researcher, Candidate of Science in Biology; SPIN-code 7826-9502; **address:** 159, 100-th anniversary of Vladivostok ave., Vladivostok, 690022, Russia; e-mail: martania@mail.ru

Mikhail V. Maslov, Senior Researcher, Candidate of Science in Biology; SPIN-code 2706-2420

Дата поступления статьи / Received by the editors 05.09.2025
Дата принятия к публикации / Accepted for publication 20.11.2025
Дата публикации / Published 10.02.2026



<https://doi.org/10.26898/0370-8799-2026-1-9>

УДК 636.5:619

Тип статьи: оригинальная

Type of article: original

Гематологический и биохимический состав крови цыплят-бройлеров при применении биологически активной добавки на фоне вакцинации

✉ Задорожная М.В., Лыско С.Б., Гофман А.А., Сунцова О.А.

Омский аграрный научный центр

Омская область, п. Морозовка, Россия

✉ e-mail: mfil2525@mail.ru

В отделе ветеринарии сельскохозяйственной птицы Омского аграрного научного центра проведено исследование по оценке влияния биологически активной добавки на основе эфирных масел на гематологические и биохимические показатели крови цыплят-бройлеров отечественного кросса на фоне вакцинации, использовавшейся в качестве модели стресс-фактора. Для проведения исследования из суточного молодняка были сформированы две группы по 70 гол. Период выращивания – с суточного до 38-дневного возраста. Представители контрольной группы получали чистую воду, а в опытной группе в первые 7 дней в воду добавляли биологически активную добавку в дозе 0,2 мл/л, с 8-го по 38-й день – в дозе 0,3 мл/л. В возрасте 9 дней проведена вакцинация клинически здоровых цыплят-бройлеров против ньюкаслской болезни живой вакциной «Ла-Сота» (интраназально, согласно схеме хозяйства). Вакцину цыплятам закапывали пипеткой поочередно в обе ноздри в объеме двух капель, при этом другую ноздрю закрывали пальцем для более глубокого попадания вакцины в носовую полость. Гематологические и биохимические исследования крови проводили за день до вакцинации, а также через 4 и 19 дней после вакцинации и по окончании опыта. Установлено, что биологически активная добавка способствовала повышению количества общего белка в сыворотке крови на 18,3–20,9%, альбуминов на 13,8–23,3%, глобулинов на 19,7–22,3%, мочевой кислоты на 4,5–6,9%, соотношения альбумин/мочевая кислота в 1,2–2,0 раза, что свидетельствует об улучшении белкового обмена в организме птицы. Кроме того, отмечено увеличение содержания эритроцитов на 13,0–37,5%, гемоглобина на 10,4–22,6%, лейкоцитов на 9,0–56,8%, что способствовало насыщению клеток крови кислородом и положительному влиянию на естественную резистентность организма цыплят.

Ключевые слова: стресс-фактор, вакцинация, биологически активная добавка, альбумины, глобулины, эритроциты, гемоглобин, цыплята-бройлеры

Hematological and biochemical composition of the blood of broiler chickens when using a biologically active supplement during vaccination

✉ Zadorozhnaya M.V., Lysko S.B., Goffman A.A., Suntsova O.A.

Omsk Agrarian Scientific Center

Morozovka village, Omsk region, Russia

✉ e-mail: mfil2525@mail.ru

The Department of Veterinary Medicine for Agricultural Poultry at the Omsk Agricultural Research Center conducted a study to evaluate the effect of a dietary supplement based on essential oils on the hematological and biochemical parameters of the blood of domestic cross broiler chickens against the background of vaccination, which was used as a model stress factor. To conduct the study, two groups of 70 heads each were formed from day-old young animals. The rearing period was from one day to

38 days of age. The control group representatives received clean water, and in the experimental group, a biologically active supplement was added to the water at a dose of 0.2 ml/l during the first 7 days, then from the 8th to the 38th day – at a dose of 0.3 ml/l. At the age of 9 days, clinically healthy broiler chickens were vaccinated against Newcastle disease with the live vaccine "La Sota" (intranasally, according to the farm's schedule). The vaccine was administered to the chickens using a pipette, one at a time, in both nostrils at a volume of two drops, while the other nostril was closed with a finger to ensure deeper penetration of the vaccine into the nasal cavity. Hematological and biochemical blood tests were performed the day before vaccination, as well as 4 and 19 days after vaccination and at the end of the experiment. It was established that the biologically active supplement contributed to an increase in the amount of total protein in the blood serum by 18.3–20.9%, albumin by 13.8–23.3%, globulin by 19.7–22.3%, uric acid by 4.5–6.9%, and the albumin/uric acid ratio by 1.2–2.0 times, which indicates an improvement in protein metabolism in the bird's body. In addition, an increase in the content of erythrocytes by 13.0–37.5%, hemoglobin by 10.4–22.6%, and leukocytes by 9.0–56.8% was noted, which contributed to the saturation of blood cells with oxygen and a positive effect on the natural resistance of the chickens' body.

Keywords: stress factor, vaccination, biologically active supplement, albumins, globulins, erythrocytes, hemoglobin, broiler chickens

Для цитирования: Задорожная М.В., Лыско С.Б., Гофман А.А., Сунцова О.А. Гематологический и биохимический состав крови цыплят-бройлеров при применении биологически активной добавки на фоне вакцинации // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 79–85. <https://doi.org/10.26898/0370-8799-2026-1-9>

For citation: Zadorozhnaya M.V., Lysko S.B., Goffman A.A., Suntsova O.A. Hematological and biochemical composition of the blood of broiler chickens when using a biologically active supplement during vaccination. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 79–85. <https://doi.org/10.26898/0370-8799-2026-1-9>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

Благодарность

Статья подготовлена при финансовой поддержке Министерства науки и высшего образования Российской Федерации в рамках проведения научно-исследовательских работ по теме FNUN-2022-0036 «Разработка различных схем применения антистрессовых препаратов с учетом их влияния на иммунологический статус и энтеробиоценоз птицы».

Acknowledgements

The article was prepared with the financial support of the Ministry of Science and Higher Education of the Russian Federation as part of research work on the topic FNUN-2022-0036 "Development of various regimens for the use of anti-stress drugs, taking into account their impact on the immunological status and enterobiocenosis of poultry".

INTRODUCTION

Raising agricultural poultry in industrial conditions is associated with numerous stress factors [1]. At the same time, the leading role is given to technological stress, which arises during regrouping, transportation, vaccination, and the like¹. Currently, at poultry farms, taking into account the epizootic situation, prophylaxis against more than 16 infections (viral, bacterial, parasitic) is carried out using a specific set of vaccines [2].

The study of the patterns of adaptation of animals' bodies to the effects of stress is one of the current problems in modern biology. Special attention is paid to protein metabolism, since an increased protein content in the blood positively affects body mass, viability, productivity, metabolism in the bird's body, including mineral metabolism, the intensity of which changes depending on the period of development [3].

Since it is not possible to completely protect a bird from stressful situations, a rather rele-

¹Sudakov K. V. Stress: Postulates, analysis from the positions of the general theory of functional systems // Pathology, Physiology, and Experimental Therapy, 1992, Iss. 4, pp. 86–93.

vant direction is the search for environmentally friendly ways to increase its stress resistance. For these purposes, preparations based on the substances capable of maximally mobilizing the body's defenses and minimizing the negative effects of stress can be used. These include the new biologically active supplement (BAS) based on essential oils "Phytogenics" (NPO "Phytogenics", Chelyabinsk). This drug has not been sufficiently studied, and data on its effect on protein metabolism in the body of broiler chickens under stress factors are lacking. Conducting biochemical and hematological studies is necessary to assess the effect of the BAS on the body of chickens during vaccination stress.

The purpose of the study is to investigate the effect of the biologically active supplement "Phytogenics" on the biochemical and hematological blood parameters of broiler chickens under stress in the context of vaccination against Newcastle disease virus.

MATERIAL AND METHODS

The study was conducted in the Department of Veterinary Science of Agricultural Poultry and in a private subsidiary farm in the Omsk region on chicks of the "Smena 9" cross. Based on live weight, one-day-old chicks were divided into a control group and an experimental group (70 heads in each). Feeding and housing conditions complied with the guidelines for working with "Smena 9" meat-type poultry cross and were the same in both groups². According to the applied technology, broiler chickens were raised on the farm on the floor with a deep, unchanging litter from one day to 38 days of age. Clean, dry (with moisture not exceeding 25%) wood shavings were used as litter, which were spread on the concrete floor in an even layer 5–7 cm high.

Chicks of the experimental group were given the drug "Phytogenics" with water, which contains cinnamon essential oils (*Cinnamomum zeylanicum*), clove (*Syzygium aromaticum*), rose-

mary (*Rosmarinus officinalis*), thyme (*Thymus vulgaris*), Indian sesame (*Sésamum indicum*) and lactic acid. At the age of 1–7 days, the drug was administered at a dose of 0.2 ml/l of water, from 8 days and older – at a dose of 0.3 ml/l. Broilers in the control group did not receive the drug. To simulate experimental stress, vaccination against Newcastle disease virus was carried out intranasally at the age of 9 days as a stress factor.

In order to study the effect of dietary supplements under stress on biochemical and hematological parameters, blood samples were collected from the subwing vein before vaccination at the age of 8 days and after it at 4, 18, and 28 days. The blood collection site was treated with alcohol. Blood was taken individually into sterile Florinsky tubes, which were pre-rinsed with saline for biochemical studies, and for hematological studies, they were treated with a 1% heparin solution [4].

Laboratory studies were conducted at the FSB-SI "Omsk Agrarian Scientific Center". The content of total protein was determined by the biuret method, albumin by the bromocresol method, and uric acid by enzymatic methods using reagent kits from Hospitex diagnostics (Italy) on a semi-automatic biochemical analyzer BS 3000 M (Sinnova Medical Science & Technology Co., Ltd, China). The number of globulins, the ratio of albumins, and uric acid were determined by calculation. Red and white blood cell counts were performed in a Goryaev chamber after preliminary dilution of the blood in erythrocyte melangers. The concentration of hemoglobin in the blood was determined by the hemichrome method using the "Olvex" kit (Olvex Diagnostikum, Russia) on an Elx800 photometer (BioTek, USA).

Experimental data were processed using the method of variational statistics ($M \pm SEM$). The significance level of differences was calculated using Student's t-test. A difference was considered statistically significant at $p < 0,05–0,001$ ³.

²Guide to working with the meat crossbreed 'Smena 9' with an autosexing maternal form: method. instructions. Sergiev Posad, 2021, 95 p.

³Lakin G.F. Biometry: a textbook. Moscow, 1973, 344 p.

RESULTS AND DISCUSSION

Biochemical and hematological indicators in the experimental group were within the physiological norm⁴. One of the factors determining the effectiveness of animals' adaptation to stress factors is considered to be blood proteins, the mobility of which reflects the degree of the organism's resource expenditure. This is due to the fact that blood proteins are closely interconnected with tissue proteins and respond very sensitively to changes in metabolic processes in the organs of birds [5, 6]. The results of protein metabolism during the use of dietary supplements against the background of immunity formation after vaccination are presented in Table 1.

Chickens receiving the drug showed a tendency toward accelerated metabolic processes. The total protein content at 8 days of age (before vaccination) in the experimental group exceeded the control by 18.3% ($p < 0,01$). During the period of antibody formation after vaccination (at 13 and 27 days of age), there was a tendency for an increase in total protein levels, while the indicators of the experimental group were 20.9% high-

er than the control group ($p < 0,01$). Moreover, this indicator at the end of the experiment (at the age of 38 days) exceeded the control values by 19.7% ($p < 0,01$). Thus, the dietary supplement contributed to the synthesis of total protein in the bodies of broiler chickens. The obtained data are consistent with the results of the studies by other scientists, who, when using a probiotic in combination with a feed additive against the background of vaccination and other stress factors, recorded an increase in the amount of total protein and a change in some protein fractions in the blood of chickens [7, 8].

It should be noted that at 8–13 days of age, the intensity of albumin synthesis decreased in both groups due to a critical period in the development of the birds caused by vaccination. In the control group, the decrease in albumin synthesis was more pronounced. Thus, their amount in the blood serum of chicks in the experimental group before vaccination exceeded that of the control by 13.8% ($p < 0,01$), at 13 days of age – на 19,4% ($p < 0,01$), at 27 days of age – на 23,3% ($p < 0,05$), at 38 days of age – на 16,2%

Табл. 1. Влияние БАД на биохимические показатели сыворотки крови после вакцинации

Table 1. The effect of dietary supplements on biochemical parameters of blood serum after vaccination

Group	Age, days	Total protein, g/l	Albumins, g/l	Uric acid, $\mu\text{mol/l}$	Albumin/uric acid, c.u.	Globulins, g/l
Control	8	$32,7 \pm 1,4$	$15,2 \pm 0,5$	$210,6 \pm 1,9$	$0,07 \pm 0,01$	$17,5 \pm 1,3$
	13	$34,9 \pm 1,3$	$11,3 \pm 0,3$	$218,7 \pm 3,1$	$0,05 \pm 0,01$	$23,6 \pm 1,3$
	27	$36,3 \pm 1,2$	$12,0 \pm 0,3$	$220,3 \pm 3,4$	$0,05 \pm 0,01$	$24,3 \pm 1,4$
	38	$37,4 \pm 0,9$	$12,9 \pm 0,6$	$220,0 \pm 2,7$	$0,06 \pm 0,01$	$24,5 \pm 1,2$
Experimental	8	$38,7 \pm 0,5^{**}$	$17,3 \pm 0,4^{**}$	$220,2 \pm 2,7^*$	$0,08 \pm 0,01$	$21,4 \pm 0,8^*$
	13	$42,2 \pm 1,4^{**}$	$13,5 \pm 0,6^{**}$	$229,9 \pm 2,9^*$	$0,06 \pm 0,01^*$	$28,7 \pm 1,6^*$
	27	$43,9 \pm 1,3^{**}$	$14,8 \pm 1,1^*$	$232,2 \pm 1,8^*$	$0,06 \pm 0,01^{**}$	$29,1 \pm 1,1^*$
	38	$44,8 \pm 1,8^{**}$	$15,0 \pm 0,5^*$	$235,2 \pm 1,6^{***}$	$0,06 \pm 0,01^{***}$	$29,8 \pm 1,7^*$

Note. In Tables 1 and 2, the differences with the control are significant at: $^*p < 0,05$; $^{**}p < 0,01$; $^{***}p < 0,001$.

⁴Vertiprakhov V.G., Grozina A.A., Karamushkina S.V., Ovchinnikova N.V., Koshcheeva M.V., Kislova I.V. Morphological and biochemical studies of blood in agricultural poultry: textbook. Blagoveshchensk, 2021, 134 p.

($p < 0,05$). Moreover, the growth rate in the experimental group for the specified period also exceeded the control by 3.3%, which indicates the influence of dietary supplements on albumin synthesis⁵ [9].

Uric acid concentrations in the experimental group before vaccination exceeded control levels by 9.6 $\mu\text{mol/l}$. At 13 and 27 days of age (the antibody formation period), this difference reached 11.2–11.9 $\mu\text{mol/l}$, with a simultaneous increase in albumin levels. The study showed that the albumin-to-uric acid ratio in the blood of chickens in both groups remained the same. This may indicate increased albumin production in the experimental group. At 38 days of age, the experimental group's albumin concentration was 16.3% higher than that of the control group, while the uric acid concentration was 6.9%. This indicates higher growth rates in the experimental group's chickens.

The obtained results are confirmed by live weight indicators: the chicks of the experimental group were 0.3% heavier compared to the control group. Thus, a higher concentration of albumin and uric acid combined with a slight but still noticeable increase in body weight indicates a stimulating effect (presumably related to the experimental conditions) on the growth of chicks in the experimental group.

In the experimental group, the level of globulins in the blood serum was significantly higher than in the control group. This difference was statistically significant throughout the observation period. In particular, on the 8th day of the chicks' life, the globulin level in the experimental group was 22.3% higher, on the 13th day – 21.6% higher, on the 27th day – 19.7% higher, and on the 38th day – 21.6% higher. The increased level of globulins in the blood serum of the experimental group chicks probably indicates an enhanced immune response. This enhancement is presumably caused by the administration of the New-

castle disease vaccine and additional immune stimulation with the supplement. In other words, the vaccine and the supplement together contributed to a more active functioning of the immune system in the experimental group chicks, which was manifested in an increased number of globulins—proteins that play a key role in the immune response. Higher globulin content indicates a more active and effective defense of the body against potential infections.

The results of hematological studies of the blood of birds from the experimental group significantly exceeded those of the control group: before vaccination, in terms of red blood cell content – by 37.5%, hemoglobin – by 22.6%, white blood cells – by 26.1%; at 13 and 27 days of age (the period of antibody formation to the virus after vaccination) in terms of red blood cell content – by 13.0–17.3%, hemoglobin – by 11.4–12.8%, white blood cells – by 9.0–56.8%; at 38 days – by 20.8, 10.4, and 32.7% respectively (see Table 2). The obtained results are consistent with the data of other researchers [10].

An increase in the number of erythrocytes indicates an enhancement of erythropoiesis, caused by the high rate of metabolic processes in growing chicks. In the blood of broilers in the experimental group, after vaccination, an increase in hemoglobin concentration was observed, which contributes to more efficient oxygen supply to tissues and organs. During the experimental period, an increase in the level of leukocytes was noted in the birds receiving the dietary supplement, which indicates a favorable reaction of the immune system. The administration of the preparation to the chicks of the experimental group stimulated the process of hematopoiesis.

In addition, throughout the entire growing period (1–38 days), the preservation of the live-stock was taken into account. This indicator in the experimental group was 100.0%, in the control group – 98.4%.

⁵Frolova O.A., Chuina D.V., Grigoryev I.V. Biochemical changes in the blood of Ross-308 chickens after vaccination against coccidiosis // Proceedings of the XIV International Scientific and Practical Conference of Young Scientists. Krasnoyarsk, 2021, vol. 1, pp. 149–153.

Табл. 2. Влияние БАД на гематологические показатели крови после вакцинации

Table 2. The effect of dietary supplements on hematological parameters of blood after vaccination

Group	Age, days	Erythrocytes, $\times 10^{12}/l$	Hemoglobin, g/l	Leukocytes, $\times 10^9/l$
Control	8	$1,6 \pm 0,1$	$100,3 \pm 4,3$	$6,5 \pm 0,8$
	13	$2,3 \pm 0,1$	$84,8 \pm 1,0$	$7,7 \pm 0,6$
	27	$2,3 \pm 0,1$	$94,8 \pm 1,0$	$8,8 \pm 0,4$
	38	$2,4 \pm 0,1$	$104,8 \pm 1,0$	$10,4 \pm 0,5$
Experimental	8	$2,2 \pm 0,1^{**}$	$123,0 \pm 3,3^{**}$	$8,2 \pm 0,5$
	13	$2,6 \pm 0,1^{**}$	$95,7 \pm 1,6^{***}$	$8,4 \pm 0,1$
	27	$2,7 \pm 0,1^*$	$105,7 \pm 1,6^{***}$	$13,8 \pm 1,8^*$
	38	$2,9 \pm 0,1^*$	$115,7 \pm 1,6^{***}$	$13,8 \pm 1,3^*$

CONCLUSION

The results of biochemical and hematological studies indicate that the use of dietary supplements based on essential oils reduces the likelihood of negative reactions of the body to vaccination. Stimulation of metabolic processes and an increase in the level of serum proteins (globulins – by 19.7–22.3%, albumins – by 13.8–23.3%) were recorded, which indicates activation of the bird's immune system. The use of the preparation also contributed to an increase in the number of red blood cells by 13.0–37.5%, hemoglobin by 10.4–22.6%, and white blood cells by 9.0–56.8%. This, in turn, contributed to an increase in flock survival by 1.6%.

СПИСОК ЛИТЕРАТУРЫ

1. Сурай П.Ф. Стрессы в птицеводстве // Животноводство России. 2015. № 1. С. 30–31.
2. Бойко В.С., Руденко Е.П., Кротовская Ю.Н. Уровень показателей белкового обмена в организме цыплят в динамике вакцинации ДНК-вакциной против болезни Марекка // Животноводство и ветеринарная медицина. 2016. № 1 (20). С. 27–31.
3. Гизатуллин А.Н., Баекенова Г.И. Особенности белкового обмена и продуктивных качеств кур кросса «Хайсекс белый» при использовании биологически активных веществ // Аграрный вестник Урала. 2011. № 2 (81). С. 19–21.
4. Садовников Н.В., Придыбайло Н.Д., Верещак Н.А., Заслонов А.С. Общие и специальные методы исследования крови птиц промышленных кроссов: монография. Екатеринбург; СПб., 2009. 86 с.
5. Середя Т.И., Дерхо М.А., Разумовская Л.М. Характеристика белковых фракций сыворотки крови кур кросса «Ломанн белый» и их связь с яичной продуктивностью // Ветеринарный врач. 2009. № 6. С. 67–69.
6. Салаутин В.В. Адаптивная реакция у цыплят при стрессах // Ветеринария. 2003. № 1. С. 23–25.
7. Мулюкова Э.Ф., Андреева А.В. Биохимические и иммунологические показатели крови цыплят-бройлеров на фоне вакцинации и при использовании пробиотика «Ветоспорин-С» в сочетании с кормовой добавкой «Витамэ-лам» // Ученые записки Казанской академии ветеринарной медицины им. Н.Э. Баумана. 2015. Т. 222 (2). С. 155–158.
8. Мифтахутдинов А.В., Сайфульмулюков Э.Р. Особенности белкового обмена в организме цыплят-бройлеров при применении в рационе кормовой добавки Пик-Антистресс // Вестник Новосибирского государственного аграрного университета. 2020. № 4 (57). С. 103–110. DOI: 10.31677/2072-6724-2020-57-4-103-110.
9. Харлап С.Ю., Дерхо М.А., Лоретц О.Г. Роль белков в реализации стресс-индуцирующего воздействия шуттелирования в организме цыплят // Аграрный вестник Урала. 2016. № 3 (145). С. 66–71.
10. Харлап С.Ю., Дерхо М.А., Середя Т.И. Особенности лейкограммы цыплят в ходе развития стресс-реакции при моделированном стрессе // Известия Оренбургского государственного аграрного университета. 2015. № 2. С. 103–105.

REFERENCES

1. Surai P.F. Stresses in poultry farming. *Zhivotnovodstvo Rossii = Animal Husbandry of Russia*, 2015, no. 1, pp. 30–31. (In Russian).
2. Boyko V.S., Rudenko E.P., Krotovskaya Yu.N. Protein metabolism parameters in chickens over the period of vaccination with DNA-vaccine against Marek's disease. *Zhivotnovodstvo i veterinarnaya meditsina = Animal Agriculture and Veterinary Medicine*, 2016, no. 1 (20), pp. 27–31. (In Russian).
3. Gizatullin A.N., Baekenova G.I. Peculiarities of protein metabolism and productive qualities of hens of the cross "Hi-Sex White" when using biologically active substances. *Agrarniy vestnik Urala = Agrarian Bulletin of the Urals*, 2011, no. 2 (81), pp. 19–21. (In Russian).
4. Sadovnikov N.V., Pridybailo N.D., Vereshchak N.A., Zaslonov A.S. *General and special methods of blood testing of birds of industrial crosses*. Yekaterinburg; St. Petersburg, 2009, 86 p. (In Russian).
5. Sereda T.I., Derkho M.A., Razumovskaya L.M. The characteristic protein fractions of whey of blood of hens of the cross "Lomann-White" and their connection with egg efficiency. *Veterinarniy vrach = Veterinarny Vrach*, 2009, no. 6, pp. 67–69. (In Russian).
6. Salautin V.V. Adaptive response in chickens under stress. *Veterinariya = Veterinary Medicine*, 2003, no. 1, pp. 23–25. (In Russian).
7. Mulyukova E.F., Andreeva A.B. Biochemical and immunological blood parameters of broiler chickens in the background of vaccination and the use of probiotic "Vetospirin-S" in combination with the feed additive "Vitamelam". *Uchenye zapiski Kazanskoy akademii veterinarnoy mediciny im. N.E. Baumana = Scientific Notes of the Kazan Academy of Veterinary Medicine named after N.E. Bauman*, 2015, vol. 222 (2), pp. 155–158. (In Russian).
8. Miftakhutdinov A.V., Sayfulmulyukov E.R. Features of protein metabolism in the body of broiler chickens when using the feed additive Peak-Antistress in the diet. *Vestnik NSAU = Bulletin of NSAU*, 2020, no. 4 (57), pp. 103–110. (In Russian). DOI 10.31677/2072-6724-2020-57-4-103-110.
9. Kharlap S.Yu., Derkho M.A., Loretz O.G. Role of blood proteins in the realization of stress inducing influence of shaking in the body of chickens. *Agrarniy vestnik Urala = Agrarian Bulletin of the Urals*, 2016, no. 3 (145), pp. 66–71. (In Russian).
10. Kharlap S.Yu., Derkho M.A., Sereda T.I. Peculiarities of chicken leukogram in the process of stimulated stress response. *Izvestiya Orenburgskogo gosudarstvennogo agrarnogo universiteta = Izvestia Orenburg State Agrarian University*, 2015, no. 2, pp. 103–105. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРАХ

✉ **Задорожная Марина Валерьевна**, ведущий научный сотрудник, кандидат ветеринарных наук; SPIN-код 1185-4997; **адрес для переписки:** Россия, 644555, Омская область, п. Морозовка, ул. 60 лет Победы, 1; e-mail: mfil2525@mail.ru

Лыско Светлана Борисовна, главный научный сотрудник, доктор ветеринарных наук; SPIN-код 2247-1909

Гофман Алёна Андреевна, ведущий научный сотрудник, кандидат ветеринарных наук; SPIN-код 8768-6208

Сунцова Ольга Александровна, ведущий научный сотрудник, кандидат ветеринарных наук; SPIN-код 5246-0463

AUTHOR INFORMATION

✉ **Marina V. Zadorozhnaya**, Lead Researcher, Candidate of Science in Veterinary Medicine; SPIN-code 1185-4997; **address:** 1, 60-let Pobedy St., Morozovka village, Omsk Region, 644555, Russia; e-mail: mfil2525@mail.ru

Svetlana B. Lysko, Head Researcher, of Science in Veterinary Medicine; SPIN-code 2247-1909

Alena A. Goffman, Lead Researcher, Candidate of Science in Veterinary Medicine; SPIN-code 8768-6208

Olga A. Suntsova, Lead Researcher, Candidate of Science in Veterinary Medicine; SPIN-code 5246-0463

Дата поступления статьи / Received by the editors 26.09.2025
Дата принятия к публикации / Accepted for publication 07.11.2025
Дата публикации / Published 10.02.2026

<https://doi.org/10.26898/0370-8799-2026-1-10>

УДК 681.5

Тип статьи: оригинальная

Type of article: original

Система автоматического сбора яблок в интенсивных садах с использованием перистальтической системы транспортировки плодов

Манцуров К.Н., Барабанов В.Г., (✉)Кухтик М.П., Федорова Н.В.

Волгоградский государственный технический университет

Волгоград, Россия

(✉)e-mail: mpkuhtik@gmail.com

Предложена система автоматического сбора яблок в интенсивных садах, представляющая автономную подвижную платформу, на которой установлен манипулятор для захвата плодов. Рассмотрены недостатки таких распространенных конструкций для транспортировки плода от устройства захвата к бункеру-накопителю, как манипуляторы и гибкие трубы с отрицательным давлением. Для того чтобы избежать приведенных недостатков и повреждения яблок при перемещении, рассмотрена их транспортировка с помощью перистальтической системы. Проведены расчеты производительности вентилятора данной системы и вентилятора разрежения трубы с выбором конкретных моделей. Получены зависимость аэродинамического сопротивления системы от расхода воздуха и зависимость требуемого давления для поднятия яблока от его диаметра. Предложенная перистальтическая система состоит из многосегментной надувной трубы и вращающегося пневматического распределителя. Разработан принцип работы перистальтической трубы, состоящий в поочередном повышении и сбросе давления в магистралях. Выполненный расчет показал, что вентилятор не подходит для отделения яблока от ветки, так как требуемое разрежение воздуха является очень высоким и недостижимо вентиляторами, габариты которых позволили бы установить их на подвижную платформу. Для этой задачи целесообразно использовать вакуумный насос, производительность которого рассчитана с выбором конкретной модели и достаточна для требуемой производительности сбора. Описан аппаратный состав установки, представлен ее общий вид и разработана ее структурная схема. Разработанная система автоматического сбора яблок позволяет автоматизировать ручной труд без повреждения плодов и обеспечить экономию благодаря использованию низкоквалифицированного труда.

Ключевые слова: яблоки, интенсивные сады, автоматический сбор плодов, подвижная платформа

An automatic apple harvesting system for intensive orchards using a peristaltic fruit transport system

Mantsurov K.N., Barabanov V.G., (✉)Kukhtik M.P., Fedorova N.V.

Volgograd State Technical University

Volgograd, Russia

(✉)e-mail: mpkuhtik@gmail.com

The proposed system of automatic apple harvesting in intensive orchards is an autonomous mobile platform on which a manipulator for gripping fruits is installed. The disadvantages of such common designs for transporting fruits from the gripping device to the storage bin as manipulators and flexible pipes with negative pressure are considered. In order to avoid the above disadvantages and damage to apples during movement, their transportation using a peristaltic system is considered. Calculations are made of the performance of the fan of this system and the fan of the pipe vacuum with the selection of

specific models. The dependence of the aerodynamic resistance of the system on the air flow rate and the dependence of the required pressure for lifting the apple on its diameter are obtained. The proposed peristaltic system consists of a multi-segment inflatable pipe and a rotating pneumatic distributor. The operating principle of the peristaltic pipe is developed, consisting in alternately increasing and releasing the pressure in the mains. The calculation performed showed that the fan is not suitable for separating an apple from a branch, since the required vacuum is very high and unachievable by fans whose dimensions would allow them to be installed on a movable platform. For this task, it is advisable to use a vacuum pump, the performance of which is calculated with the selection of a specific model and is sufficient for the required collection performance. The hardware composition of the installation is described, its general appearance is presented and its structural diagram is developed. The developed system of automatic apple collection allows for the automation of manual labor without damaging the fruit and provides savings due to the use of low-skilled labor.

Keywords: apples, intensive orchards, automatic fruit picking, mobile platform

Для цитирования: Манцуров К.Н., Барабанов В.Г., Кухтик М.П., Федорова Н.В. Система автоматического сбора яблок в интенсивных садах с использованием перистальтической системы транспортировки плодов // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 86–94. <https://doi.org/10.26898/0370-8799-2026-1-10>

For citation: Manturov K.N., Barabanov V.G., Kukhtik M.P., Fedorova N.V. An automatic apple harvesting system for intensive orchards using a peristaltic fruit transport system. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 86–94. <https://doi.org/10.26898/0370-8799-2026-1-10>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

INTRODUCTION

Apple tree is one of the agricultural crops whose fruit is currently mostly harvested by hand. While the use of a harvester that grips the tree trunk and causes the apples to fall through vibration is acceptable for fruits used for juice production, this method is not suitable for fruits intended for sale as whole, because the falling apples inevitably get damaged, leading to rapid spoilage. The intensive orchard technology involves maintaining a young orchard of low trees. Special varieties yield a harvest as early as the second year after planting, which allows the plantation to recoup costs faster and reduces the impact of plant diseases. The small size of the apple trees makes it possible to harvest apples at human height without special equipment. Young trees do not have a dense crown, have few leaves, and present no obstacles to easily spotting and picking the fruits. Such conditions facilitate automatic fruit harvesting.

Analysis of scientific and technical literature has shown interest in developments in the field

of automatic fruit harvesting [1–5], in particular apples [6–9], including in intensive orchards [10]. Robots of this type can be divided into research prototypes¹ [11–13] and commercial.

The goal of the work is to develop a system for automatic apple harvesting in intensive orchards, ensuring the collection and movement of fruits from the gripping device to the receiving hopper without damaging them.

Objectives of the work are:

- to theoretically substantiate the fundamental possibility of transporting apples using a peristaltic system;
- justify the choice of a peristaltic system fan, a pipe vacuum fan, and a device for separating the apple from the branch by calculating their performance;
- describe the principle of operation of a peristaltic tube;
- to describe the hardware components of the automatic apple harvesting system and develop its structural diagram.

The most common types of structures for transporting the crop from the gripping device to

¹De-An Z., Jidong L., Wei J., Ying Z., Yu C. Design and control of an apple harvesting robot // *Biosystems Engineering*, 2011, vol. 110 (2), pp. 112–122. DOI: 10.1016/j.biosystemseng.2011.07.005.

the receiving hopper are manipulators [14] and flexible pipes with negative pressure².

Let's consider the disadvantages of these structures. The drawback of manipulators with redundant kinematics is the low movement speed and difficulty of control, since not only the position of the end effector but also each individual link is programmed. The drawback of parallel kinematics manipulators is complex control, which must provide protection of the manipulator from singularity, i.e., such a combination of actuator positions for which the solution of the kinematic equations tends to infinity.

The disadvantage of Cartesian (portal) manipulators is the limitation in three axes, since further addition of kinematic links will convert the manipulator into a category of manipulators with redundant kinematics and will no longer be considered Cartesian. Another disadvantage is the relatively low movement speed, as the drive of each preceding link provides acceleration to the subsequent one. This leads to the fact that with a small mass of the working body, the moment of inertia of the links may to a greater extent consist of the inertia of the guides and drives if they are located on movable links. Overall, it can be noted that transporting fruits using a manipulator reduces harvesting productivity and increases requirements for the number of degrees of freedom of the manipulator.

The disadvantages of flexible pipes, in which fruits are moved using negative pressure, are the inability to control the speed of movement, which is especially dangerous for apples when entering the receiving hopper, and a decrease in productivity for smaller sized apples due to parasitic air flow.

To ensure the movement of fruits without damaging them, let us consider a peristaltic tube as a transportation device. As a result of the search conducted in domestic and foreign bib-

liographic and patent databases, no devices or systems using peristaltic tubes for transporting fruits from the capture device to the collector were found, except for one design³. This design is a peristaltic system consisting of electromagnetic valves and has the corresponding drawbacks: dependence on electrical power and susceptibility to contamination and wear.

MATERIAL AND METHODS

The Microsoft Excel package was used to build graphical dependencies. The nanoCAD package was used to create the drawings illustrating the principle of the peristaltic tube operation, the general view of the automatic apple collection system, and its structural diagram. Theoretical calculations were carried out based on the basic laws of physics and the hydraulic head loss formula.

RESULTS AND DISCUSSION

The proposed automatic apple picking system is an autonomous mobile platform equipped with a manipulator for fruit handling. A stereoscopic camera mounted on the mobile platform determines the position of the apples in space as the installation moves along the tree row. The manipulator successively brings the working tool to the fruits, which performs the apple grasping.

For transporting fruits from the gripping device to the receiving hopper, a peristaltic system is proposed, consisting of a multi-segment inflatable tube and a rotating pneumatic distributor. The tube consists of groups of inflatable segments connected to corresponding segments of other groups and operating synchronously. The smoothness of apple movement depends on the number of segments in the group. The length of a single segment should not exceed half of the minimum diameter of the fruit; otherwise, there

²Robots for picking apples and similar fruits. URL: <http://robotrends.ru/robopedia/roboty-dlya-sbora-yablok-i-analogichnyh-fruktov> (date of reference: 24.08.2025).

³Patent (CN) № 108029341A A 01 D 46/24. Pipeline creeping mechanism and fruit picking robot / L. Zhou, L. Wang, N. Yu, Y. Mou, applied 2017.12.15; published 2018.05.15.

will be an uncertainty in the direction of movement. The number of segments in a group is determined by the maximum diameter of the fruit, since the fruit must fit into one group; otherwise, it will get stuck between the corresponding segments of different groups.

Let's set the fruit diameter from 40 to 120 mm. In this case, the segment length l_{seg} will be 20 mm, that is, half of the minimum fruit diameter. We will take the number of segments in a group to be six, then the length of each group l_{gr} will be 120 mm. The range of segment diameters will be from 150 to 30 mm to ensure the advancement of fruits of any diameter.

Let's find the volume of air required to activate one segment:

Let's find the volume of air

$$V_{\text{cer}} = l_{\text{cer}} \cdot \frac{\pi \cdot (D_{\text{max}}^2 - D_{\text{min}}^2)}{4} = 0,02 \cdot \frac{\pi \cdot (0,15^2 - 0,03^2)}{4} = 0,339 \cdot 10^{-3} \text{ m}^3. \quad (1)$$

Let's take the length of the pipe l_{pp} as 3.1 m, then the number of segment groups will be

$$n = \frac{l_{\text{pp}}}{l_{\text{gr}}} = \frac{3,1}{0,12} \approx 26. \quad (2)$$

Thus, the volume of air required for the simultaneous activation of the corresponding segments will be

$$V_n = V_{\text{cer}} \cdot n = 0,339 \cdot 10^{-3} \cdot 26 = 8,814 \cdot 10^{-3} \text{ m}^3. \quad (3)$$

In order for one group of segments to be passed by the fruit and freed for another fruit, it is necessary to sequentially activate each segment. Then the required air volume per cycle will be

$$V_{\text{н}} = V_n \cdot 6 = 8,814 \cdot 6 = 52,884 \cdot 10^{-3} \text{ m}^3. \quad (4)$$

Let's assume the performance of the collection system is equal to 12 apples per minute. Then the required performance of the fan, ensuring the movement of the fruits in the peristaltic tube without damaging them, will be

$$Q_{\text{н}} = 52,884 \cdot 10^{-3} \cdot 720 = 38,1 \text{ m}^3/\text{h}. \quad (5)$$

Since the sequential activation of the segments does not result in the movement of the apple, but only in the narrowing of the lumen to prevent parasitic air intake for movement due to air flow in the pipe, there are no requirements for pressure in the segments.

Let's calculate the pressure losses due to friction in the supply pipes

$$P_{\text{тр}} = 0,11 \cdot \left(\frac{k_{\text{ш}}}{d_{\text{эKB}}} + \frac{68}{\text{Re}} \right)^{0,25} \cdot \frac{l_{\text{B}}}{d_{\text{эKB}}} \cdot \frac{\rho \cdot v^2}{2}, \quad (6)$$

where $k_{\text{ш}}$ – absolute equivalent roughness of the air duct; l_{B} – air duct length; $d_{\text{эKB}}$ – air duct equivalent diameter; ρ – air density (under normal conditions is 1.2754 kg/m³); Re – Reynolds number; v – air movement speed.

Each of the six segments of the group requires a separate tube for power supply. Let's assume their inner diameter is 32 mm, and their material is silicone, which has a roughness of 0.01 m. We will determine the length of the air duct as the length of the main pipe. We will obtain a graph of the dependence of the system's aerodynamic resistance on the air flow rate (see Fig. 1).

As follows from Fig. 1, the fan should provide a capacity of 38.1 m³/h at a pressure of 280 Pa. This condition is met by a centrifugal fan Ebmpapst G1G140-AV17-02.

In Fig. 2, the numbers from 1 to 6 indicate the numbers of the mains supplying air to the segments. Currently, pressure is maintained in

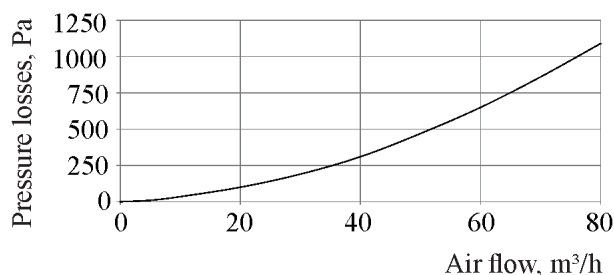


Рис. 1. Зависимость аэродинамического сопротивления системы от расхода воздуха

Fig. 1. Dependence of the aerodynamic resistance of the system on the air flow rate

main No. 3. Fig. 3 explains the principle of operation of the peristaltic tube during the further advancement of the fetus, which consists in the sequential increase and release of pressure in the mains.

Let's determine the performance of the tube vacuum fan. Since both the mass of the apple

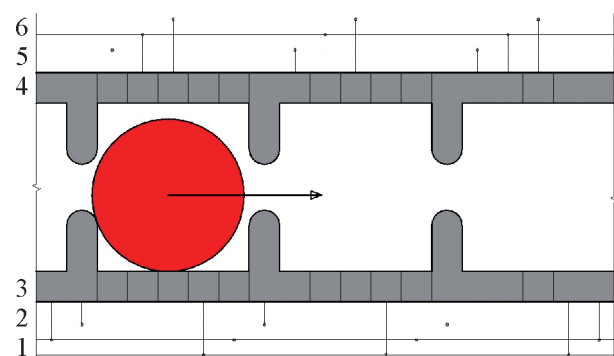


Рис. 2. Перистальтическая труба

Fig. 2. Peristaltic tube

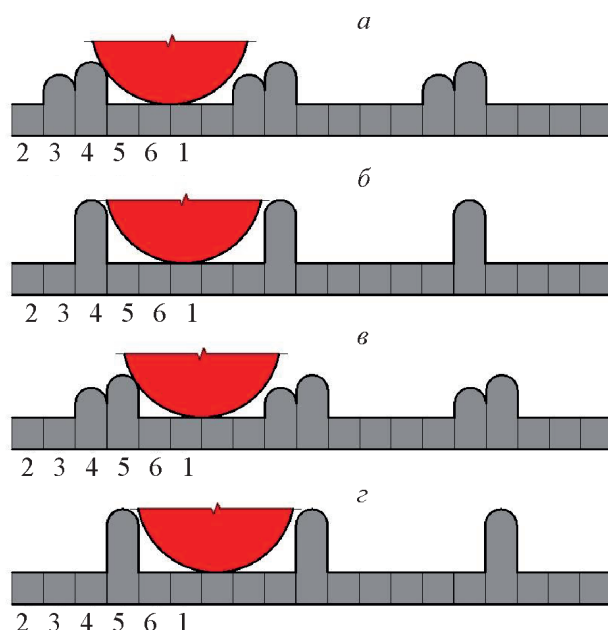


Рис. 3. Принцип работы перистальтической трубы:

a – повышение давления в магистрали № 4, сброс давления в магистрали № 3; *б* – поддержание давления в магистрали № 4; *в* – повышение давления в магистрали № 5, сброс давления в магистрали № 4; *г* – поддержание давления в магистрали № 5

Fig. 3. Operating principle of peristaltic tube:
a – increasing pressure in line No. 4, releasing pressure in line No. 3; *б* – maintaining pressure in line No.4; *в* – increasing pressure in line No. 5, releasing pressure in line No. 4; *г* – maintaining pressure in line No. 5

and the area on which the pressure acts change with different apple diameters, we will construct a graph of the dependence of the required pressure to lift the apple on its diameter according to formula (6). From Fig. 4, it can be seen that the maximum required pressure of 670 Pa corresponds to the maximum apple diameter of 120 mm.

A minimal airflow is required here, sufficient only to move the fruit through the peristaltic tube. Based on the accepted performance of the collection system, the time between the collection of adjacent apples is 5 seconds. During this time, the fruit must pass through a group of segments 120 mm long. We determine the corresponding air volume using formula (1)

$$V_{\text{rp}} = 0,12 \cdot \frac{\pi \cdot 0,15^2}{4} = 2,12 \cdot 10^{-3} \text{ m}^3. \quad (7)$$

The vacuum fan performance of the pipe will be

$$Q_p = \frac{V_{\text{rp}}}{5} \cdot 3600 = \frac{2,12 \cdot 10^{-3}}{5} \cdot 3600 = 1,53 \text{ m}^3/\text{h}. \quad (8)$$

Air resistance due to friction can be neglected at such a low flow rate. An axial fan Ebmpapst 3218 JH4 meets this condition.

Let's consider the possibility of using a fan to separate an apple from a branch. The key characteristics of a fan in an automatic harvesting system are static pressure and air flow volume.

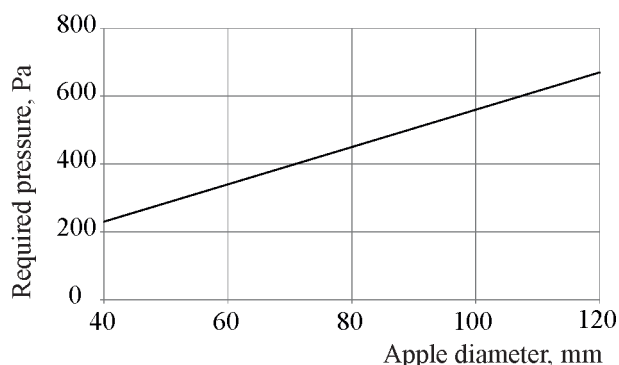


Рис. 4. Зависимость требуемого давления для поднятия яблока от его диаметра

Fig. 4. Dependence of the required pressure to lift an apple on its diameter

The pressure must be sufficient to detach the fruit from the branch, and the flow volume determines how quickly the pressure in the main line reaches the required value when sucking in the apple.

The force F required to detach the apple is about 20 N. The minimum diameter of the apple is 40 mm. Let's determine the minimum contact area of the airflow with the fruit:

$$S = \frac{\pi \cdot D^2}{4} = \frac{\pi \cdot 0,04^2}{4} = 1,26 \cdot 10^{-3} \text{ m}^2. \quad (9)$$

Let's determine the required air rarefaction:

$$P = \frac{F}{S} = \frac{20}{1,26 \cdot 10^{-3}} = 15873 \text{ Pa}. \quad (10)$$

The vacuum value of 15873 Pa is very high and unattainable by fans whose dimensions would allow them to be mounted on a movable platform. Therefore, the fan is not suitable for separating the apple from the branch.

Let's consider a vacuum pump for this task and determine its required capacity. The outer diameter of the gripping device is equal to the diameter of the pipe, i.e., 150 mm. The length of the chamber should be at least the diameter of the apple. Taking into account the allowance for the deformation of the cuff, we will assume the length of the chamber to be 200 mm. Then we find the volume of air using the formula (7)

$$V_{\text{н}} = 0,2 \cdot \frac{\pi \cdot 0,15^2}{4} = 3,53 \cdot 10^{-3} \text{ m}^3. \quad (11)$$

The evacuation of this volume of air should be provided by the vacuum pump in 5 seconds. Then the required pump capacity will be

$$Q_{\text{н}} = \frac{3,53 \cdot 10^{-3}}{5} \cdot 3600 = 2,54 \text{ m}^3/\text{h}. \quad (12)$$

This condition is satisfied by the Pfeiffer Vacuum 3 DC permanent magnet rotary vane vacuum pump with a capacity of 2.7 m³/h. At a vacuum of 200 hPa, its capacity will be 2.6 m³/h, which is sufficient for the required collection performance.

The hardware components of the apple automatic harvesting system include the following elements: a mobile platform, a gantry manipulator, a peristaltic system, an industrial computer, a gripping and moving system, a navigation system, and a power source. Figure 5 shows the general view of the apple automatic harvesting system.

Figure 6 shows the block diagram of the automatic apple picking system.

CONCLUSION

The proposed method of transporting apples from the gripping device to the hopper-accumulator using a peristaltic system is free from the drawbacks of the most common types of such

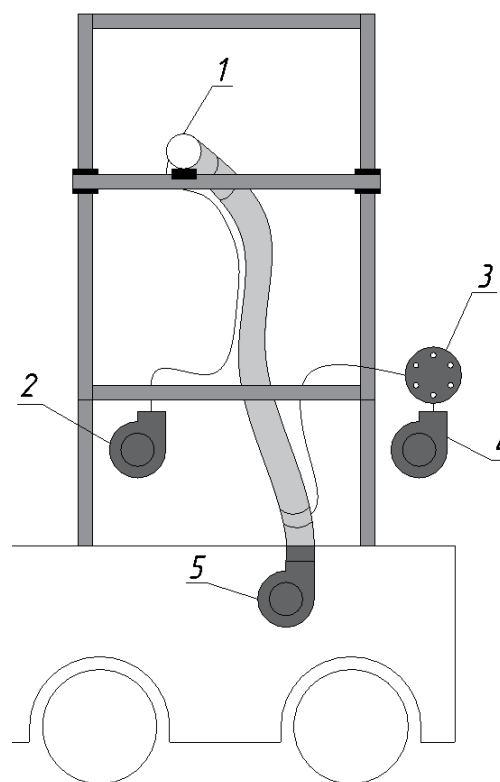


Рис. 5. Общий вид системы автоматического сбора яблок:

1 – вакуумный захват; 2 – вакуумный насос захвата; 3 – вращающийся пневматический распределитель; 4 – вентилятор перистальтической системы; 5 – вентилятор разрежения трубы

Fig. 5. General view of the automatic apple picking system:

1 – vacuum gripper; 2 – vacuum pump gripper; 3 – rotating pneumatic distributor; 4 – fan of the peristaltic system; 5 – fan of the pipe vacuum

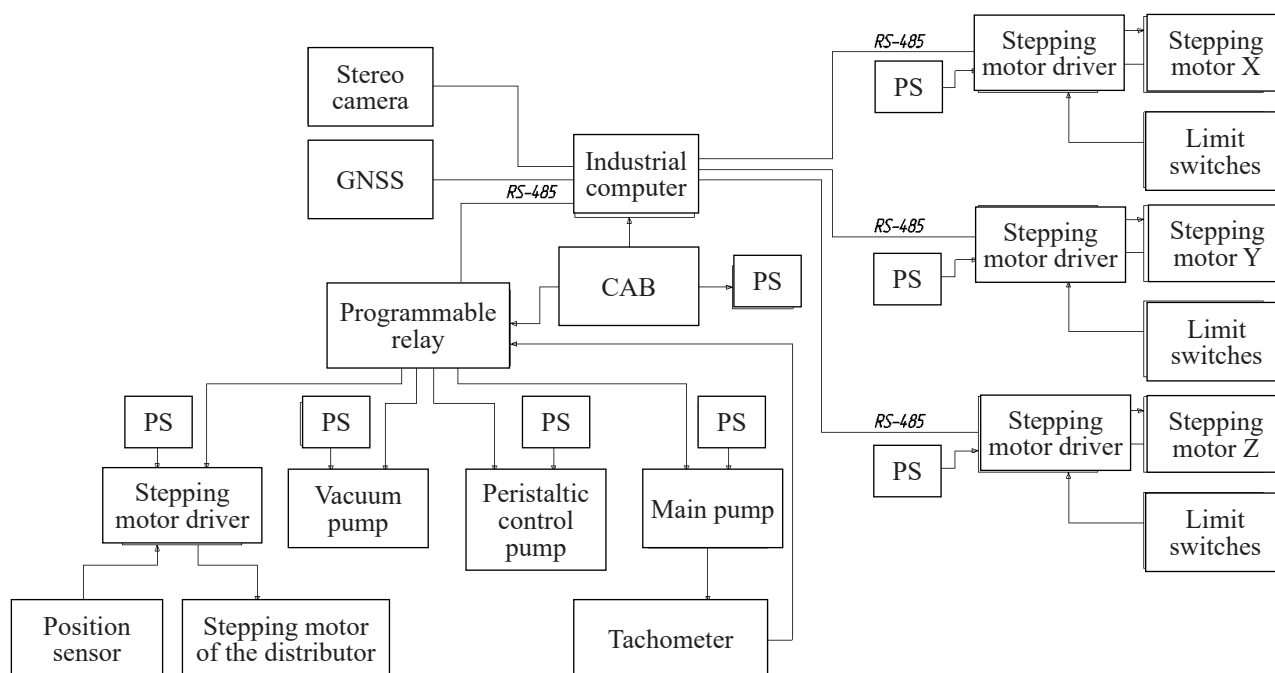


Рис. 6. Структурная схема системы автоматического сбора яблок:

БП – блок питания; АКБ – автомобильная кислотная батарея; GNSS – навигационный модуль

Fig. 6. Block diagram of the automatic apple picking system:

PS – power supply; CAB – car acid battery; GNSS – navigation module

designs – manipulators and flexible tubes with negative pressure. The performed calculation of the performance of the peristaltic system fan and the tube vacuum fan with the selection of specific models, as well as the developed principle of operation of the peristaltic tube and the proposed structural scheme of the automatic apple collection system, demonstrate the fundamental feasibility of using the peristaltic system for automatic fruit collection. As a result of the calculations performed, it was established that it is most rational to use a vacuum pump to separate the fruit from the branch, since the fan cannot provide the required force. The developed automatic apple collection system extends the duration of the shift during harvesting, as the installation is used at a time of day when manual collection would be impossible or ineffective, and it eliminates the need for employment and training of personnel each harvesting season. The prospects for the development of this research consist in the development of the system's operation algorithm, its implementation in the form of a

control program, the development of an apple detection algorithm, and the development of the system's navigation technology.

СПИСОК ЛИТЕРАТУРЫ

1. Zhang J., Kang N., Qu Q., Zhou L., Zhang H. Automatic fruit picking technology: a comprehensive review of research advances // *Artificial Intelligence Review*. 2024. Vol. 57. DOI: 10.1007/s10462-023-10674-2.
2. Fei Z., Vougioukas S.G. A robotic orchard platform increases harvest throughput by controlling worker vertical positioning and platform speed // *Computers and Electronics in Agriculture*. 2024. Vol. 218. DOI: 10.1016/j.compag.2024.108735.
3. Zhao Y., Wan X., Duo H. Review of rigid fruit and vegetable picking robots // *International Journal of Agricultural and Biological Engineering*. 2023. Vol. 16 (5). P. 1–11. DOI: 10.25165/ijabe.20231605.8120.
4. Wang Z., Xun Y., Wang Y., Yang Q. Review of smart robots for fruit and vegetable picking in agriculture // *International Journal of Agricultural and Biological Engineering*. 2022. Vol. 15 (1). P. 33–54. DOI: 10.25165/ijabe.20221501.7232.

5. Моисеев Г.В., Соловьев В.И., Феклин В.Г., Тань Л., Хо Ц. Состав, структура, функции и алгоритмы управления сельскохозяйственной роботизированной платформой // Вестник Технологического университета. 2022. Т. 25. № 5. С. 94–98. DOI: 10.55421/1998-7072_2022_25_5_94.
6. Кафиев И.Р., Романов П.С., Романова И.П. Сравнительный анализ роботов для сбора яблок // Вестник НГИЭИ. 2024. № 10 (161). С. 33–51. DOI: 10.24412/2227-9407-2024-10-33-51.
7. Чирков В.В., Крахмалев О.Н., Ожерельев В.Н. Разработка автоматизированной системы для сбора плодов с колоновидных яблонь на основе манипуляционного робота // Агрофорсайт. 2018. № 6 (18). С. 15–19.
8. Чирков В.В., Пимонов А.Ю. Автоматизация сбора плодов яблоневого культур // Журнал передовых исследований в области естествознания. 2020. № 9. С. 40–47. DOI: 10.26160/2572-4347-2020-9-40-47.
9. Семенов К.Д., Ахметзянов А.Р., Чирков С.А., Сидыганов Ю.Н. Исследование эффективности сбора яблок экспериментальной установкой на основе гибкого манипулятора // Известия Международной академии аграрного образования. 2024. № 69. С. 93–96.
10. Смирнов И.Г., Хорт Д.О., Кутырев А.И. Интеллектуальные технологии и роботизированные машины для возделывания садовых культур // Сельскохозяйственные машины и технологии. 2021. Т. 15. № 4. С. 35–41. DOI: 10.22314/2073-7599-2021-15-4-35-41.
11. Jia W., Zhang Y., Lian J., Zheng Y., Zhao D., Li C. Apple harvesting robot under information technology: A review // International Journal of Advanced Robotic Systems. 2020. Vol. 17 (3). DOI: 10.1177/1729881420925310.
12. Silwal A., Davidson J.R., Karkee M., Mo C., Zhang Q., Lewis K. Design, integration, and field evaluation of a robotic apple harvester // Journal of Field Robotics. 2017. Vol. 34 (2). DOI: 10.1002/rob.21715.
13. Li T., Xie F., Zhao Z., Zhao H., Guo X., Feng Q. A multi-arm robot system for efficient apple harvesting: Perception, task plan and control // Computers and Electronics in Agriculture. 2023. Vol. 211. DOI: 10.1016/j.compag.2023.107979.
14. Подковырин А.А. Аналитический обзор роботизированных манипуляторов для уборки сельскохозяйственных культур // Управление рисками в АПК. 2024. № S3 (53). С. 130–138.

REFERENCES

1. Zhang J., Kang N., Qu Q., Zhou L., Zhang H. Automatic fruit picking technology: a comprehensive review of research advances. *Artificial Intelligence Review*, 2024, vol. 57. DOI: 10.1007/s10462-023-10674-2.
2. Fei Z., Vougioukas S.G. A robotic orchard platform increases harvest throughput by controlling worker vertical positioning and platform speed. *Computers and Electronics in Agriculture*, 2024, vol. 218. DOI: 10.1016/j.compag.2024.108735.
3. Zhao Y., Wan X., Duo H. Review of rigid fruit and vegetable picking robots. *International Journal of Agricultural and Biological Engineering*, 2023, vol. 16 (5), pp. 1–11. DOI: 10.25165/j.ijabe.20231605.8120.
4. Wang Z., Xun Y., Wang Y., Yang Q. Review of smart robots for fruit and vegetable picking in agriculture. *International Journal of Agricultural and Biological Engineering*, 2022, vol. 15 (1), pp. 33–54. DOI: 10.25165/j.ijabe.20221501.7232.
5. Moiseev G.V., Soloviev V.I., Feklin V.G., Tan L., Huo J. Components, structure, functions and control algorithms of agricultural robotic platform. *Vestnik Tehnologicheskogo universiteta = Herald of Technological University*, 2022, vol. 25, no. 5, pp. 94–98. (In Russian). DOI: 10.55421/1998-7072_2022_25_5_94.
6. Kafiev I.R., Romanov P.S., Romanova I.P. Comparative analysis of robots for apple picking. *Vestnik NGIEI = Bulletin NGIEI*, 2024, no. 10 (161), pp. 33–51. (In Russian). DOI: 10.24412/2227-9407-2024-10-33-51.
7. Chirkov V.V., Krahmal'ov O.N., Ozherel'ev V.N. Development of the automated system for picking fruits from columnar apple tree on the basis of manipulating robot. *Agroforsait = Agrofor-sight*, 2018, no. 6 (18), pp. 15–19. (In Russian).
8. Chirkov V.V., Pimonov A.Yu. Automation of harvesting apple fruits. *Zhurnal peredovykh issledovaniy v oblasti estestvoznaniya = Journal of Advanced Research in Natural Science*, 2020, no. 9, pp. 40–47. (In Russian). DOI: 10.26160/2572-4347-2020-9-40-47.
9. Semenov K.D., Akhmetzyanov A.R., Chirkov S.A., Sidyganov Yu.N. Investigation of the effectiveness of apple harvesting by an experimental installation based on a flexible manipulator. *Izvestiya Mezhdunarodnoy akademii agrarnogo obrazovaniya = Proceedings of the*

- International Academy of Agrarian Education*, 2024, no. 69, pp. 93–96. (In Russian).
10. Smirnov I.G., Khort D.O., Kutyrev A.I. Intelligent technologies and robotic machines for garden crops cultivation. *Sel'skokhozyaistvennyye mashiny i tekhnologii = Agricultural Machinery and Technologies*, 2021, vol. 15, no. 4, pp. 35–41. (In Russian). DOI: 10.22314/2073-7599-2021-15-4-35-41.
 11. Jia W., Zhang Y., Lian J., Zheng Y., Zhao D., Li C. Apple harvesting robot under information technology: A review. *International Journal of Advanced Robotic Systems*, 2020, vol. 17 (3). DOI: 10.1177/1729881420925310.
 12. Silwal A., Davidson J.R., Karkee M., Mo C., Zhang Q., Lewis K. Design, integration, and field evaluation of a robotic apple harvester. *Journal of Field Robotics*, 2017, vol. 34 (2). DOI: 10.1002/rob.21715.
 13. Li T., Xie F., Zhao Z., Zhao H., Guo X., Feng Q. A multi-arm robot system for efficient apple harvesting: Perception, task plan and control. *Computers and Electronics in Agriculture*, 2023, vol. 211. DOI: 10.1016/j.compag.2023.107979.
 14. Podkovyrin A.A. Analytical review of robotic platforms and machines used in agriculture. *Upravlenie riskami v APK = Management of economic risks at agricultural enterprises*, 2024, no. S3 (53), pp. 130–138. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРАХ

Манцуров Константин Николаевич, студент
Барабанов Виктор Геннадьевич, доцент кафедры, кандидат технических наук, доцент; SPIN-код 4968-7390

✉ **Кухтик Михаил Петрович**, доцент кафедры, кандидат технических наук, доцент; SPIN-код 4899-7020; **адрес для переписки:** Россия, 400005, Волгоград, проспект им. Ленина, 28; e-mail: mpkuhtik@gmail.com

Федорова Наталья Валерьевна, старший преподаватель; SPIN-код 3082-2498

AUTHOR INFORMATION

Konstantin N. Mantsurov, Student
Victor G. Barabanov, Assistant Professor, Candidate of Science in Engineering, Associate Professor; SPIN-code 4968-7390

✉ **Mikhail P. Kukhtik**, Assistant Professor, Candidate of Science in Engineering, Associate Professor; SPIN-code 4899-7020; **address:** 28, Lenina ave., Volgograd, 400005, Russia; e-mail: mpkuhtik@gmail.com

Natalia V. Fedorova, Senior Lecturer; SPIN-code 3082-2498

Дата поступления статьи / Received by the editors 19.08.2025
Дата принятия к публикации / Accepted for publication 28.10.2025
Дата публикации / Published 10.02.2026

Влияние климатических условий на эффективность использования машинно-тракторного парка в агропромышленном комплексе

(✉)Иванников А.Б.¹, Деменок И.В.¹, Кононенко Н.В.¹, Ильиченков А.С.²

¹Сибирский федеральный научный центр агробиотехнологий Российской академии наук

Новосибирская область, р.п. Краснообск, Россия

²Новосибирское высшее военное командное ордена Жукова училище

Новосибирск, Россия

(✉)e-mail: ivannikovab@sfscs.ru

Влияние климатических факторов и погодных явлений на людей и машины начали изучать в начале XX в. Одним из пионеров этого направления стал шведский физик и полярный исследователь Гёста Бодман, который предложил методику оценки суровости климата в балльной системе. Позднее советский ученый П.И. Кох продолжил исследования в этом направлении, ввел понятие технической жесткости климата и предложил концепцию деления территории СССР на пять зон в зависимости от технической жесткости климата. Целью исследования является оценка условий эксплуатации тракторного парка агропромышленного комплекса Российской Федерации применительно к условиям технической жесткости холодного климата. В основу исследования положен метод оценки технической жесткости климата, разработанный П.И. Кохом. Определено распределение тракторов по зонам жесткости климата, изучены последствия негативного влияния климатических факторов и погодных явлений на эффективность эксплуатации техники. Установлено, что, согласно официальным данным, в АПК РФ по состоянию на конец 2022 г. имелось 214,8 тыс. тракторов всех тяговых классов. Из них лишь около 21% эксплуатируются в условиях, приближенных к нормальным. Остальной тракторный парк приходится на хозяйства, расположенные в зонах умеренно жесткого, жесткого, очень жесткого и наиболее жесткого климата. К климатическим факторам и погодным явлениям, оказывающим наиболее сильное негативное влияние на работу узлов и агрегатов тракторов и машин, в первую очередь относятся температура воздуха, его влажность и скорость ветра. Выполненное исследование свидетельствует о серьезном масштабе проблем, связанных с зимней эксплуатацией машинно-тракторного парка. Примерные расчеты издержек от перерасхода топлива в результате потерь мощности в моторно-трансмиссионной установке трактора свидетельствуют о необходимости дальнейших исследований в области обеспечения оптимальных температур в узлах и агрегатах тракторов и машин в условиях пониженных температур окружающей среды.

Ключевые слова: техническая жесткость, холодный климат, зимняя эксплуатация, машинно-тракторный парк, бросовая теплота

The influence of climatic conditions on the efficiency of using the machine and tractor fleet in the agro-industrial complex

(✉)Ivannikov A.B.¹, Demenok I.V.¹, Kononenko N.V.¹, Ilyichenkov A.S.²

¹Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences

Krasnoobsk, Novosibirsk Region, Russia

²Novosibirsk Higher Military Command Order of Zhukov School

Novosibirsk, Russia

(✉)e-mail: ivannikovab@sfscs.ru

The influence of climatic factors and weather phenomena on people and machines began to be studied at the beginning of the 20th century. One of the pioneers of this field was the Swedish physicist and polar researcher Gesta Bodman, who proposed a method for assessing the severity of the climate in a scoring system. Later, Soviet researcher P.I. Koch continued his research in this direction and introduced the concept of "technical rigidity" of the climate and proposed the concept of dividing the territory of the USSR into five zones of technical rigidity of the climate. The purpose of the study is to assess the operating conditions of the tractor fleet of the agro-industrial complex of the Russian Federation in relation to the conditions of technical rigidity of the cold climate. The study is based on

the P.I. Koch method of assessing the cold climate technical rigidity. The distribution of tractors by cold climate severity zones was determined and the consequences of the negative impact of climatic factors and weather events on the operational efficiency was studied. It was found that, according to official data, the agro-industrial complex of the Russian Federation had 214.8 thousand tractors of all traction classes as of the end of 2022. Of these, only about 21% are operated in conditions close to normal. The rest of the tractor fleet is located on the farms in moderately harsh, harsh, very harsh and most harsh climate zones. The climatic factors and weather phenomena that have the strongest impact on the operation of the components and aggregates of tractors and machines primarily include air temperature, humidity and wind speed. The conducted studies indicate the serious scale of the problems associated with the winter operation of the machine and tractor fleet. Approximate calculations of the cost of fuel overruns associated with power losses in the tractor's engine and transmission indicate the need for further research in the field of ensuring optimal temperatures in components and assemblies of tractors and machines at low ambient temperatures.

Keywords: technical rigidity, cold climate, winter operation, machine and tractor fleet, waste heat

Для цитирования: Иванников А.Б., Деменок И.В., Кононенко Н.В., Ильиченков А.С. Влияние климатических условий на эффективность использования машинно-тракторного парка в агропромышленном комплексе // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 95–106. <https://doi.org/10.26898/0370-8799-2026-1-11>

For citation: Ivannikov A.B., Demenok I.V., Kononenko N.V., Ilyichenkov A.S. The influence of climatic conditions on the efficiency of using the machine and tractor fleet in the agro-industrial complex. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 95–106. <https://doi.org/10.26898/0370-8799-2026-1-11>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

INTRODUCTION

At present, the negative impact of climatic factors and weather phenomena on the operation of the machine and tractor fleet (MTF), as well as the properties of materials used in mechanical engineering and various technical fluids, has been studied fairly well. Analysis of the available data indicates that of all the factors that in one way or another affect the efficiency of equipment operation, the strongest negative influence is exerted by low ambient temperature (air).

The study of the influence of climatic factors and weather phenomena on machines, technical systems, and people working outdoors began at the beginning of the 20th century. One of the pioneers of this field of scientific activity was the Swedish physicist and polar explorer Gösta Bodman (1875–1960), who, based on the results of the Swedish Antarctic Expedition of

1901–1903, proposed a method for assessing the severity of the climate using a scoring system¹.

With the development of mechanical engineering and the process of mechanization of the national economy, the negative consequences of the influence of climatic factors on machines began to manifest more intensively, which led to the emergence of the concept of winter operation problems. Many researchers dealt with and continue to deal with the solution of these problems. For example, the Soviet scientist P.I. Kokh proposed a method for improving G. Bodman's methodology². He introduced the concept of technical harshness of climate and weather, which could be determined not only for cold climates but also for hot ones, taking into account air humidity. It was separately proposed to determine the technical harshness of climate and weather for high-altitude regions. This is explained by the fact that in Bodman's method-

¹Bodman G. Results of scientific research of the Swedish expedition to the South Pole in 1901–1903, Moscow, 1910, vol. 2.

²Kokh P.I. Climate and reliability of machines. Moscow: Mashinostroenie, 1981, 175 p.

ology, an unjustifiably large role is assigned to wind speed, as a result of which the calculation of climate harshness, for example, for Yakutsk and Stavropol, gives the same value. P.I. Kokh also developed the concept of dividing the territory of the USSR into five zones depending on the technical harshness of the climate.

Since Soviet times, research on natural and climatic zoning has been conducted at the Institute of Geography of the Russian Academy of Sciences [1]. Taking into account the climatic features of the Russian Federation, issues of the impact of climate on human life remain constantly relevant and are reflected in the works of many researchers. For example, D.E. Mingalev in his article considers the problems of agroclimatic zoning of Russia and Kazakhstan under climate change conditions [2]. Yu.V. Rodionov et al. [3] propose a methodology for determining the technical condition of automotive and tractor equipment using an automated monitoring and diagnostic system under low-temperature conditions. A.N. Yakubovich and I.A. Yakubovich [4] assess climate risks in relation to the transport infrastructure of the northern regions of Russia. In the article with the self-explanatory name "Western Agro-Investors in Russia and Ukraine: Enchanted by Soil – Disappointed by Climate" [5], the discussion is about the inadmissibility of ignoring climatic features when conducting economic activities and investing in agribusiness.

In the context of modern economic management, studying the influence of climate on the economic indicators of the activities of national economy enterprises is, in essence, no longer a whim, but a necessity. Thus, in their article, A.S. Apatenko and A.M. Timofeev examine the peculiarities of the influence of climatic factors on the technical and economic indicators of the operation of technological machines³, I.M. Shkol-

nik et al. [6] study the issues of the impact of climate change on the economy of the federal districts of the Russian Federation.

The problem of winter operation of equipment has been actively studied by many researchers, which has made it possible to accumulate a fairly substantial body of experimental data, technical and design solutions, some of which have been adopted in production, and some are used in the educational process.

For example, the works of N.G. Berezhnov^{4, 5} have trained generations of specialists in the field of operating marine transport systems in the agro-industrial complex of Siberia and the Far East. Despite their age, these works remain relevant today. Prominent scientist and educator G.M. Krokhta, in his monograph "Features of Tractor Operation in Low Temperature Conditions," summarizes and analyzes the problems of MTF winter operation⁶. M.M. Razyapov [7] raises the issue of increasing the reliability of the transmission of automotive and tractor equipment when operating in low temperature conditions. N.G. Grinchar and N.A. Shilyaev [8] investigate the issues of hydraulic losses in the hydraulic drive of machines when operating in low temperature conditions.

The impact of low temperatures on the properties of various materials is also of interest to researchers. For example, D.S. Aleksandrova et al. [9] examine the negative impact of cold climates on polymer and composite materials widely used in modern mechanical engineering. In low-temperature conditions, starting a car engine, especially a diesel engine, becomes a pressing issue. For example, in [10] it is proposed to use a heat accumulator for these purposes, in [11] – a fire heat exchanger with an autonomous heating module. A.V. Kucher et al. [12] are investigating the issue of increasing the efficiency of engine

³Apatenko A.S., Timofeev A.M. The influence of climatic factors on the technical and economic performance of technological machines // Environmental Engineering, 2011, N 4, pp. 76–79.

⁴Berezhnov N.G. Lectures on the winter operation of machine-tractor fleet. Barnaul, 1972, 151 p.

⁵Berezhnov N.G. Fundamentals of operation of the machine-tractor fleet in winter conditions of Western Siberia. Barnaul, 1975, 330 p.

⁶Krokhta G.M. Features of tractor operation in low-temperature conditions. Novosibirsk: Zolotoy Kolos, 2017, 376 p.

starting in winter by increasing the performance of the battery.

The purpose of this study is to assess the operating conditions of the machinery and tractor fleet of the agro-industrial complex of the Russian Federation in relation to the technical severity of the cold climate.

MATERIAL AND METHODS

A multitude of problems that arise in the process of winter MTF operation can be difficult for even experienced specialists to correlate with economics and labor productivity. The most illustrative way to solve this problem can be demonstrated by the example of the author's methodology for determining the economic efficiency of implementing a technical means to ensure the optimal oil temperature in the gearbox of a self-propelled machine in winter conditions⁷.

During the MTF operation, the main part of the costs is associated with the expenses for purchasing fuel and lubricants. Therefore, it can be stated that the greater the fuel savings from the implementation of technical solutions that facilitate winter operation, the higher the economic efficiency of implementing such developments.

The main costs associated with MTF operating can be calculated using the formula

$$U = 3_{\text{TCM}} + 3_{\text{TO}} + A, \quad (1)$$

where U – annual cost of operating one unit of MTF, rubles; 3_{TCM} – annual costs for the purchase of fuel and lubricants, rubles; 3_{TO} – annual costs for scheduled maintenance, rubles; A – annual depreciation charges, rubles.

Fuel and lubricant costs can be determined by the following formula:

$$3_{\text{TCM}} = \frac{G_{\text{TCP}}}{p} \cdot D_{\text{pr}} \cdot T_{\text{pc}} \cdot \Pi_{\text{T}} + 3_{\text{CM}}, \quad (2)$$

where G_{TCP} – average annual hourly fuel consumption of a single MTF unit, kg; p – fuel density, g/cm³; D_{pr} – number of working days in a year; T_{pc} – working shift duration, h; Π_{T} – price per liter of fuel, rubles; 3_{CM} – annual costs for the purchase of lubricants, rubles.

Formula (2) can be easily adjusted for the interested time period to obtain more detailed information on operational periods. The main term of this formula, determining the amount of costs, all else being equal, is the hourly fuel consumption, a reduction of which will allow increasing the economic efficiency of winter operation.

It is known that when transmitting torque from the engine to the propulsion system, part of the engine power is lost in overcoming resistance in the transmission units and kinematic pairs. These losses are especially high during the winter operation period when oils thicken due to decreased temperatures. For example, in a study of power losses in the gearbox of the T-150K tractor, it was found that at an ambient temperature of –30 °C, they reach about 52 kW during the initial period of operation, and the stabilization of power losses occurs approximately after 3 hours at a level of 12 kW⁸.

A similar situation occurs during winter operation of all types of machines, with the only exception being that the figures for power losses will depend on the type of machine and the ambient air temperature. During the study of power losses in the gearbox of the K-701 tractor, it was determined that at an oil temperature of 60 to 80 °C, power losses in the transmission are minimal (about 4 kW). Moreover, if power losses before reaching this temperature range are associated with oil thickening, then at a temperature above 80 °C, losses increase due to the loss of oil properties as a result of its thinning⁹.

⁷Ivannikov A.B. Secondary use of engine exhaust heat to improve the efficiency of unit operation using the example of a tractor gearbox: dissertation for the degree of Candidate of Science in Engineering, Novosibirsk, 2017, 181 p.

⁸Krokhta G.M., Gosman A.I. Determination of power and oil temperature losses in the T-150K transmission depending on the ambient air temperature // Scientific works of the Novosibirsk Agricultural Institute, Novosibirsk, 1983.

⁹Selivanov N.I., Filimonov K.V., Kirin V.S., Boldaruk Yu.N. Power losses in the gearbox of the K-701 tractor // Collection of scientific works of the Krasnoyarsk State Agrarian University, Krasnoyarsk, 2000, part 1.

Therefore, to reduce the hourly fuel consumption, it is necessary to decrease power losses in the transmission units by creating and maintaining an optimal temperature regime in them. However, under routine operating conditions, achieving the optimal temperature regime in the gearbox is difficult even in the summer period, especially in the conditions of Russia's Far North, Siberia, and the Far East.

To understand the scale of the problem, during the study we used the method of assessing the technical severity of a cold climate according to P.I. Kokh.

The technical rigidity of a cold climate is calculated using the following formula (see footnote 2):

$$N_K = (0,75t_{\min \text{ cp}} + 0,25t_{\min \text{ а6с}}) \times \\ \times (1 + 0,015\sigma_x) \times (1 + 0,07v_x) \times \\ \times (1 + 0,26\varphi_x) \times (1 + 0,14n_{\text{TM}}) \times \\ \times (1 + 0,022\tau_x), \quad (3)$$

where N_K – cold climate technical stiffness, point; $t_{\min \text{ cp}}$ – the average value of minimum air temperatures for the three coldest months, °C; $t_{\min \text{ а6с}}$ – the average value of the absolute minimum air temperatures for the three coldest months, °C; σ_x – the average aperiodic temperature of daily air temperature fluctuations for the three coldest months, °C; v_x – the average wind speed for the three coldest months, m/s; φ_x – average value of the relative air humidity for the three coldest months, fractions of a unit; n_{TM} – the average monthly number of days with fog and blizzards during the three coldest months; τ_x – duration of the period with an average air temperature below zero, months

The cold climate technical stiffness assessment system involves a division into five groups (points):

- 1) low stiffness – 0–30;
- 2) moderate stiffness – 31–60;
- 3) stiff – 61–90;
- 4) very stiff – 91–120;
- 5) the stiffest – 121–170.

In addition to the methods presented above,

the study used scientific research methods such as analysis and synthesis, deduction, induction and analogy, description and measurement.

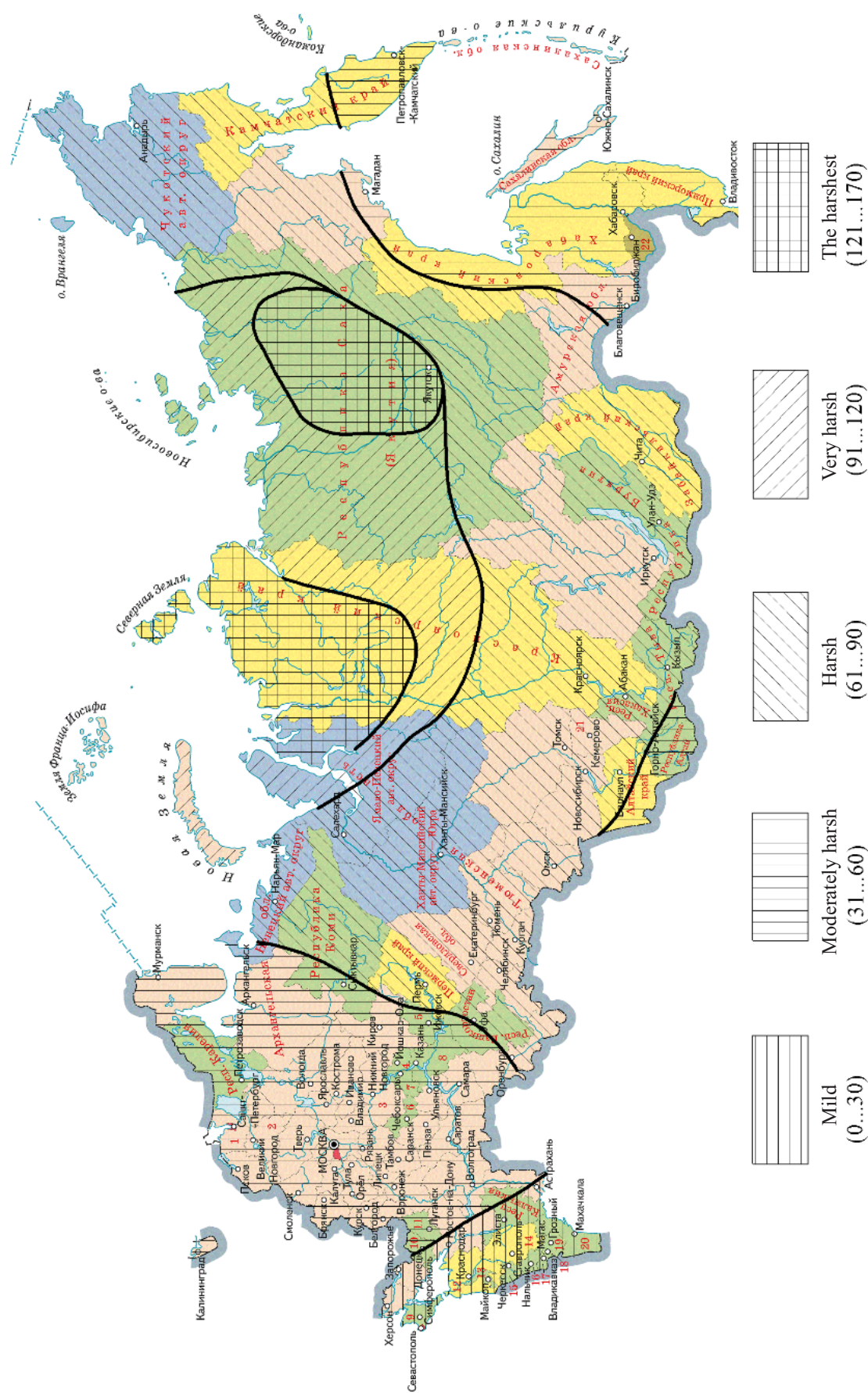
RESULTS AND DISCUSSION

From the analysis of formula (3), it becomes obvious that the climatic factors and weather phenomena that have the strongest impact on the operation of machine units and aggregates primarily include air temperature, its humidity, and wind speed.

The nature of the adverse effects of air humidity on materials depends on the percentage of moisture content. At high humidity (above 90%), the operational properties of materials decrease due to the penetration of moisture into these materials or the formation of a liquid film on their surface. At humidity below 50%, the moisture contained in materials evaporates, which also changes their properties: they become brittle and cracks appear in them. Moisture in the air, interacting with liquid mineral oils, hydrates them, reducing their lubricating and anticorrosion properties. Wind speed affects the intensity of heat exchange between the surface of the engine-transmission unit and the surrounding air, leading to a decrease in the thermal regime of components and assemblies during operation and inter-shift storage. At the same time, the factor that has the most negative impact on the operation of machine units and assemblies is, as noted earlier, the low ambient air temperature.

During the study, the visualization of cold climate technical stiffness zones by regions of the Russian Federation was refined (see the figure).

The analysis of the presented map indicates that the distribution of cold climate technical stiffness zones across the territory of Russia is uneven. Approximately half of the country's territory is located in the severe climate zone, and about 75% are in three zones: severe, very severe, and the most severe climate. At the same time, about half of the subjects of the Russian Federation are located in the moderately severe



Распределение зон технической жесткости холодного климата на территории Российской Федерации
Distribution of the cold climate technical severity zones on the territory of the Russian Federation

climate zone, and only 18 regions belong to the low-severity climate zone. This is explained by the administrative and historical division of the territory of the Russian Federation. For example, the Krasnoyarsk Territory and the Republic of Sakha (Yakutia) are simultaneously located in three zones, and the total area of their territory is

approximately equal to the total area of the territories of the Russian Federation subjects that fall into the zone of moderately severe climate. The distribution of the Russian Federation subjects by technical climate severity zones is presented in Table 1.

According to the Federal State Statistics Ser-

Табл. 1. Распределение субъектов РФ по зонам технической жесткости холодного климата

Table 1. Distribution of the subjects of the Russian Federation by the cold climate technical severity zones

Subject of the Russian Federation	Percentage of territory	Subject of the Russian Federation	Percentage of territory
1	2	3	4
<i>Mild climate</i>			
Astrakhan Region	10	Republic of Daghestan	100
Volgograd Region	100	Republic of Ingushetia	100
Sevastopol	100	Republic of Kalmykia	70
Donetsk People's Republic	20	Republic of Crimea	100
Zaporizhzhia Region	100	Republic of North Ossetia – Alania	100
Kabardino-Balkarian Republic	100	Rostov Region	50
Karachayevo-Cherkessian Republic	100	Stavropol Territory	100
Krasnodar Territory	100	Kherson Region	100
Adyghe Republic	100	Chechen Republic	100
<i>Moderately harsh climate</i>			
Altai Territory	50	Oryol Region	100
Amur Region	40	Penza Region	100
Arkhangelsk Region	100	Perm Territory	100
Astrakhan Region	90	Primorsky Territory	100
Belgorod Region	100	Pskov Region	100
Bryansk Region	100	Republic of Altai	100
Vladimir Region	100	Republic of Bashkortostan	40
Vologda Region	100	Republic of Kalmykia	30
Voronezh Region	100	Republic of Karelia	100
Moscow	100	Komi Republic	20
Donetsk People's Republic	80	Republic of Mari El	100
Jewish Autonomous Region	100	Republic of Mordovia	100
Ivanovo Region	100	Republic of Tatarstan	100
Kaliningrad Region	100	Republic of Tyva	5
Kaluga Region	100	Rostov Region	50
Kamchatka Territory	50	Ryazan Region	100
Kirov Region	95	Samara Region	100
Kostroma Region	100	Saratov Region	100
Kursk Region	100	Sakhalin Region	100
Leningrad Region	100	Smolensk Region	100
Lipetsk Region	100	Tambov Region	100
Lugansk People's Republic	100	Tver Region	100
Magadan Region	10	Tula Region	100
Moscow Region	100	Udmurt Republic	95

Окончание табл. 1

1	2	3	4
Murmansk Region	100	Ulyanovsk Region	100
Nizhni Novgorod Region	100	Khabarovsk Territory	75
Novgorod Region	100	Chuvash Republic	100
Orenburg Region	50	Yaroslavl Region	100
<i>Harsh climate</i>			
Altai Territory	50	Republic of Bashkortostan	60
Amur Region	60	Republic of Buryatia	100
Trans-Baikal Territory	100	Komi Republic	80
Irkutsk Region	95	Republic of Sakha (Yakutia)	30
Kamchatka Territory	50	Republic of Tyva	95
Kemerovo Region	100	Republic of Khakassia	100
Kirov Region	5	Sverdlovsk Region	100
Krasnoyarsk Territory	35	Tomsk Region	100
Kurgan Region	100	Tyumen Region	100
Magadan Region	90	Udmurt Republic	5
Novosibirsk Region	100	Khabarovsk Territory	25
Omsk Region	100	Chelyabinsk Region	100
Orenburg Region	50	Chukotka Autonomous Region	100
Perm Territory	95		100
<i>Very harsh climate</i>			
Irkutsk Region	5	Republic of Sakha (Yakutia)	40
Krasnoyarsk Territory	30		
<i>The harshest climate</i>			
Krasnoyarsk Territory	35	Republic of Sakha (Yakutia)	30

vice, by the end of 2022 there were 214.8 thousand tractors of all traction classes in the country's farms, including tractors on which earth-moving, reclamation, and other machines were mounted¹⁰. It should be noted that tractors operated by industrial enterprises, in the field of municipal services, etc., are not taken into account. The distribution of tractors by zones of technical severity of cold climate is presented in Table 2.

It should be especially noted that the figure and Table 1 reflect only the territorial and proportional distribution of regions by zones of technical severity of the cold climate. An exact count of the number of tractors corresponding to specific parts of the Russian Federation subjects located in different zones is quite problematic, so the information presented in Table 2 is of a reference nature and illustrates the approximate number of tractors corresponding to each of the five zones.

Табл. 2. Распределение тракторов по зонам технической жесткости холодного климата

Table 2. Distribution of tractors by the cold climate severity zones

Climate	Number of tractors	Percentage ratio
Mild	45 290	21
Moderately harsh	122 109	57
Harsh	43 839	20
Very harsh	1739	1
The harshest	1871	1
Total	214 849	100

The figures presented indicate that only about 21% of tractors are operated under conditions close to normal (mild climate zone) and are less exposed to the negative effects of the climate. More than half of the tractor fleet (57%) is operated in a moderately harsh climate zone and is periodically exposed to cold climate, es-

¹⁰Availability of machinery and energy capacities in agricultural organizations of the Russian Federation in 2022: statistical compilation / Federal State Statistics Service (Rosstat), Moscow, 2023.

pecially late in the autumn, in winter, and early in the spring. About 22% of tractors are in the areas of harsh, very harsh, and the harshest climates. Operation in these areas is associated with practically constant negative effects of the cold climate. For example, the average annual temperature in Novosibirsk and the Novosibirsk region is 0.2 °C, and ground frosts begin in the second half of September and end at the end of May¹¹. Thus, it becomes evident that the vast majority of the tractor fleet of the agro-industrial complex of the Russian Federation is subjected to the negative effects of a cold climate during operation, which reduces the efficiency of tractors according to their intended use and increases costs associated with winter operation problems. Simple analytical calculations can help estimate the volume of costs related to increased fuel consumption due to engine power losses in overcoming friction forces in the tractor's power-transmission system.

According to the data of the 2016 All-Russian Agricultural Census¹², the structure of the tractor fleet of the Russian agro-industrial complex is conventionally divided into four categories (see Table 3). At the same time, more than 50% of tractors fall into three traction classes (1.4; 2 and 3), which are the most common in farms. Based on the existing patterns, it can be determined that in the zones of moderately harsh, harsh, very harsh, and the harshest cold climates, there are approximately 88,100 tractors of the specified classes. It is quite obvious that not all tractors are operated for a full shift every day, especially in winter. Therefore, it is advisable in calculations to start from one operating unit, increasing the obtained data by the number of working tractors if necessary.

Taking the above into account, based on the formula (2), the costs associated with fuel overconsumption due to the influence of low ambient temperature can be calculated as follows:

Табл. 3. Структура тракторного парка РФ
Table 3. Structure of the tractor fleet of the Russian Federation

Power, kW (hp)	Traction class	Percentage of total number
Up to 37,0 (50,3)	До 0,9	5
37,1–75,0 (50,3–102,0)	1,4; 2; 3	52
75,1–150,0 (102,1–204,0)	4; 5	27
Over 150,0 (204,0)	5; 6	16

$$И_T = \frac{q_T \cdot N_{en}}{1000 \cdot p} \cdot T_{cn} \cdot D_{pn} \cdot Ц_T, \quad (4)$$

where q_T – specific fuel consumption by the engine, g/kW·h; N_{en} – current engine power losses to overcome resistance in the tractor's powertrain, kW; p – density of diesel fuel kg/m³ (for winter fuel we assume 840 kg/m³); T_{cn} – power loss stabilization time, h; D_{pn} – number of days (shifts) in the work period.

As noted earlier, it was experimentally established that the stabilization of power losses in the T-150 tractor's engine-transmission unit in winter occurs on average within 3 hours of operation. We will assume this dependence is valid for all tractors and will use it in further calculations.

The specific fuel consumption is a technical characteristic of the engine, and its value is known for each tractor brand. As the calculation period, we will take the number of working days or shifts during which the tractor was operated (for example, 10 days). Also, for the purpose of calculations, we will assume that the price of 1 liter of diesel fuel is 60 rubles, and the power loss is 5 kW. As examples of tractors, we will use MTZ models belonging to the three traction classes mentioned above (MTZ-80, MTZ-1221, MTZ-2022).

Simple calculations using formula (4) with the accepted initial data show that for MTZ-80

¹¹Climate of Novosibirsk and the Novosibirsk Region // FSBI “West Siberian AHM”: website.URL: <http://www.meteo-nso.ru/pages/46>.

¹²Results of the All-Russian Agricultural Census 2016: statistical collection / Federal State Statistics Service (Rosstat). Moscow, 2018, vol. 6: Technical means, production facilities and infrastructure, 526 p. (<https://rosstat.gov.ru/vshp/2016>).

and MTZ-1221 tractors, the costs of fuel overconsumption will amount to about 2420 rubles for ten shifts per tractor. For the MTZ-2022 tractor with an MMZ D-260 engine, the costs will be about 2360 rubles, and with a TCD0213L06-2V engine – about 2670 rubles. According to the calculated data, even with minimal power losses, there are significant costs, which increase exponentially with the decrease in ambient air temperature and accumulate according to the number of tractors and machines in operation.

Thus, the obtained results indicate the necessity of developing the methods and means to reduce power losses in the motor-transmission unit in order to increase the economic efficiency of MTF operation.

One of the promising directions for solving the problems of winter operation (in particular, reducing power losses in the powertrain) is to ensure optimal temperatures in the powertrain components through the implementation of technical solutions for the secondary use of waste heat from the internal combustion engine. Research in this direction is actively being carried out by the members of the author team of this article [13].

CONCLUSIONS

1. It has been established that about 75% of the territory of our country is located in the zones of harsh, very harsh, and the most severe climate, while only 27 subjects of the Russian Federation are situated here.

2. Analysis of the distribution of the tractor fleet by zones of technical severity of cold climates shows that about 57% of tractors are subject to periodic negative effects of cold climate during operation, and about 22% experience such effects constantly.

3. The main factor having the maximum negative impact on the operational efficiency of the MTF is low ambient temperature.

4. Calculations of the costs associated with the overconsumption of fuel by a tractor engine in winter conditions indicate the existing poten-

tial for improving economic efficiency and the need to develop methods and means to ensure optimal temperature regimes in the units and assemblies of the tractor's powertrain.

СПИСОК ЛИТЕРАТУРЫ

1. Бокучава Д.Д., Бородин Т.Л., Виноградова В.В., Глезер О.Б., Золотокрылин А.Н., Соколов И.А., Титкова Т.Б., Черенкова Е.А., Ширяева А.В. Природно-климатические условия и социально-географическое пространство России: монография. М., 2018. 154 с.
2. Мингалев Д.Э. Агроклиматическое районирование России и Казахстана в условиях современного изменения климата // География и природные ресурсы. 2021. Т. 42. № 2. С. 24–31. DOI: 10.15372/GIPR20210203.
3. Родионов Ю.В., Пантелеев П.Т., Ломовских А.Е., Свиридов А.А., Руденко С.В., Рыбин Г.В. Методика определения технического состояния автотракторных средств с применением автоматизированной системы контроля и диагностики в условиях низких температур // Наука в Центральной России. 2024. № 3 (69). С. 61–72. DOI: 10.35887/2305-2538-2024-3-61-72.
4. Якубович А.Н., Якубович И.А. Оценка климатических рисков в отношении транспортной инфраструктуры северных регионов России // Интеллект. Инновации. Инвестиции. 2021. № 2. С. 96–104. DOI: 10.25198/2077-7175-2021-2-96.
5. Виссер О. Западные агроинвесторы в России и Украине: очарованные почвой – разочарованные климатом // Крестьяноведение. 2021. Т. 6. № 4. С. 21–49. DOI: 10.22394/2500-1809-2021-6-4-21-49.
6. Школьник И.М., Акентьева Е.М., Ключева М.В., Стадник В.В., Хлебникова Е.И., Фасолько Д.В., Разова Е.Н., Рудакова Ю.Л., Павлова В.Н. Федеральные округа России: изменения климата и экономика // Труды Главной геофизической обсерватории им. А.И. Воейкова. 2022. № 604. С. 55–201.
7. Разянов М.М. Повышение надежности агрегатов трансмиссии автотракторной техники при эксплуатации в условиях низких температур // Инновации в АПК: проблемы и перспективы. 2020. № 2 (26). С. 77–86.
8. Гринчар Н.Г., Шильяев Н.А. О влиянии отрицательных температур на гидравлические потери в объемном гидроприводе машин //

- Известия Тульского государственного университета. Технические науки. 2022. № 7. С. 309–314. DOI: 10.24412/2071-6168-2022-7-309-314.
9. Александрова Д.С., Злобина И.В., Егоров А.С., Анисимов А.В. Влияние неблагоприятных климатических факторов, характерных для Арктической зоны, на свойства полимерных материалов и композитов (обзор) // Вопросы материаловедения. 2023. № 4 (116). С. 144–168. DOI: 10.22349/1994-6716-2023-116-4-144-168.
10. Агеева Е.В., Щербаков А.В. Повышение эффективности запуска ДВС автомобилей при низких температурах // Мир транспорта и технологических машин. 2020. № 4 (71). С. 19–28. DOI: 10.33979/2073-7432-2020-71-4-19-28.
11. Сырбаков А.П., Бережнов Н.Н., Корчуганова М.А., Матяш С.П. Тепловая подготовка дизельных двигателей // Вестник Алтайского государственного аграрного университета. 2019. № 8 (178). С. 167–174.
12. Кучер А.В., Кривуца З.Ф., Щитов С.В., Кузнецов Е.Е. Повышение пусковых качеств источников энергии автомобиля при адаптации к условиям низкотемпературного использования в агропромышленном комплексе // Известия Оренбургского государственного аграрного университета. 2021. № 4 (90). С. 173–178.
13. Иванов Н.М., Иванников А.Б., Дусантаев А.И., Крохта Г.М., Крум В.А. Технологическая схема использования теплоты отработавших газов самоходной машины // Сельскохозяйственные машины и технологии. 2024. Т. 18. № 3. С. 23–30. DOI: 10.22314/2073-7599-2024-18-3-23-30.
- bin G.V. Methodology for determining the technical condition of automotive vehicles using an automated control system and diagnostics at low temperatures. *Nauka v Central'noj Rossii = Science in Central Russia*, 2024, no. 3 (69), pp. 61–72. (In Russian). DOI: 10.35887/2305-2538-2024-3-61-72.
4. Yakubovich A.N., Yakubovich I.A. Assessment of climatic risks in relation to the transport infrastructure of the northern regions of Russia. *Intellect. Innovacii. Investicii = Intelligence. Innovation. Investment*, 2021, no. 2, pp. 96–104. (In Russian). DOI: 10.25198/2077-7175-2021-2-96.
5. Visser O. Western agricultural investors in Russia and Ukraine: from fascination with soil to disappointment with climate. *Krest'yanovedenie = Russian Peasant Studies*, 2021, vol. 6, no 4, pp. 21–49. (In Russian). DOI: 10.22394/2500-1809-2021-6-4-21-49.
6. Shkolnik I.M., Akentieva E.M., Klyueva M.V., Stadnik V.V., Khlebnikova E.I., Fasolko D.V., Razova E.N., Rudakova Yu.L., Pavlova V.N. Federal districts of Russia: climate change and economics. *Trudy Glavnoj geofizicheskoy observatorii im. A.I. Voejkova = Proceedings of Voeikov Main Geophysical Observatory*, 2022, no. 604, pp. 55–201. (In Russian).
7. Razyapov M.M. Increasing the reliability of transmission units of autotractor equipment when operating under the conditions of low temperatures. *Innovacii v APK: problemy i perspektivy = Innovations in agricultural complex: problems and perspectives*, 2020, no. 2 (26), pp. 77–86. (In Russian).
8. Grinchar N.G., Shilyaev N.A. On the effect of negative temperatures on hydraulic losses in the volumetric hydraulic drive of machines. *Izvestiya Tul'skogo gosudarstvennogo universiteta. Tekhnicheskie nauki = News of the Tula state university*, 2022, no. 7, pp. 309–314. (In Russian). DOI: 10.24412/2071-6168-2022-7-309-314.
9. Alexandrova D.S., Zlobina I.V., Egorov A.S., Anisimov A.V. Influence of unfavorable climatic factors characteristic of the arctic zone on the properties of polymeric materials and composites: a review. *Voprosy materialovedeniya = Problems of Materials Science*, 2023, no. 4 (116), pp. 144–168. (In Russian). DOI: 10.22349/1994-6716-2023-116-4-144-168.

REFERENCES

1. Bokuchava D.D., Borodina T.L., Vinogradova V.V., Glezer O.B., Zolotokrylin A.N., Sokolov I.A., Titkova T.B., Cherenkova E.A., Shiryayeva A.V. *Natural and climatic conditions and socio-geographical space of Russia*. Moscow, 2018, 154 p. (In Russian).
2. Mingalev D.E. Agro-climatic zoning of Russia and Kazakhstan under current climate change. *Geografiya i prirodnye resursy = Geography and Natural Resources*, 2021, vol. 42, no. 2, pp. 24–31. (In Russian). DOI: 10.15372/GIPR20210203.
3. Rodionov Yu.V., Panteleev P.T., Lomovskikh A.E., Sviridov A.A., Rudenko S.V., Ry-

10. Ageeva E.V., Shcherbakov A.V. Improving the efficiency of starting the internal combustion engine of cars at low temperatures. *Mir transporta i tekhnologicheskikh mashin = World of transport and technological machinery*, 2020, no. 4 (71), pp. 19–28. (In Russian). DOI: 10.33979/2073-7432-2020-71-4-19-28.
11. Syrbakov A.P., Berezhnov N.N., Korchuganova M.A., Matyash S.P. Thermal preparation of diesel engines. *Vestnik Altajskogo gosudarstvennogo agrarnogo universiteta = Bulletin of Altai State Agricultural University*, 2019, no. 8 (178), pp. 167–174. (In Russian).
12. Kucher A.V., Krivutsa Z.F., Shchitov S.V., Kuznetsov E.E. Improving the starting qualities of car energy sources when adapting to the conditions of low-temperature use in the agro-industrial complex. *Izvestiya Orenburgskogo gosudarstvennogo agrarnogo universiteta = Izvestia Orenburg State Agrarian University*, 2021, no. 4 (90), pp. 173–178. (In Russian).
13. Ivanov N.M., Ivannikov A.B., Dusantaev A.I., Krokhta G.M., Krom V.A. Technological scheme for utilizing exhaust gas heat from a self-propelled machine. *Sel'skohozyajstvennyye mashiny i tekhnologii = Agricultural Machinery and Technologies*, 2024, vol. 18, no. 3, pp. 23–30. (In Russian). DOI: 10.22314/2073-7599-2024-18-3-23-30.

ИНФОРМАЦИЯ ОБ АВТОРАХ

✉ **Иваников Алексей Борисович**, ведущий научный сотрудник, кандидат технических наук, доцент; SPIN-код 2305-9701; **адрес для переписки:** Россия, 630501, Новосибирская область, р.п. Краснообск, а/я 463; e-mail: ivannikov-ab@sfscs.ru

Деменок Ирина Васильевна, старший научный сотрудник, кандидат технических наук; SPIN-код 3852-8034

Кононенко Николай Владимирович, научный сотрудник; SPIN-код 1389-3340

Ильиченков Александр Сергеевич, преподаватель, доцент; SPIN-код 2150-4970

AUTHOR INFORMATION

✉ **Alexei B. Ivannikov**, Lead Researcher, Candidate of Science in Engineering, Associate Professor; SPIN-code 2305-9701; **address:** PO Box 463, Krasnoobsk, Novosibirsk Region, 630501, Russia; e-mail: ivannikovab@sfscs.ru

Irina V. Demenok, Senior Researcher, Candidate of Science in Engineering; SPIN-code 3852-8034

Nikolai V. Kononenko, Researcher; SPIN-code 1389-3340

Alexander S. Ilyichenkov, Lecturer, Associate Professor; SPIN-code 2150-4970

Дата поступления статьи / Received by the editors 18.07.2025
Дата принятия к публикации / Accepted for publication 02.09.2025
Дата публикации / Published 10.02.2026

Применение кольцевых и винтовых катков при посеве пшеницы по обработанной залежной почве

✉ Яковлев Н.С., Рассомахин Г.К., Чернышов А.П.

Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Новосибирская область, р.п. Краснообск, Россия

✉ e-mail: yakovlevns@sfscs.ru

В статье представлены результаты сравнительных испытаний кольцевого и винтового катков на посеве пшеницы по обработанной залежной почве. Полевые эксперименты проводили на полигоне Сибирского научно-исследовательского института механизации и электрификации сельского хозяйства и на опытном поле Сибирского научно-исследовательского института кормов с апреля по сентябрь 2024 г. Для обработки залежной почвы использовали почвообрабатывающий агрегат КЛ-2,5Н, для посева – экспериментальную посевную машину ППМ-2,5ЗТ. Рабочий орган КЛ-2,5Н и ППМ-2,5ЗТ изготовлен в виде стандартной прямой стойки с лапой размером 410 мм. Кольцевой каток состоит из отдельных колец в форме усеченного конуса, с определенным шагом собранных в батареи, винтовой каток – из навитой по спирали с определенным шагом ленты. Ширина ленты у винтового катка такая же, как и у кольцевого, – 40 мм, толщина – 8 мм. В результате расчетов установлено, что у кольцевого катка сила реакции почвы, оказывающая сопротивление перемещению кольца, значительно превышает силу, препятствующую деформации почвы. Соответственно, при малом угле атаки почва, поднятая ободом кольца, оставит высокие гребни. У винтового катка сила сопротивления перемещению ленты и сила, препятствующая деформации почвы, практически равны. Следовательно, увеличение угла атаки приведет к большему перемещению почвы и увеличению высоты гребней. В результате полевого эксперимента установлено, что при работе в активном режиме у винтового катка минимальная высота гребня получена при установке катка на угол атаки 15°, у кольцевого – 25°. При восстановлении залежных земель, находящихся в пионерной стадии, необходимо использовать кольцевые или винтовые катки для выравнивания поверхности поля и вычесывания сорняков. Весеннюю обработку при подготовке к посеву целесообразно проводить культиваторами, оборудованными кольцевыми катками, предпосевную обработку – кольцевой бороной.

Ключевые слова: почва, кольцевой и винтовой катки, залежные земли, сорняки, угол атаки, посев

Using ring and screw rollers when sowing wheat on cultivated fallow soil

✉ Yakovlev N.S., Rassomakhin G.K., Chernyshov A.P.

Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk region, Russia

✉ e-mail: yakovlevns@sfscs.ru

The article presents the results of comparative tests of ring and screw rollers for sowing wheat on cultivated fallow soil. Field experiments were conducted at the site of the Siberian Research Institute of Mechanization and Electrification of Agriculture and at the experimental field of the Siberian Research Institute of Fodder Crops from April to September 2024. Fallow soil was cultivated with the KL-2.5N tillage unit, and sowing was carried out with the PPM-2.5ZT experimental seeding machine. The working body of the KL-2.5N and PPM-2.5ZT is designed as a standard straight rack with a 410 mm paw. The ring roller consists of individual rings made in the shape of a truncated cone, assembled into batteries with a certain pitch, and the screw roller is made of a tape wound in a spiral with a certain pitch. The width of the belt of the screw roller is the same as that of the ring roller (40 mm), the thickness is 8 mm. As a result of calculations, it was established that for a ring roller, the soil reaction force that resists the movement of the ring significantly exceeds the force that prevents soil deformation. Accordingly, at a low angle of attack, the soil raised by the rim of the ring will leave high ridges. In a screw roller, the force of resistance to belt movement and the force preventing soil deformation are practically equal. Therefore, increasing the angle of attack will result in greater soil movement and

increased ridge height. As a result of the field experiment, it was established that when operating in an active mode, the minimum ridge height of the screw roller was obtained when the roller was set to an attack angle of 15°, and for the ring roller it was 25°. When restoring fallow lands in the pioneer stage, it is necessary to use ring or screw rollers to level the field surface and remove weeds. Spring tillage in preparation for sowing is best carried out with cultivators equipped with ring rollers, and pre-sowing cultivation should be carried out with a ring harrow.

Keywords: soil, ring roller and screw roller, fallow lands, weeds, angle of attack, sowing

Для цитирования: Яковлев Н.С., Рассомахин Г.К., Чернышов А.П. Применение кольцевых и винтовых катков при посеве пшеницы по обработанной залежной почве // Сибирский вестник сельскохозяйственной науки. 2026. Т. 56. № 1. С. 107–118. <https://doi.org/10.26898/0370-8799-2026-1-12>

For citation: Yakovlev N.S., Rassomakhin G.K., Chernyshov A.P. Using ring and screw rollers when sowing wheat on cultivated fallow soil. *Sibirskii vestnik sel'skokhozyaistvennoi nauki* = *Siberian Herald of Agricultural Science*, 2026, vol. 56, no. 1, pp. 107–118. <https://doi.org/10.26898/0370-8799-2026-1-12>

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Conflict of interest

The authors declare no conflict of interest.

INTRODUCTION

When cultivating soil for grain crops, leveling the field and clearing it of weeds are crucial. This problem is especially pressing when restoring abandoned fields during the first five years, when the neglected field is in its pioneer stage and the sod layer has not yet formed. The field is overgrown with weeds, and the surface soil contains a large number of weed seeds. Weedy vegetation has a powerful root system and large, tall stems, which makes it difficult to cultivate such fields. According to agrotechnical requirements, when sowing cereal crops, the height of the ridges on the field surface after the passage of the implement should not exceed 30 mm. According to the results of our research, when working with fallow soils, it is most advisable to use ring or helical rollers as raking and leveling devices [1].

Similar research is conducted by many scientific organizations. The greatest interest is shown in ring rollers as the most versatile working tools. Thus, at the Institute of Agroengineering and Environmental Problems of Agricultural Production, technologies and technical means with ring working tools were studied for the primary restoration of fallow lands in the North-

western region of the Russian Federation, which is a zone of increased moisture [2–5]. Experimental samples of new soil-cultivating working bodies were created, which ensure a reduction in energy consumption and environmental impact, and improve soil treatment quality [6, 7]. Employees of the Tver Agricultural Academy recommend using a soil-treating rod roller after a set of measures for bringing fallow land into circulation. According to their data, this contributes to obtaining a well-prepared soil surface for sowing [8, 9].

Research aimed at identifying effective methods for developing virgin lands was carried out at the All-Russian Scientific Research Institute of Agriculture and Soil Erosion Protection. It was established that soil treatment with the BDT-3 disc harrow leads to increased weediness, thinning of crops, weaker crop development, and reduced yields compared to plowing¹. At the Voronezh State Agrarian University, together with the All-Russian Scientific Research Institute of Plant Protection, experiments were conducted at the ООО "Lebyazhye" (Ramonsky District, Voronezh Region) on weed control in fallow lands. The treatment involved using disc

¹Cherkasov G.N., Sosov N.A. The effectiveness of the method of developing fallow lands for grain crops on the slopes of the Central Black Earth region // *Achievements of Science and Technology of AIC*, 2016, vol. 30, N 2, pp. 35–37.

implements to turn the soil layer on its edge². At the National Research Mordovia State University named after N. P. Ogarev, the effectiveness of the combined use of the herbicide 'Roundup' and treatment with a disc harrow on fallow lands is being studied [10].

The problem of returning fallow lands to agricultural use is addressed, in particular, by specialists of the All-Russian Research Institute of Hydraulic Engineering and Land Reclamation named after A.N. Kostyakov. Thus, based on conducted studies, the feasibility of further use of lands withdrawn from circulation is established depending on the age of the fallow period [11]. Weed control in organic farming means using cultivation methods that allow fighting rhizomes by bringing them to the surface of the soil, where they wither and dry out. At the Soil Science and Agrochemistry Institute of the Siberian Branch of the Russian Academy of Sciences, research was conducted to determine the plant cover of middle-aged fallows in the forest-steppe zone of the Novosibirsk region [12]. It was noted that hay mowing and grass burning block the development of succession, returning it to previous stages of overgrowth³.

The purpose of the study is to examine the influence of the operating mode of ring and screw rollers on the quality of wheat sowing on treated fallow land.

The research objectives are:

1) the identification of patterns of changes in the surface ridgedness of the field depending on the angle of attack and the operating mode of the rollers;

2) assessment of the impact of rollers on weed removal when sowing wheat using no-till technology after the destruction of weed vegetation.

MATERIAL AND METHODS

Field experiments were conducted at the testing ground of the Siberian Research Institute of Mechanization and Electrification of Agriculture and at the experimental field of the Siberian Research Institute of Fodder Crops from April to September 2024. Fallow land was cultivated with the KL-2.5N soil cultivation unit, and sowing was carried out using the experimental sowing machine PPM-2.5ZT.

The units used are adapted for operation with the MTZ 80 tractor. The working body KL-2.5N and PPM-2.5ZT is made in the form of a standard straight tine with a foot 410 mm in size [13]. The ring roller consists of individual rings in the shape of a truncated cone, assembled in banks at a certain pitch (Fig. 1, *a*). When the machine moves, the rings of the roller capture a part of the soil with their inner surface and move it to the side, while cutting the ridges and filling the furrows. The screw roller consists of a tape wound in a spiral with a certain pitch (Fig. 1, *b*). The belt width of the screw roller is the same as that of the ring roller, – 40 mm, thickness – 8 mm. Two spirals with a pitch of 190 mm are wound onto a roller with a diameter of 500 mm. The screw roller, like the ring roller, moves the soil as a result of shearing and tossing [14] (see Fig. 2).

The effect of the roller ring on the soil depends on its geometric dimensions, attack angle, as well as the speed of the machine⁴.

When moving, the roller ring leaves a furrow bottom in the soil in the form of a sector of a circle. Between the sectors along the furrow bottom, ridges are formed, the height of which depends on the diameter of the roller ring, the distance between the rings, and the attack angle of the roller⁵:

²Saratovsky L.I., Khryukina E.I. Use of fallow lands // Plant Protection and Quarantine, 2008, N 10, pp. 38–41.

³Miller G.F., Solovov S.V., Bezborodova A.N., Filimonova D.A., Chumbaev A.S. Revisiting the changes of some properties of the soil developed under young fallow on the territory of the Novosibirsk region // Modern problems of science and education, 2017, N 6, URL: <https://science-education.ru/ru/article/view?id=27133>.

⁴Yakovlev N.S., Kolinko P.V. Soil displacement by the ring of a ring roller // Agricultural machinery and technologies, 2013, N 3, pp. 32–34.

⁵Yakovlev N.S., Kolinko P.V. Interaction of a ring roller with soil // Siberian Herald of Agricultural Science, 2012, N 3 (226), pp. 95–100.



Рис. 1. Катки на посевной машине:

a – кольцевой; *б* – винтовой

Fig. 1. Rollers on a seeding machine:

a – ring; *б* – screw

$$h = \frac{D}{2} - \frac{1}{2} \sqrt{D^2 - b_1^2 \cdot c \cdot \operatorname{tg} \alpha}, \quad (1)$$

where h – ridge height, m; D – roller diameter, m; b_1 – distance between the rings of the roller, m; α – roller attack angle, degrees.

The distance between the crests is determined from the ratio

$$c = 2 \sin \alpha \cdot \sqrt{h \cdot (D - h)}, \quad (2)$$

where c – distance between the crests, m.

When the unit moves, the ring of the ring roller cuts into the soil with a force P , which can be broken down into two components: P_1 – a force acting perpendicular to the plane of the ring rim; P_2 – a force acting perpendicular to the end of the ring rim (see Fig. 3, *a*). Accordingly, forces P_1 and P_2 cause soil reactions R_1 and R_2 . In turn,

reaction R_1 can be decomposed into the force R_B , acting in the plane of the roller's rotation and rotating it with an angular velocity ω around the axis, and force R_C , counteracting the displacement of the roller towards its turning. Reaction R_2 can be broken down into the resistance force to the movement of the ring in the soil R_{Π} , acting in the plane perpendicular to the roller's rotation, and the soil's resistance force to deformation during its compaction R_{Δ} . Given the fact that $P_1 = R_1$, and $P_2 = R_2$, we have

$$R_1 = P \cdot \cos(\alpha + \sigma); \quad (3)$$

$$R_2 = P \cdot \sin(\alpha + \sigma), \quad (4)$$

where P – pressure force of the roller ring on the soil; α – roller attack angle; σ – the angle of inclination of the roller ring rim to its axis of rotation.

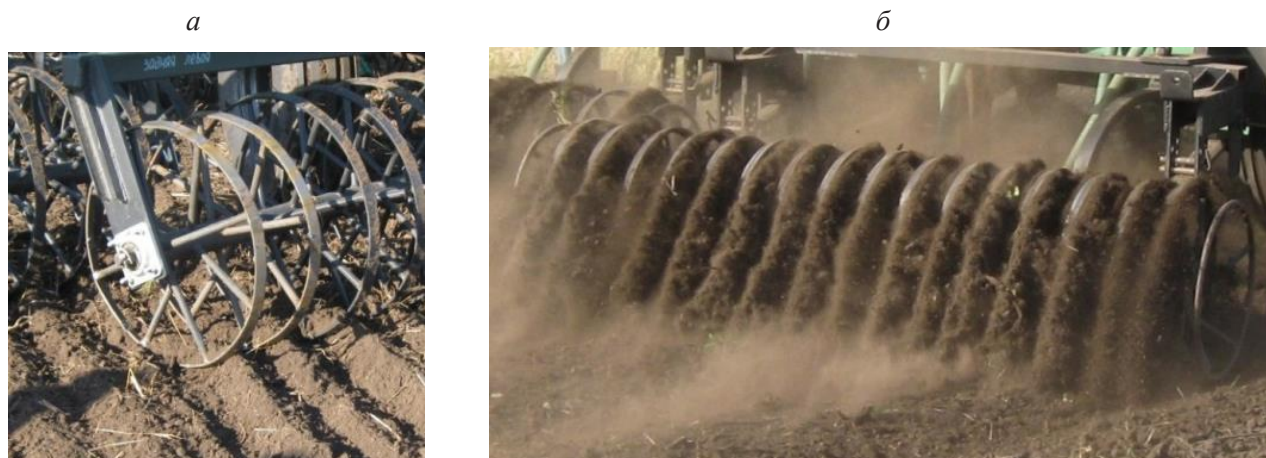


Рис. 2. Перемещение почвы кольцами кольцевого катка:

a – сдвиг; *б* – сдвиг и пересыпание

Fig. 2. Soil movement by rings of a ring roller:

a – shift; *б* – shift and pouring

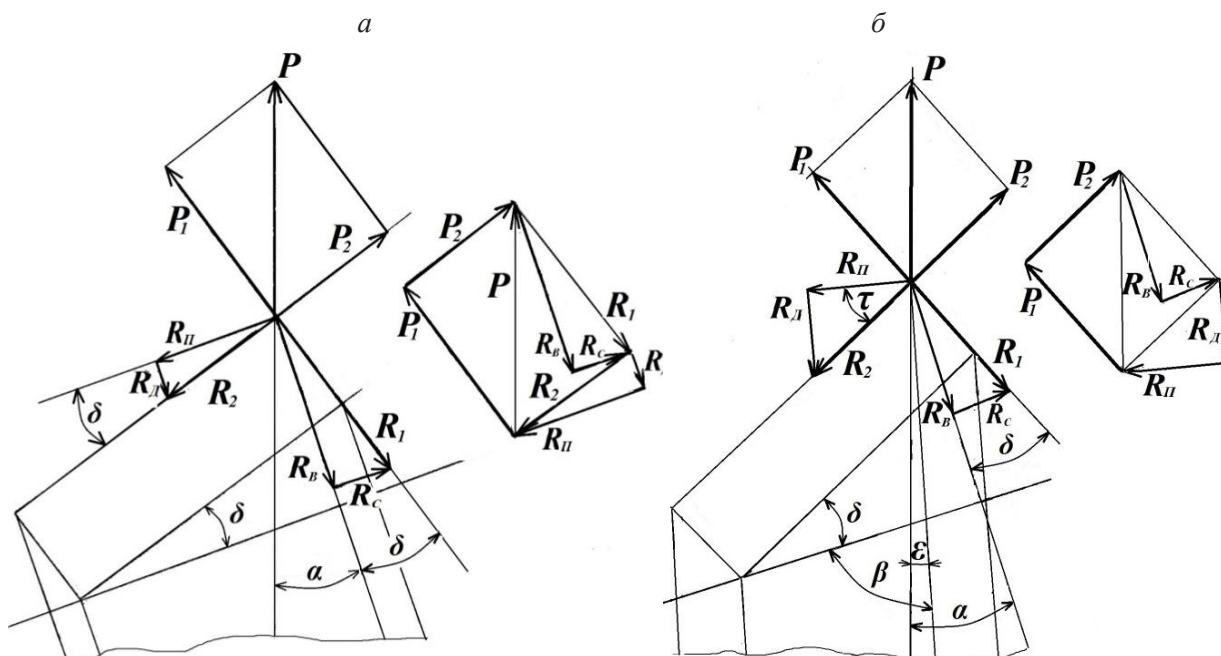


Рис. 3. Силы, действующие на грань катка:

a – кольцевого; *б* – винтового

Fig. 3. Forces acting on the edge of the roller:

a – ring; *б* – screw

As a result, the force that rotates the roller around the axis can be determined by the formula

$$R_B = P \cdot \cos(\alpha + \sigma) \cdot \cos \sigma, \quad (5)$$

and the force opposing the displacement of the roller in the direction of its rotation – using the expression

$$R_C = P \cdot \cos(\alpha + \sigma) \cdot \sin \sigma. \quad (6)$$

Accordingly, the force resisting the movement of the ring in the soil and the force resisting the deformation of the soil can be determined by the formulas

$$R_{II} = P \cdot \sin(\alpha + \sigma) \cdot \cos \sigma; \quad (7)$$

$$R_{II} = P \cdot \sin(\alpha + \sigma) \cdot \sin \sigma. \quad (8)$$

When the helical roller moves, the edge of the helical belt also cuts into the soil with a force

P , which can be broken down into the following components: P_1 – a force acting perpendicular to the plane of the tape rim; P_2 – a force acting perpendicular to the end of the tape (see Fig. 3, δ). Soil reactions R_1 and P_2 from the actions of forces P_1 and P_2 can also be decomposed into two component forces: R_1 – into force R_B , rotating the roller around the axis, and force R_C , counteracting the roller's displacement toward its rotation; R_2 – into force R_{Π} , which is trying to turn the roller, and force R_{Δ} , preventing soil deformation (compaction). These forces can be determined by formulas (3) – (6). The force acting in the plane perpendicular to the rotation of the roller and tending to turn the roller is calculated by the formula

$$R_{\Pi} = P \cdot \sin(\alpha + \sigma) \cdot \cos \tau, \quad (9)$$

and the force resisting soil deformation – using the expression

$$R_{\Delta} = P \cdot \sin(\alpha + \sigma) \cdot \sin \tau, \quad (10)$$

where τ – the angle between the perpendicular to the direction of the line of contact of the tape end with the soil and the surface of the tape rim, determined by the formula

$$R_{\Delta} = P \cdot \sin(\alpha + \sigma) \cdot \sin \tau, \quad (10)$$

where β – helix belt entry angle.

Analyzing the calculation results presented as

graphs in Fig. 4, it can be noted that the ring roller's soil reaction force R_{Π} , resisting the movement of the ring, significantly exceeds force R_{Δ} , preventing soil deformation. Consequently, with an increase in the angle of attack α the soil will rise along the rim of the ring and scatter over a larger area, hiding the ridges formed by its shift. In a screw roller, the soil resistance to movement R_{Π} and the force R_{Δ} , which prevents soil deformation, are practically equal. Thus, increasing the attack angle will lead to greater soil displacement and an increase in the height of the ridges.

The identification of patterns in the change of ridging and field contamination when sowing wheat on treated fallow soil depending on the type of roller, its installation angle, and mode of operation was carried out at a working speed of 7.25 km/h, which corresponds to the third gear of the MTZ-80L tractor. When the speed of the unit increased, the soil was thrown to the side opposite to the roller installation angle, which made measuring the ridges difficult. In addition, lateral forces caused the roller to drift to the side, and the attack angle of the roller changed.

Ring and screw rollers were installed in active (base of the cone in the direction of the machine) and passive modes of operation (apex of the cone in the direction of the machine). At

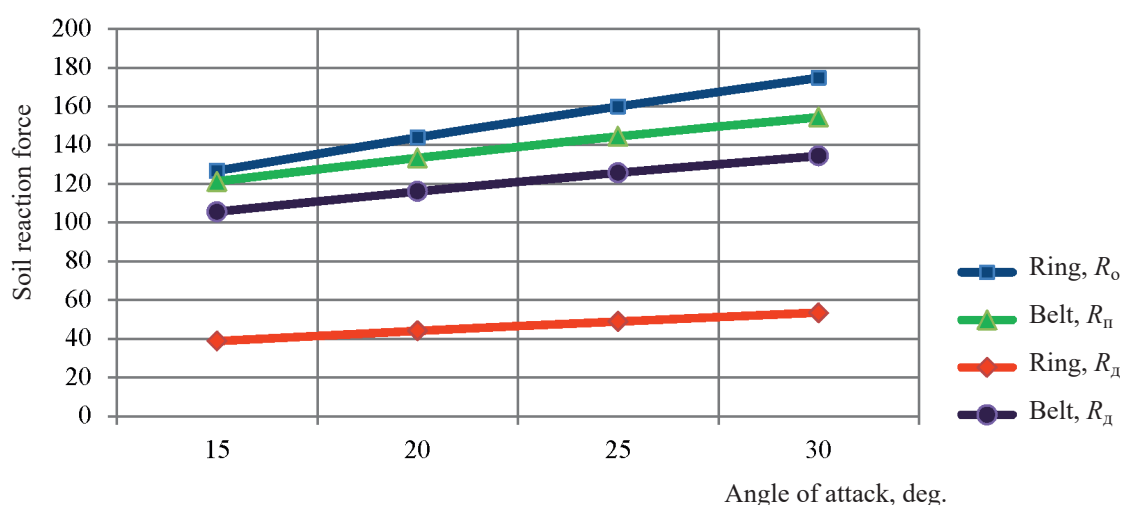


Рис. 4. Изменение сил давления почвы R_{Π} и R_{Δ} на торец кольца и ленты у кольцевого и винтового катков в зависимости от угла атаки

Fig. 4. Change in soil pressure forces R_{Π} and R_{Δ} on the end of the ring and belt of a ring and screw roller depending on the angle of attack

the same time, the attack angle was 15, 20, and 25° at a working speed of 7.25 km/h, which allowed for stable operation of the sowing unit. In the active position, the roller ring works like a plowshare, cutting into the soil; in the passive position, it works like a roller, pressing the soil. The rollers were installed behind the sowing machine, which sowed grain crops under the paw. The sowing strip was 20–22 cm with a row spacing of 14–16 cm.

The field trial scheme for determining the performance quality of rollers is shown in Fig. 5. The field trial was established on May 31, 2024, at the field of the Siberian Research Institute of Fodder Crops. The seeding machine in operation is shown in Fig. 6.

The field was left fallow until 2023 and became overgrown with weeds. In the autumn of 2023, the weeds were mowed with a KRN-2.1 mower, after which it was treated with a BDN-2.5 disc harrow. The characteristics of the field were the presence of a large number of organic residues from dense weedy vegetation and a high infestation with weed seeds.

The field was divided into two plots: the first, measuring 30 × 170 m, was cultivated before sowing with a KL-2.5N cultivator-ripper, while the second was left uncultivated. On the cultivated plot, the surface roughness was determined. At the same time, the rollers were set to active and passive operating modes at attack angles of 15, 20, and 25°. In the untreated area, the oper-

Cultivated field												Uncultivated field											
Ring roller Active mode			Ring roller Passive mode			Screw roller Active mode			Screw roller Passive mode			Ring roller Active mode			Ring roller Passive mode			Screw roller Active mode			Screw roller Passive mode		
15	20	25	25	20	15	25	20	15	15	20	25	15	20	25	25	20	15	25	20	15	15	20	25
Roller installation angle, degrees																							

Рис. 5. Схема полевого опыта по определению качества работы катков
Fig. 5. Scheme of field experiment to determine the quality of roller operation



Рис. 6. Посев пшеницы посевной машиной ППМ-2,53Т на опытном поле
Fig. 6. Sowing wheat with the PPM-2.5ZT seeding machine on an experimental field

ation of the rollers was tested for the quality of weed combing during sowing using the no-till technology. The rollers were also set to active and passive modes of operation at attack angles of 15, 20, and 25°. The installation of the attack angle was carried out by moving the beams along the guide rails. Field roughness measurements were carried out using an overlay rail along the working width of the seeding machine. Roughness was measured along the length of the run in three locations. The length of the run was 170 m. Field roughness was determined as the average value of the three measurements. Experimental data were processed using mathematical and statistical methods [15].

RESULTS AND DISCUSSION

Based on theoretical studies of the interaction of pressure forces of ring and screw rollers on

the soil, it can be noted that for the ring roller, as the attack angle increases, the soil pressure on the end of the roller rim decreases, so the ridge should be reduced; for the screw roller, as the attack angle increases, the soil pressure on the end of the roller rim increases, therefore, the ridge should be increased. Generalized data of field ridge measurements are presented in Table 1, and graphs were constructed based on the measurement results (see Fig. 7).

Analyzing the graphs presented in Fig. 7, it can be noted that for the screw roller, the height of the ridges increases with the attack angle (more intensively in the active operating mode). According to the results of three measurements, the minimum ridge height for the screw roller was recorded in the active operating mode at an attack angle of 15°, and for the ring roller – in the active operating mode at an attack angle of

Табл. 1. Гребнистость поверхности поля после посева сеялкой с кольцевым и винтовым катками, мм
Table 1. Field surface ridge after sowing with a seeder with ring and screw rollers, mm

Measurement number	Ring roller						Screw roller					
	Active mode			Passive mode			Active mode			Passive mode		
	Roller installation angle, degrees											
	15	20	25	25	20	15	25	20	15	15	20	25
1	24,2	23,5	16,8	30,0	20,8	21,8	22,5	22,0	29,5	25,0	31,0	19,8
2	21,3	9,8	11,3	17,0	17,0	15,5	23,3	24,3	10,3	22,5	21,0	33,5
3	13,5	14,5	16,3	16,5	14,0	15,8	36,3	15,8	15,8	16,0	14,5	25,8
Average	19,6	15,9	14,8	21,2	17,3	17,7	27,3	20,7	18,5	21,2	22,2	26,3

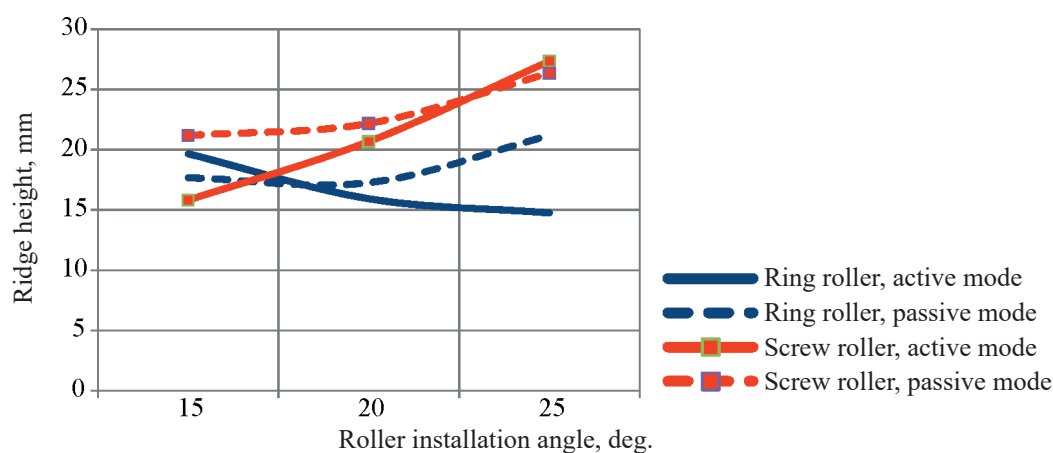


Рис. 7. Изменение гребнистости поля при обработке кольцевым и винтовым катками
Fig. 7. Change in field ridgeness during processing with ring and screw rollers



Рис. 8. Посев по обработанному (а) и необработанному (б) фону 31.05.2024 г.
Fig. 8. Sowing on the treated (a) and untreated (b) background 31.05.2024

Табл. 2. Количество сорняков при посеве по необработанному фону, шт./м²
Table 2. Presence of weeds per square meter when sowing on an untreated background, pcs./m²

Roller	Mode	Roller installation angle, degrees	Repetition				Average
			1	2	3	4	
Ring	Active	15	9	19	20	30	20
		20	3	4	2	2	3
		25	8	18	19	6	14
	Passive	25	9	20	29	3	15
		20	5	17	10	6	10
		15	13	16	18	12	15
Screw	Active	25	9	8	3	5	4
		20	11	7	4	7	7
		15	13	10	8	5	9
	Passive	15	12	9	7	10	10
		20	14	7	10	11	11
		25	13	17	7	13	12

25°. Considering that the ridge of the ring roller noticeably decreases when operating in active mode at an angle of attack of 20°, it can be concluded that the ring roller in active operation mode should be set at an angle of attack of 20°.

In Fig. 8 a, a field with wheat crops hoed over

a treated background is shown. No weeds beyond the permissible limit are observed, despite the fact that part of the field was treated 2 hours before sowing the wheat.

On the untreated plot during the spring period, sowing was carried out using the no-till tech-

nology. According to the experimental scheme, the rollers were set to active and passive operating modes at attack angles of 15, 20, and 25°. The results of weed counting on the plot are presented in Table 2. Analyzing the obtained results, it can be concluded that a single treatment of unprepared soil during sowing does not provide guaranteed weed-free crops. In almost all sowing options on untreated fields, a large number of weeds remain (see Fig. 8 б). The results differ only for the helical roller when operating in active mode. However, this could have been influenced by the presence of an area with a small number of weeds, as the first and second measurements showed almost identical results compared to the operation of the rollers in other modes. The small number of weeds in the third and fourth measurements occurred in places where the field background differed from the main one. For a more objective assessment, it is necessary to apply the method of randomization.

CONCLUSIONS

1. According to the obtained results, the ring roller's soil reaction force R_{Π} , resisting the movement of the ring, significantly exceeds force $R_{\text{Д}}$, preventing soil deformation. Therefore, the roller ring will not dig deeply into the soil, and at a small angle of attack, the soil lifted by the ring's rim will leave high ridges. In a screw roller, the soil resistance to the movement of the belt R_{Π} and force $R_{\text{Д}}$, hindering soil deformation, are almost equal. Accordingly, increasing the angle of attack will lead to greater soil movement and an increase in the height of the ridges.

2. It has been established that for a screw roller, the ridge height increases with an increase in the attack angle, with a more intense increase in the active operating mode. The minimum ridge height in the active mode corresponds to an attack angle of 15°. For a ring roller, the minimum ridge height is observed when operating in the active mode at an attack angle of 25°. Since for a ring roller the ridge noticeably decreases in the active mode already at an attack angle of 20°,

it is possible to set the ring roller in the active mode at an attack angle of 20°.

3. The technological process for the restoration of fallow lands in the pioneering stage has been justified. Ring or screw rollers for leveling the field surface and combing weeds should be used in accordance with the recommended operating modes. During preparation for sowing, it is advisable to carry out spring cultivation to a depth of 10–12 cm with cultivators equipped with ring rollers, and pre-sowing treatment with a ring harrow.

СПИСОК ЛИТЕРАТУРЫ

1. Яковлев Н.С., Рассомахин Г.К., Иванников А.Б., Чернышов А.П. Изменение физических свойств залежных земель при их восстановлении // Сибирский вестник сельскохозяйственной науки. 2024. Т. 54. № 7. С. 106–116.
2. Шамонин В.И., Джаббаров Н.И. Результаты экспериментальных исследований почвообрабатывающего агрегата УКПА-2,4 с кольцевыми рабочими органами // Технологии и технические средства механизированного производства продукции растениеводства и животноводства. 2020. № 1 (102). С. 55–63.
3. Шамонин В.И. Оценка показателей качества и энергоэффективности в технологиях первичного восстановления залежных земель для условий органического земледелия // Известия Санкт-Петербургского государственного аграрного университета. 2019. № 2 (55). С. 192–198.
4. Ценч Ю.С., Миронова А.В. Эволюция развития землепользования почвенными угодьями (отечественный и зарубежный опыт) // Технический сервис машин. 2023. № 1 (150). С. 176–186.
5. Ахалая Б.Х., Ценч Ю.С., Миронова А.В., Золотарев А.С., Лонин С.Э. Комбинированный почвообрабатывающий агрегат // Сельский механизатор. 2022. № 6. С. 4–5.
6. Миронова А.В., Лискин И.В., Панов А.И. Технология восстановления целинных и залежных земель // Технический сервис машин. 2020. № 2 (139). С. 111–121.
7. Джаббаров Н.И., Шамонин В.И., Сергеев А.В. Энергосберегающая технология восстановления залежных земель // Технологии

- и технические средства механизированного производства продукции растениеводства и животноводства. 2018. № 4 (97). С. 149–159.
8. Ларин Д.В., Голубев В.В. Технологические аспекты введения залежных земель в сельскохозяйственное производство // Международный сельскохозяйственный журнал. 2025. Т. 68. № 3 (405). С. 301–304.
 9. Блинов Ф.Л., Белякова Е.С., Туманов И.В., Берней В.И. Предпосевная обработка залежных земель // Вестник НГИЭИ. 2020. № 11 (114). С. 17–26.
 10. Бочкарев Д.В., Девяткина Т.Ф., Емельянов С.В., Тюкина Е.В., Бочкарев В.Д. Освоению залежных земель – системный подход // Аграрная наука. 2020. № 2. С. 48–50.
 11. Кирейчева Л.В., Шевченко В.А., Юрченко И.Ф. Оценка экономической эффективности ввода в агропроизводство залежных земель Нечерноземной зоны РФ // Московский экономический журнал. 2021. № 3. С. 245–258.
 12. Соловьев С.В., Миллер Г.Ф., Безбородова А.Н., Филимонова Д.А. Сукцессия на молодых и средневозрастных залежах лесостепной зоны Западной Сибири в пределах Новосибирской области // Международный журнал прикладных и фундаментальных исследований. 2018. № 10. С. 116–120.
 13. Яковлев Н.С., Рассомахин Г.К., Чекусов М.С., Чернышов А.П., Черных В.И. Освоение залежных серых лесных почв, находящихся в разнотравно-костровой стадии // Вестник Алтайского государственного аграрного университета. 2024. № 11 (241). С. 85–94.
 14. Лепешкин Н.Д., Мижурин В.В., Филипов А.И., Пузевич К.Л. Анализ конструкций и технологических возможностей почвообрабатывающих катков // Вестник Белорусской государственной сельскохозяйственной академии. 2022. № 4. С. 144–149.
 15. Никифоров М.В., Голубев В.В. Определение критерия качества предпосевной обработки почвы при использовании различных почвообрабатывающих машин // Вестник ФГОУ ВПО «МГАУ им. В.П. Горячкина». 2018. № 6 (88). С. 11–16.
 1. Yakovlev N.S., Rassomakhin G.K., Ivanikov A.B., Chernyshov A.P. Changes in the physical properties of fallow lands during their regeneration. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2024, vol. 54, no. 7, pp. 106–116. (In Russian).
 2. Shamonin V.I., Jabborov N.I. Experimental study of the soil cultivating unit UKPA-2.4 with ring-shaped tools. *Tekhnologii i tekhnicheskie sredstva mekhanizirovannogo proizvodstva produktii rastenievodstva i zhivotnovodstva = Technologies and Technical Means for Mechanized Production of Crop and Livestock Products*, 2020, no. 1 (102), pp. 55–63. (In Russian).
 3. Shamonin V.I. Assessment of indicators of quality and energy efficiency in the technology of primary restoration of fixed lands for conditions of organic farming. *Izvestiya Sankt-Peterburgskogo gosudarstvennogo agrarnogo universiteta = Izvestiya Saint-Petersburg state agrarian university*, 2019, no. 2 (55), pp. 192–198. (In Russian).
 4. Tsench Yu.S., Mironova A.V. Evolution of the soil land use (domestic and foreign experience). *Tekhnicheskii servis mashin = Machinery Technical Service*, 2023, no. 1 (150), pp. 176–186. (In Russian).
 5. Akhalaya B.Kh., Tsench Yu.S., Mironova A.V., Zolotarev A.S., Lonin S.E. Combined tillage unit. *Sel'skii mekhanizator = Selskiy Mechanizator*, 2022, no. 6, pp. 4–5. (In Russian).
 6. Mironova A.V., Liskin I.V., Panov A.I. Technology for restoring virgin and fallow lands. *Tekhnicheskii servis mashin = Machinery Technical Service*, 2020, no. 2 (139), pp. 111–121. (In Russian).
 7. Jabborov N.I., Shamonin V.I., Sergeev A.V. Energy-saving technology for long fallow land rehabilitation. *Tekhnologii i tekhnicheskie sredstva mekhanizirovannogo proizvodstva produktii rastenievodstva i zhivotnovodstva = Technologies and Technical Means for Mechanized Production of Crop and Livestock Products*, 2018, no. 4 (97), pp. 149–159. (In Russian).
 8. Larin D.V., Golubev V.V. Technological aspects of introducing fallow lands into agricultural production. *Mezhdunarodnyi sel'skokhozyaistvennyi zhurnal = International Agricultural Journal*, 2025, vol. 68, no. 3 (405), pp. 301–304. (In Russian).
 9. Blinov F.L., Belyakova E.S., Tumanov I.V., Berney V.I. Pre-sowing treatment of fallow lands. *Vestnik NGIEI = Bulletin NGIEI*, 2020, no. 11 (114), pp. 17–26. (In Russian).

10. Bochkarev D.V., Devyatkina T.F., Yemelyanov S.V., Tyukina E.V., Bochkarev V.D. The development of fallow lands requires a systematic approach. *Agrarnaya nauka = Agrarian Science*, 2020, no. 2, pp. 48–50. (In Russian).
11. Kireicheva L.V., Shevchenko V.A., Yurchenko I.F. Economic efficiency estimation on fallow lands return into agricultural cultivation in the Non-Chernozem zone of the Russian Federation. *Moskovskii ekonomicheskii zhurnal = Moscow Economic Journal*, 2021, no. 3, pp. 245–258. (In Russian).
12. Solovyov S.V., Miller G.F., Bezborodova A.N., Filimonova D.A. Succession on young and medium age fallows of the forest-steppe zone of Western Siberia in the Novosibirsk region. *Mezhdunarodnyi zhurnal prikladnykh i fundamental'nykh issledovaniy = International Journal of Applied and Fundamental Research*, 2018, no. 10, pp. 116–120. (In Russian).
13. Yakovlev N.S., Rassomakhin G.K., Chekusov M.S., Chernyshov A.P., Chernykh V.I. Development of fallow gray forest soils of the forb-bromegrass stage. *Vestnik Altaiskogo gosudarstvennogo agrarnogo universiteta = Bulletin of Altai State Agricultural University*, 2024, no. 11 (241), pp. 85–94. (In Russian).
14. Lepeshkin N.D., Mizhurin V.V., Filippov A.I., Puzevich K.L. Analysis of designs and technological capabilities of tillage rollers. *Vestnik Belorusskoi gosudarstvennoi sel'skokhozyaistvennoi akademii = Bulletin of the Belarusian State Agricultural Academy*, 2022, no. 4, pp. 144–149. (In Russian).
15. Nikiforov M.V., Golubev V.V. Determination of the quality criterion of pre-sowing tillage using various tillage machines. *Vestnik FGOU VPO "MGAU im. V.P. Goryachkina" = Bulletin of the Federal State Educational Institution of Higher Education "MGAU named after V. P. Goryachkin"*, 2018, no. 6 (88), pp. 11–16. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРАХ

✉ **Яковлев Николай Степанович**, главный научный сотрудник, заведующий лабораторией, доктор технических наук, старший научный сотрудник; SPIN-код 9053-3606; **адрес для переписки:** Россия, 630501, Новосибирская область, р.п. Краснообск, а/я 463; e-mail: yakovlevns@sfsca.ru

Рассомахин Геннадий Климентьевич, ведущий научный сотрудник, кандидат технических наук; SPIN-код 1389-4132

Чернышов Александр Павлович, старший научный сотрудник; SPIN-код 5643-9277

AUTHOR INFORMATION

✉ **Nikolay S. Yakovlev**, Head Researcher, Laboratory Head, Doctor of Science in Engineering, Senior Researcher; SPIN-code 9053-3606; **address:** PO Box 463, Krasnoobsk, Novosibirsk region, 630501, Russia; e-mail: yakovlevns@sfsca.ru

Gennady K. Rassomakhin, Lead Researcher, Candidate of Science in Engineering; SPIN-code 1389-4132

Alexandr P. Chernyshov, Senior Researcher; SPIN-code 5643-9277

Дата поступления статьи / Received by the editors 07.07.2025
Дата принятия к публикации / Accepted for publication 03.10.2025
Дата публикации / Published 10.02.2026

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-bis>) = 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

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. *Sibirskii vestnik sel'skokhozyaystvennoi nauki = Siberian Herald of Agricultural Science*, 2018, vol. 48, no. 4, pp. 27–35. (In Russian). DOI: 10.26898/0370-8799-2018-4-4.

FOOTNOTES:

Quoted text₁.

1Klimova 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.