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ВЛИЯНИЕ СПОСОБОВ ОБРАБОТКИ ПОЧВЫ НА УРОЖАЙНОСТЬ ОЗИМОЙ РЖИ СОРТА СУДАРУШКА

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Изложены результаты изучения элементов технологии возделывания нового сорта озимой ржи Сударушка. Исследования проходили в 2019, 2020 гг. в условиях подтаежной зоны Томской области. Дана оценка влияния способов обработки почвы, а также воздействия удобрения гуминового из торфа Гумостим на урожайность озимой ржи Сударушка. Почвы опытного участка кислые (pH 4,3) дерново-подзолистые супесчаного механического состава. Пахотный горизонт характеризуется низким (1,5%) содержанием гумуса, слабой обеспеченностью нитратным азотом (0,2 мг/100 г), средней (19,2) – подвижным фосфором и обменным калием (7,1), высоким (11,0 мг/100 г) содержанием подвижного алюминия. Схема опыта включала четыре варианта обработки почвы: вспашка пара ПЛН-4-35 + культивация КПН-4,2, посев без прикатывания и с прикатыванием; дискование БДМК-2,8 + культивация КПН-4,2, посев без прикатывания и с прикатыванием. Обработку удобрением гуминовым из торфа Гумостим в концентрации 0,001% проводили по вегетации в фазе начала выхода в трубку. Средняя урожайность озимой ржи сорта Сударушка за годы исследований составила 4,66 т/га в варианте с дискованием, последующей культивацией перед посевом и дальнейшим посевом с прикатыванием, что на 0,34 т/га выше, чем при традиционном способе обработки почвы. Применение удобрения гуминового из торфа Гумостим на холодных дерново-подзолистых почвах позволило в среднем по опыту получить урожайность озимой ржи 4,31 т/га, что на 0,39 т/га выше, чем без удобрения.

Ключевые слова: озимая рожь Сударушка, урожайность, способы обработки почвы, Гумостим

INFLUENCE OF TILLAGE METHODS ON THE YIELD OF WINTER RYE VARIETY SUDARUSHKA

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The results of studying the elements of the technology of cultivation of a new variety of winter rye Sudarushka are presented. The research took place in 2019, 2020 in the sub-taiga zone of the Tomsk region. The impact of soil cultivation methods as well as the impact of humic fertiliser from peat Gumostim on the yield of winter rye Sudarushka is evaluated. The soils of the experimental plot are acidic (pH 4.3) soddy-podzolic loamy sandy loam. The arable horizon has a low humus content (1.5%), a low (0.2 mg/100g) content of nitrate nitrogen, a medium content of mobile phosphorus

(19.2) and exchangeable potassium (7.1) and a high (11.0 mg/100g) content of mobile aluminium. The scheme of the experiment included four variants of cultivation: ploughing of fallow lands with PlN-4-35 + cultivation KPN-4,2, sowing without packing and with packing; disking with BDMK-2,8 + cultivation KPN-4,2, sowing without packing and with packing. Treatment with humic fertilizer from peat Gumostim at a concentration of 0.001% was carried out during the growing season in the beginning phase of the leaf-tube formation. The average yield of winter rye in the variety Sudarushka during the years of research was 4.66 t/ha in the variant with disking, subsequent cultivation before sowing and further sowing with packing, which is 0.34 t/ha higher than with the traditional method of soil cultivation. The application of humic fertilizer from peat Gumostim on cold sod-podzolic soils enabled the average yield of winter rye to be 4.31 t/ha y, which is 0.39 t/ha higher than without the fertilizer.

Keywords: winter rye Sudarushka, yield, soil cultivation methods, Gumostim

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INTRODUCTION

Winter rye is a strategic food grain crop in Russia, the most plastic in its range and the most adaptable for regions with difficult natural and climatic conditions. Only rye can withstand the lowest temperature at the depth of the tillering node down to -23 °C. It is widely regarded as a low economic risk crop, especially in areas with poor soils. Rye is mainly distributed in areas with sandy and clay soils with low fertility and high acidity, where other cereal crops have lower yields [1-3].

The use of a set of agronomic measures is aimed at obtaining high and sustainable crop yields and should be based on their biological characteristics, which contributes to the manifestation of the maximum potential of the variety [4].

One of the ways to increase rye yields is proper tillage, which should solve a set of problems depending on the forecrop, soil, climatic and hydrothermal conditions, phytosanitary state of the fields. To save material and energy resources it is necessary to minimize the number of technological operations and at the same time to ensure optimal conditions for plant development.

There are different opinions and conclusions in the scientific literature about the impact of different tillage technologies on crop yields [5-7]. According to some scientists [8-10], the non-mouldboard system compared to the mouldboard system worsens the fertility of the arable layer. A number of authors note an increase in the yield of crops grown by non-mouldboard (compared to plowing) against the background of high doses of mineral fertilizers [11].

In the sub-taiga zone on cold sod-podzolic soils, a system of tillage with obligatory seed rolling of crops is adopted [12]. The rolled soil increases moisture reserves, stimulates the processes of seed germination.

The purpose of the study - to develop elements of cultivation technology of the new variety of winter rye Sudarushka.

Edaphic stresses, biotic factors and climatic conditions limiting high yields of crops in the West Siberian region allow the most complete assessment of the degree of influence of agro-

nomic practices on the yield, in particular of winter rye. In previous experiments, the sowing dates and seeding rates of winter rye varieties Sudarushka were determined [1,2]. The objective of the present study was to determine the rational methods of tillage during cultivation of the variety.

MATERIAL AND METHODS

The study of agrotechnics of cultivation of the new variety of winter rye Sudarushka was conducted in 2019, 2020 on the fields of agrotechnical crop rotation of the Narym Department of Breeding and Seed Production of the Siberian Research Institute of Agriculture and Peat - a branch of SFSCA RAS.

Soils of the experimental site are acidic (pH 4.3) sod-podzolic loamy sandy loam texture. The arable horizon is characterized by low (1.5%) humus content, low supply of nitrate nitrogen (0.2 mg/100 g), medium supply of mobile phosphorus (19.2) and exchangeable potassium (7.1), high content of mobile aluminum (11.0 mg/100 g) [13].

Winters of 2019/20 and 2020/21 were severe (down to -45 °C) and prolonged with significant (up to 110 cm) snow blanket laying for 175-186 days. The meteorological conditions of the growing seasons differed significantly in the amount of precipitation and temperature regime.

A peculiarity of the growing season 2019 was the late onset of spring. Disintegration of the snow blanket occurred on 16 April, but due to very cool weather, the resumption of the growing season was noted only on 5 May. The shooting and earing stages were delayed until 10 June and 3 June, respectively. Rye flowering did not start until late June. Moisture deficit was observed during the whole vegetation period, especially during grain ripening, which affected the yield.

In 2020, the snow blanket disintegrated on 11 April and vegetation resumed on 19 April. The shooting and earing took place in a short period of time. The flowering of rye was observed on 7 June. Sufficient moisture supply and warm weather allowed the formation of a fair yield.

The material for the study was a new variety of winter rye Sudarushka, which was included in the State Register of Selection Achievements in the West Siberian region in 2021; it is protected by a patent[3].

The variety is medium-late maturing, with a growing season of 340-350 days. The plant height is 106-110 cm. Resistance to lodging is high. It belongs to the varieties of extensive type, is characterized by high winter hardiness, medium resistance to brown rust and powdery mildew, less affected by snow mold. In competitive variety trials, the average yield for 2015-2017 was 5.1 tons, which is 0.41 tons higher than that of the released variety Petrovna. The activity of alpha-amylase is low, the fall number - 241. Grain unit is 699 g/l. The variety has a high stable productivity and the ability to maintain an optimal density throughout the growing season.

The scheme of experiments was to study the effect of methods of cultivation and humic fertilizer from peat Gumostim on the yield of winter rye varieties Sudarushka.

The experiments included four variants of tillage:

- fallow plowing PLN-4-35 + cultivation KPN-4,2, seeding with rolling;
- fallow plowing PLN-4-35 + cultivation KPN-4,2, seeding without rolling;
- disking BDMK-2,8 + cultivation KPN-4,2, seeding with rolling;
- disking BDMK-2,8 + cultivation KPN-4,2, seeding without rolling.

[1]Brazhnikov P.N. Influence of sowing dates and seeding rates on the yield of winter rye variety Sudarushka. Optimization of the breeding process - a factor of stabilization and growth of crop production in Siberia: Proceedings of the International Conference Krasnoyarsk, 2019. pp. 200-203.

[2]Brazhnikov P.N. Elements of cultivation technology of a new variety of winter rye Sudarushka in the northern taiga zone. Agrarian science to agricultural production of Siberia, Mongolia, Kazakhstan, Belarus and Bulgaria: collection of scientific papers. 22nd International Scientific and Practical Conference Yakutsk, 2019. pp. 17-18.

[3]Patent 11665 (Russian Federation). Winter rye Sudarushka. P.N. Brazhnikov, A.B. Sainakova. Siberian Federal Research Center for Agrobiotechnology RAS; No 75001; publ. 18.05.2021.

In four replications out of eight at the onset of stem elongation phase, the crops were sprayed with Gumostim designed to increase crop yields and quality. The fertilizer contains humic, carboxylic acids and amino acids, including indispensable, as well as macronutrients - nitrogen, phosphorus, calcium, iron, trace elements - copper, zinc, manganese, vitamins - A, B1, B2, B5, B6, B12, C, E. The content of the main active ingredient - 1% humic acids. For foliar feeding of plants, we used 0.001% solution of the drug[4].

Location of the plots in the experiments is systematic, the accounting area of the plot is 20 m^2. Seeding was carried out on August 15 with central seeding planter SKS-6-10 with seeding rate of 5.5 million germinated seeds/ha. Fallow plowing PLN-4-35 + cultivation KPN-4,2 with rolling was taken as a control. Pressing was carried out by smooth rollers KVG-1,4, spraying - with a Palisad backpack sprayer (12 l) at a rate of 200 l/ha. Under pre-sowing cultivation nitrogen-phoska (N16P16K16) was applied at a dose of 50 kg/ha in physical weight.

Experimental material was statistically processed according to B.A. Dospekhov[5] using application software package[6].

RESULTS AND DISCUSSION

Under unfavorable conditions of 2019 the variant with traditional tillage - plowing with cultivation and rolling of crops (control) had the advantage. Variant with non-mouldboard tillage (disking, cultivation + rolling) was the most productive in the optimal conditions of the growing season 2020, the average yield of winter rye Sudarushka was 5.50 t/ha (+0.64 t/ha, NCR05 = 0.25). On the average for 2 years the yield at the variant of tillage "disking BDMK-2,8 + cultivation KPN-4,2, seeding with rolling" also reliably exceeded the control (+0.34 t/ha, NCR05 = 0.15).

Spraying of crops with Gumostim solution (0,001%) in the phase of stem elongation in all variants increased rye yield by 0,20-0,57 t/ha in 2019 and by 0,30-0,50 t/ha in 2020. Increases are significant in the variant disking BDMK-2,8 + cultivation KPN-4,2, seeding with rolling (+0.57 t/ha, NSR05 = 0.47) in unfavorable con-

Урожайность сорта Сударушка при разных способах обработки почвы и внекорневой подкормке Гумостимом, т/га
Yield of the Sudarushka variety with different methods of soil cultivation and foliar feeding with Gumostim, t/ha

Option	2019		2020		Average for 2 years	± to the control
	Without подкормки	Gumostim	Without подкормки	Gumostim		
Plowing, cultivation, seeding with rolling	3,68	3,88	4,62	5,12	4,32	Control
Plowing, cultivation, seeding without rolling	2,39	2,83	4,25	4,66	3,53	–0,79
Disking, cultivation, seeding with rolling	3,57	4,14	5,32	5,68	4,66	+0,34
Disking, cultivation, seeding with rolling	3,04	3,47	4,50	4,80	3,95	–0,37
LSD_{05}	0,254	0,476	0,264	0,216	0,151	0,322

[4]Patent 2530145C1 (Russian Federation). Method of obtaining plant growth stimulant from lowland peat. L.V. Kasimova, A.E. Donkin, A.A. Krasnoschekov, V.A. Klimovich; Siberian Research Institute of Agriculture and Peat RASKhN; № 2013122952/13; Application. 21.05.2013; publ. 10.10.2021.

[5]Dospekhov B.A. Methodology of field experiment (with the basics of statistical processing of research results). Moscow: Agropromizdat, 1985. 416 p.

[6]Sorokin O.D. Applied statistics on the computer. Novosibirsk, 2007 p.

ditions in 2019 and in all variants in favorable 2020 (NSR05 = 0.22). On average for 2 years, the yield in all variants with Gumostim treatment was significantly higher than the variants without treatment (+0.35-0.46 t/ha, NCR05 = 0.11).

Two-year experiments confirmed the necessity of such an agricultural technique as rolling the soil: in all variants without rolling the crops rye yield was significantly lower than the control (see the table).

CONCLUSIONS

1. The average yield of winter rye Sudarushka in 2019, 2020 was 4.66 t/ha in the variant with disking, followed by cultivation before seeding and further seeding with rolling, which is 0.34 t/ha higher than with the traditional method of tillage.

2. Application of humic fertilizer from peat Gumostim on cold sod-podzolic soils allowed to get an average yield of 4.31 t/ha of rye in the experiment, which is 0.39 t/ha higher than without the fertilizer.

СПИСОК ЛИТЕРАТУРЫ

1. *Уткина Е.И., Кедрова Л.И.* Зимостойкость озимой ржи: проблемы и решения // Аграрная наука Евро-Северо-Востока. 2018. № 62 (1). С. 11–18. DOI: 10.30766/2072-9081.2018.62.1.11-18.
2. *Сысуев В.А.* Комплексные научные исследования по озимой ржи – важнейшей национальной и стратегической зерновой культуре РФ // Достижения науки и техники АПК. 2012. № 6. С. 8–11.
3. *Жученко А.А.* Потенциальная продуктивность и экологическая устойчивость ржи // Агропродовольственная политика. 2012. № 2. С. 19–24.
4. *Сдобников С.С.* Обработка почвы, условия питания растений и использования удобрений в интенсивном земледелии // Параметры плодородия основных типов почв: монография. М.: Агропромиздат, 1988. С. 44–56.
5. *Колкова И.А.* Влияние обработки почвы на плодородие и агрофизические свойства // Молодой ученый. 2017. № 29 (163). С. 39–42.
6. *Плескачёв Ю.Н., Кощев И.А., Кандыбин С.С.* Влияние способов основной обработки почвы на урожайность зерновых культур // Вестник Алтайского государственного аграрного университета. 2013. № 1. С. 23–26.
7. *Перфильев Н.В., Вьюшина О.А., Власенко А.Н.* Эффективность систем основной обработки темно-серой лесной почвы при возделывании ячменя // Сибирский вестник сельскохозяйственной науки. 2021. № 51 (1). С. 11–17. DOI: 10.26898/0370-8799-2021-1-1.
8. *Пегова Н.А., Владыкина Н.И.* Изменение показателей плодородия и продуктивности дерново-подзолистой почвы при разных системах обработки // Достижения науки и техники АПК. 2016. Т. 30. № 6. С. 72–76.
9. *Куликова А.Х., Ерофеев С.Е.* Агроэкологическая оценка основной обработки почвы под яровую пшеницу // Земледелие. 2003. № 2. С. 16–17.
10. *Цыбулько Н.Н., Ермоленко А.В., Лазаревич С.С.* Влияние обработки дерново-подзолистых супесчаных почв разной степени гидроморфности на влагообеспеченность и урожайность сельскохозяйственных культур // Мелиорация. 2012. № 1. С. 103–118.
11. *Беседин Н.В., Сахн-Вальд Ф.В., Котельникова М.Н.* Влияние различных способов обработки почвы и систем удобрений на урожайность озимой пшеницы в условиях серых лесных почв Курской области // Главный агроном. 2019. № 12. С. 12–16.
12. Системы земледелия Томской области на ландшафтной основе: монография / под ред. В.К. Каличкина Томск, 2018. Ч. 1. 266 с.
13. *Анкудович Ю.Н., Макарикова Р.П., Наумова Н.Б., Савенков О.А., Вервайн О.Д.* Изменение содержания кислоторастворимой формы элементов в агродерново-подзолистой почве при внесении удобрений в длительном полевом опыте с севооборотом // Проблемы агрохимии и агроэкологии. 2013. № 1. С. 16–21.

REFERENCES

1. Utkina E.I., Kedrova L.I. Winter hardiness of winter rye: problems and solutions. *Agrarnaya nauka Evro-Severo-Vostoka = Agricultural Science Euro-North-East,* 2018, no. 62 (1), pp. 11–18. (In Russian). DOI: 10.30766/2072-9081.2018.62.1.11-18.
2. Sysuev V.A. Comprehensive scientific research on winter rye-the most important national and strategic grain crop of the Russian Federation. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of the Agro-Industrial Complex,* 2012, no. 6, pp. 8–11. (In Russian).

3. Zhuchenko A.A. Potential productivity and environmental sustainability of rye. Agroprodovol'stvennaya politika. *Agroprodovol'stvennaya politika = Agri-food policy*, 2012, no. 2, pp.19–24. (In Russian).
4. Sdobnikov S.S. *Soil treatment, conditions of plant nutrition and the use of fertilizers in intensive agriculture. Fertility parameters of the main soil types*. Moscow, Agropromizdat Publ., 1988, pp. 44–56. (In Russian).
5. Kolkova I.A. Influence of tillage on fertility and agrophysical properties. *Molodoi uchenyi = Young scientist*, 2017, no. 29 (163), pp. 39–42. (In Russian).
6. Pleskachev Yu.N., Koshchev I.A., Kandybin S.S. The influence of basic tillage methods on the yield of grain crops. *Vestnik Altaiskogo gosudarstvennogo universiteta = Bulletin of the Altai State University*, 2013, no. 1, pp. 23–26. (In Russian).
7. Perfil'ev N.V., V'yushina O.A., Vlasenko A.N. Efficiency of systems of basic processing of dark gray forest soil in the cultivation of barley. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Bulletin of Agricultural Science*, 2021, no. 51 (1), pp. 11–17. (In Russian). DOI: 10.26898/0370-8799-2021-1-1.
8. Pegova N.A., Vladykina N.I. Changes in the indicators of fertility and productivity of sod-podzolic soil under different treatment systems. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of the Agro-Industrial Complex*, 2016, vol. 30, no. 6, pp. 72–76. (In Russian).
9. Kulikova A.Kh., Erofeev S.E. Agroecological assessment of the main tillage for spring wheat. *Zemledelie = Zemledelie*, 2003, no. 2, pp. 16–17. (In Russian).
10. Tsybul'ko N.N., Ermolenko A.V., Lazarevich S.S. Influence of processing of sod-podzolic sandy loam soils of different degrees of hydromorphy on the moisture supply and yield of agricultural crops. *Melioratsiya = Land reclamation*, 2012, no. 1, pp. 103–118. (In Russian).
11. Besedin N.V., Sakhn-Val'd F.V., Kotel'nikova M.N. Influence of various tillage methods and fertilizer systems on winter wheat yield in the conditions of gray forest soils of the Kursk region. *Glavnyi agronom = Chief Agronomist*, 2019, no. 12, pp. 12–16. (In Russian).
12. *Agricultural systems of the Tomsk region on a landscape basis* / edited by V.K. Kalichkin. Tomsk, 2018, Part 1. 266 p. (In Russian).
13. Ankudovich Yu.N. Makarikova R.P., Naumova N.B., Savenkov O.A., Vervain O.D. Changes in the content of the acid-soluble form of elements in agrodernovo-podzolic soil when applying fertilizers in a long field experiment with crop rotation. *Problemy agrokhimii i agroekologii = Problems of Agrochemistry and Agroecology*, 2013, no. 1, pp. 16–21. (In Russian).

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ВЛИЯНИЕ РАЗЛИЧНЫХ СОСТАВОВ ПИТАТЕЛЬНОЙ СРЕДЫ НА РАЗВИТИЕ МИКРОРАСТЕНИЙ КАРТОФЕЛЯ СОРТА СОЛНЕЧНЫЙ

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Представлены результаты исследования влияния питательных сред различного состава на рост оздоровленных микрорастений картофеля сорта Солнечный, выращиваемых в лабораторных условиях *in vitro*. Изучено шесть составов питательной среды: стандартная среда по прописи Мурасиге-Скуга, модифицированная для микрочеренкования (контроль), модифицированная среда Мурасиге-Скуга со сниженным содержанием минеральных компонентов (до 1/2 и 1/3), модифицированная среда Мурасиге-Скуга с повышенным содержанием агар-агара (10 г/л), модифицированная среда Мурасиге-Скуга с пониженным содержанием агар-агара (4 г/л), среда Мурасиге-Скуга, модифицированная с добавлением 3 мг/л гиберреллиновой кислоты и 1 мг/л индолилуксусной кислоты. Учтены параметры растений: длина растения, наличие корня, число междоузлий, общая масса растения, масса листьев, масса корней, площадь поверхности листовой пластины. Применение сред со сниженным содержанием минеральных компонентов привело к увеличению длины растений на 28–30%, массы побега на 25% за счет массы листьев на 18%, массы стебля на 31%, суммарной площади поверхности листовых пластин на 12%. На среде с 1/3 минеральных компонентов отмечено увеличение массы корневой системы на 20%. На среде с повышенным содержанием агар-агара зарегистрировано уменьшение длины растений на 6%, уменьшение массы побега на 12% за счет уменьшения массы стебля на 15%. Растения на среде с пониженным содержанием агар-агара отличались большей массой корневой системы на 10%, побега на 17% за счет увеличения массы листьев на 27% и суммарной площади поверхности листовых пластин на 22%. При добавлении в среду регуляторов роста (гиберреллиновой и индолилуксусной кислоты) отмечено увеличение высоты растений на 70%, уменьшение массы корневой системы на 50% и листьев на 46%, увеличение массы стебля на 23%. Суммарная площадь поверхности листьев была ниже контрольных значений на 28%. Для ускоренного микроразмножения оздоровленных растений и подготовки растений для пересаживания на аэрогидропонные установки с целью получения миниклубней оптимальными являются модифицированные питательные среды со сниженным количеством минеральных компонентов 1/2 и 1/3 и со сниженным содержанием агар-агара.

Ключевые слова: картофель, состав питательной среды, клональное микроразмножение, регуляторы роста

THE EFFECTS OF DIFFERENT COMPOSITIONS OF GROWTH MEDIA ON THE DEVELOPMENT OF MICROPLANTS OF THE SOLNECHNY POTATO VARIETY

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The results of studying the effect of nutrient media of various compositions on the growth of improved micro-plants of potatoes of the Solnechny variety grown under laboratory conditions in

vitro are presented. Six compositions of the nutrient medium were studied: standard Murashige-Skuga medium modified for micropropagation (considered as a control), modified Murashige-Skuga medium with a reduced content of mineral components (up to 1/2 and up to 1/3), modified Murashige-Skuga medium with an increased content of agar-agar (10 g/l), modified Murashige-Skuga medium with a reduced content of agar-agar (4 g/l), Murashige-Skuga medium modified with the addition of 3 mg/L giberrellinic acid and 1 mg/L indoliacetic acid. The following parameters of cultivated plants were taken into account: plant length, root presence, number of internodes, total plant mass, leaf mass, root mass, leaf plate surface area. The use of modified nutrient media with a reduced content of mineral components led to an increase in plant length (by 28-30%), stem mass (by 25%) due to leaf mass (by 18%) and stem mass (by 31%) and the total surface area of leaf plates (by 12%). In the variant using a medium with 1/3 mineral components an increase in the mass of the root system was observed (by 20%). When growing plants on a modified nutrient medium with a high content of agar-agar, a decrease in the length of plants (by 6%), a decrease in the mass of the scion (by 12%) due to a decrease in the mass of the stem (by 15%) was observed. Plants grown on a modified nutrient medium with a reduced content of agar-agar were distinguished by a larger mass of the root system (by 10%), scion (by 17%) (due to an increase in leaf mass (by 27%), as well as the total surface area of leaf plates (by 22%). When growth regulators (giberrellin and indoliacetic acid) were added to the modified nutrient medium, a significant increase in plant height (by 70%), a decrease in the mass of the root system (by 50%) and leaves (by 46%), and an increase in the mass of the stem (by 23%) were observed. The total leaf surface area was 28% lower than the control values. For accelerated micropropagation of improved potato plants of the Solnechny variety and preparation of plants for transplanting to aerohydroponic systems in order to produce mini-tubers, the following modified nutrient media are optimal options: with a reduced number of mineral components (1/2 and 1/3) and with a reduced content of agar-agar.

Keywords: potatoes, nutrient medium composition, clonal micropropagation, growth regulators

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INTRODUCTION

The potato is one of the most important crops in agricultural production in Russia and around the world. According to FAO, potatoes are grown in 180 countries [1]. One of the main factors affecting the yield of this crop is high susceptibility to viral, bacterial and fungal diseases. The use of clonal micropropagation method can solve the problem of obtaining healthy planting material free from viral, fungal and bacterial infection, and increase the yield of this crop [2-4]. Compared to traditional methods, micropropagation has the following advantages: obtaining genetically homogeneous planting material, high multiplication rate, reducing the time of the breeding process, the possibility of cultivation of hard-to-reproduce plants by traditional methods [1,2] [5].

One of the important factors influencing the process of plant micropropagation under

[1]Dorofeeva V.Y., Medvedeva Y.V., Karnachuk R.A. Selective light and productivity of potato plants under in vitro and hydroponic cultivation. Actual problems of potato growing: materials of the All-Russian Scientific-Practical Conference with international participation (Tomsk, April 10-13, 2018). Tomsk, 2018. pp. 215-218.

[2]Fedorova Y.N., Fedorova L.N. The combined effect of nutrient medium and light on the formation of microgrowths in vitro. Traditions and innovations in the development of agriculture: materials of international scientific and practical conference (Velikie Luki, 17-19 April 2019). Velikie Luki, 2019. pp. 53-59.

laboratory conditions is the composition of the nutrient medium. Thus, the plant requires 17 chemical elements for complete growth and development [6, 7]. Therefore, it is important to choose the composition of the medium optimal for the growth of plants of a particular variety in seed production of healthy potatoes.

Currently, for microclonal propagation of potato nutrient medium Murashige- Skoog (MS) with various modifications is used. In the work of S.V. Kushnarenko et al. [8] it is shown that when growing potato plants on nutrient medium MS with full mineral part, the tendency to reduce the growth of potato plants is observed, while growing on 1/2 mineral part did not show this effect. In addition, potato plants rooted better on the medium with 1/2 mineral part. In our work we conducted a series of experiments to identify the effect of different concentrations of mineral part in the modified nutrient medium MS on potato microgrowths of the Solnechny variety.

According to the literature data, growing plants on modified nutrient media with a lower content of agar-agar (4 g/l) leads to an increase in the number of internodes because the liquid nutrient medium provides greater mobility of trophic elements. From the economic point of view, growing plants on liquid nutrient media is more profitable since less agar-agar is used to prepare one liter of medium [9, 10].

Researchers are searching for methods to slow down the growth of plants in vitro to reduce the cost of microtransplanting when maintaining the variety in the collection [11-13]. One of such approaches can be the use of modified nutrient media with different contents of agar-agar.

In our work, we conducted a series of experiments to determine the effect of liquid (4 g/l agar-agar) and solid (10 g/l agar-agar) MS nutrient medium on the growth and development of potato plants of the Solnechny variety.

The purpose of the study was to study the effect of different compositions of modified nutrient media on the growth and development of potato plants in the Solnechny variety in vitro under laboratory conditions.

To achieve the goal, the effect of nutrient medium on morphometric indicators (plant height, number of internodes, rhizogenesis, root system weight, shoot weight, leaf weight, stem weight and leaf surface area) of recovered potato microplants of the Solnechny variety was studied and the economic efficiency of using nutrient media of different composition was determined.

MATERIAL AND METHODS

The work was carried out in the Siberian Research Institute of Agriculture and Peat - branch of the Siberian Federal Scientific Center of Agro-BioTechnologies of the Russian Academy of Sciences. The object of the experiment was the healthy maternal microclones of potato Solanum tuberosum L. cultivar Solnechny, obtained from the apical meristems by cultivation on standard nutrient medium MS with modifications. Preparation and cultivation of plants were carried out according to the recommendations[3].

The Solnechny variety is mid-maturing, suitable for processing into potato products. Marketable yields are 21-27 tons per hectare. The tuber is rounded with medium-deep eyes. The skin is smooth yellow. The flesh is yellow. The mass of the commodity tuber is 139-290 g. The starch content is of 14,4-16,0%. The taste is good. Productivity is 85-98%. Storability is 94%. This variety is resistant to the pathogen of potato cancer, weakly affected by the golden potato cyst nematode. It is included in the State Register of the Russian Federation for the West Siberian (10) region.

After isolation of meristem and emergence of complete microplant from the meristem, its microclonal propagation was carried out and

[3]Trofimets L.N., Boyko V.V., Anisimov B.V. et al. Non-viral seed production of potatoes: recommendations. Moscow: Agropromizdat, 1990.

the experiment was established. Microclonal propagation of in vitro potato plants was carried out by microtransplanting in sterile laminar boxes. All microplants were diagnosed by real-time PCR for X-, Y-, M-, L-, S-, A-viruses and potato spindle tuber viroids before setting up the experiment. According to the results of the analysis, all plants used in the work were free from the infectious agents.

Gibberellic acid (GA) and indole acetic acid (IAA) were dissolved in 70% ethyl alcohol or in a small amount (a few drops of 0.5 n) of HCl or KOH. All concentrated solutions of the required elements were labeled and stored in the refrigerator. Six compositions of the modified nutrient medium were studied (see Table 1).

The composition of the modified nutrient medium used as a control was selected on the

Табл. 1. Состав модифицированной питательной среды для выращивания оздоровленных растений картофеля

Table 1. Composition of a Modified Nutrient Medium for Improved Potato Plants

Nutrient medium component	Experiment variant number					
	1	2	3	4	5	6
	MS medium (control), mg/l	MS medium with 1/2 content of mineral components, mg/l	MS medium with 1/3 content of mineral components, mg/l	MS medium with increased content of agar-agar (10 g/l), mg/l	MS medium with reduced agar-agar content (4 g/l), mg/l	Medium with GA and IAA content, mg/l
Macrosalts						
NH_4NO_3	1650	825	550,00	1650	1650	1650
KNO_3	1900	950	633,34	1900	1900	1900
$CaCl_2$ $2H_2O$	440	220	146,67	440	440	440
$MgSO_4$ $4H_2O$	370	185	123,34	370	370	370
KH_2PO_4	170	85	56,67	170	170	170
Microsalts						
H_3BO_3	6,2	3,1	2,07	6,2	6,2	6,2
$MnSO_4$ $4H_2O$	22,3	11,15	7,44	22,3	22,3	22,3
$CoCl_2$ $6H_2O$	0,025	0,0125	0,0084	0,025	0,025	0,025
$ZnSO_4$ $7H_2O$	8,6	4,3	2,87	8,6	8,6	8,6
$CuSO_4$ $5H_2O$	0,025	0,0125	0,0084	0,025	0,025	0,025
Na_2MoO_4 $2H_2O$	0,25	0,125	0,084	0,25	0,25	0,25
KI	0,83	0,415	0,28	0,83	0,83	0,83
Ferric chelate						
Fe_2SO_4 $7H_2O$	27,8	13,9	9,27	27,8	27,8	27,8
Na_2–EDTA $2H_2O$	37,3	18,65	12,44	37,3	37,3	37,3
Vitamins						
Thiamine – HCl	2,5	2,5	2,5	2,5	2,5	0,1
Pyridoxin – HCl	5	5	5	5	5	0,5
АС-К	2,5	2,5	2,5	2,5	2,5	–
Growth regulators						
GA	–	–	–	–		3
IAA	–	–	–	–		1
Saccharose	30000	30000	30000	30000	30000	10000
Agar-agar	7000	7000	7000	10000	4000	7000

basis of data given in the literature, which the authors of this work have been successfully used for several years for cultivation of healthy potato microplants during microtransplanting [14, 15].

In the modified nutrient media 2 and 3 the content of mineral components is reduced in order to identify the influence of the amount of mineral part on the growth and development of potato microplants. Modified nutrient media 4 and 5 are distinguished by increased and decreased content of agar-agar. Adding more agar-agar to the modified nutrient medium leads to a slower growth and development rate of potato microplants, which allows to reduce the cost of micrografting. The use of a modified nutrient medium with a lower content of agar-agar allows for greater mobility of trophic elements and a higher rate of growth and development of microplants. The use of modified nutrient medium 5 is more profitable from an economic point of view and can provide more active plant growth. The modified nutrient medium of the Kemerovo Research Institute of Agriculture (KemNIISKh) [16] was used for the basis of modified nutrient medium 6. Against the background of other media, it stands out due to the presence of growth regulators, composition of vitamins, and low sucrose content. This nutrient medium contributes to an increase in the multiplication factor and plant height.

During the experiment, the cuttings were cultivated at 20-22 °C with a photoperiod (light/dark) of 16/8 h in tubes for 28 days using OSRAM fluorescent lamps (cold daylight, power 36 W, illumination section of 5 thousand lux). Thirty-five plants of each variety were grown on each variant. Repeatability was threefold. During the experiment on the 3rd, 7th, 14th, 21st, 28th days we measured the indices characterizing plant development: plant length, root presence, number of internodes per plant. On the 28th day, we measured the total plant weight, leaf weight, root weight, and surface area of the leaf plate.

The appearance of roots was determined visually at certain intervals. The height was measured with a ruler from the base of the plant to the upper point of growth. The number of internodes was determined by counting them on one microplant. The weight of plants with leaves, the weight of leaves, and the weight of roots were determined by weighing on laboratory scales. Scanned images of leaves were used to determine leaf surface area, which were processed using the program "ImageJ". Statistical processing of the results was performed using the Windows Statistica 8.0 software package. Mann-Whitney test was used to compare the studied values.

RESULTS AND DISCUSSION

The results of the study of different compositions of the modified nutrient medium on the height of plants at different stages of their development are shown in Table 2. The studied compositions of nutrient medium are given in Table 1.

Analysis of the data of Table 2 shows that growing of healthy potato plants of the Solnechny variety on modified nutrient medium MS with 1/2 of mineral components led to an increase in plant height (the difference was 1 cm on the 14th day of growing, 2 cm on the 21st day and 2.52 cm on the 28th day of growing). Using a modified nutrient medium MC with 1/3 mineral components led at first to a decrease in the plant height compared to the control (0,39 cm on the 7th day of growth), but at a later date to an increase in the plant height (plants of experimental variant were higher than the control by 0.6 cm on the 14th day of development, by 2.25 cm on the 21st day and by 2.7 cm on the 28th day). It should be noted that different varieties respond differently to this factor. For example, N.V. Lebedeva[4] notes

[4] Lebedeva N.V. Accelerated multiplication of early potato varieties under in vitro conditions and its use in seed production of the North-West of Russia: Ph.D. in Agricultural Sciences. Velikie Luki, 2015. 186 p.

Табл. 2. Влияние различных составов модифицированной питательной среды на высоту оздоровленных микрорастений сорта Солнечный, см

Table 2. Effects of Different Compositions of the Modified Nutrient Medium on the Height of Improved Microplants of the Solnechny Variety, cm

Experiment option	Cultivation time, days				
	3	7	14	21	28
1	0,17 ± 0,018	1,15 ± 0,06	4,92 ± 0,21	7,38 ± 0,25	8,95 ± 0,27
2	0,20± 0,015**	1,07 ± 0,06	5,92 ± 0,20***	9,38 ± 0,25***	11,47 ± 0,29***
3	0,12 ± 0,009	0,76 ± 0,04***	5,52 ± 0,16**	9,63 ± 0,27***	11,65 ± 0,31***
4	0,13 ± 0,016*	0,87 ± 0,05***	4,89 ± 0,16	7,07 ± 0,27	8,46 ± 0,32*
5	0,13 ± 0,010	1,04 ± 0,05	5,42 ± 0,17*	7,64 ± 0,23	9,13 ± 0,22
6	0,11 ± 0,009**	1,35 ± 0,06**	7,53 ± 0,19***	11,85 ± 0,23***	15,22 ± 0,27***

Here and in Tables 3, 4:

* Differences are significant with $p < 0.05$ compared to control.

** Differences are significant with $p < 0.01$ compared to control.

*** Differences are significant with $p < 0.001$ compared to controls.

a significant negative impact of reducing the mineral part on the growth and development of potato varieties Udacha, Charodey, Zagadka Pitera and Snegir. The plants grown on MS medium with increased content of agar-agar insignificantly lagged behind the control plants in growth (0,04 cm on the 3rd day of growth, 0,28 cm on the 7th day of growth and 0,49 cm on the 28th day of growth). Use of modified MS nutrient medium with reduced content of agar-agar did not cause statistically significant deviations from the control. The only difference appeared on the 14th day of cultivation - the plants were 0.5 cm higher than controls, but no differences were noted on later terms of cultivation. With the modified medium with added GA and IAA, the plants first lagged behind the control (by 0.6 cm on the 3rd day of cultivation), then caught up and exceeded the length of control plants (1.2 cm on the 7th day, 2.61 cm on the 14th day, 4.47 cm on the 21st day and 6.27 cm on the 28th day). The increase in the height of potato microplants by 7.6-24.1% when using the medium of KemNIISKh is also noted by V.P. Khodaeva and V.I. Kulikova [16].

The results of measuring the number of internodes when growing microplants using a modified nutrient medium of different composition are presented in Table 3.

In the variant with the use of modified nutrient medium MS with 1/2 mineral components in the experiment with potato plants of the Solnechny variety an increase in the number of internodes on the 14th and 21st days of growth (0.38 and 0.41 units, respectively) was noted, but on the 28th day of growth reliable differences were not revealed (see Table 3). On the 21st day of cultivation, there was also an increase in the number of internodes in plants grown on medium with the addition of GA and IAA (by 0.29 units). On the 28th day of growth reliable differences were not revealed. Khodaeva V.P. and Kulikova V.I. [16] also indicate that the number of internodes in some cases increased by 30% when using the modified nutrient medium of KemNIISKh. In addition, the studies by E.P. Myakisheva and others [10] show that adding 4 g/l agar-agar to the modified nutrient medium contributes to an increase in the number of internodes. However, no such effect was observed in our work.

The effect of different compositions of the modified nutrient medium on the morphometric parameters of growing plants is shown in Table 4.

Табл. 3. Влияние различных составов модифицированной питательной среды на количество междоузлий оздоровленных микрорастений сорта Солнечный, шт.

Table 3. Effects of Different Compositions of the Modified Nutrient Medium on the Number of Internodes of Improved Microplants of the Solnechny Variety, pcs.

Experiment option	Cultivation time, days			
	7	14	21	28
1	0,75 ± 0,091	3,08 ± 0,121	4,81 ± 0,111	6,57 ± 0,100
2	0,87 ± 0,083	3,46 ± 0,104*	5,22 ± 0,106**	6,78 ± 0,104
3	0,54 ± 0,072	3,11 ± 0,077	4,93 ± 0,090	6,50 ± 0,094
4	0,81 ± 0,084	3,18 ± 0,086	4,75 ± 0,103	6,53 ± 0,110
5	0,81 ± 0,080	3,20 ± 0,087	4,77 ± 0,102	6,62 ± 0,095
6	0,90 ± 0,072	3,27 ± 0,078	5,10 ± 0,099*	6,77 ± 0,107

The analysis of the data presented in Table 4 shows that on the modified MS nutrient medium with 1/2 mineral components the plants had a greater shoot mass due to a slight increase in leaf mass (by 0.02 g, or 18%) and stem mass (by 0.04 g, or 31%). At the same time, the area of leaf plates was also larger (by 0.83 cm^2 or 12%). Plants grown on MS nutrient medium with 1/3 mineral components had the same parameters as those grown on medium with 1/2 mineral components, but were additionally distinguished by an increased root mass (by 0.02 g, or 20%). The plants grown on a modified medium with increased content of agar-agar had a less massive shoot due to a decrease in stem mass (by 0.02 g, or 15%). By contrast, the plants grown on a modified medium with a lower content of agar-agar had a more massive shoot due to an increase in leaf weight (by 0.03 g, or 27%). The total surface area of leaves in the experimental variant was higher than in the control by 1.49 cm^2, or 22.1%. The use of the modified medium with the addition of GAs and IAAs resulted in a significant decrease in the weight of the root system of plants (by 0.05 g, or 50%), a decrease in the weight of leaves (by 0.05 g, or 54.5%) and an increase in the stem weight (by 0.03 g, or 23%). The surface area of leaf plates was reduced by 1.87 cm2, or 27.8%.

The dynamics of rhizogenesis in plants grown on modified nutrient media of different composition is presented in Table 5.

When growing potato microplants of the Solnechny variety on modified MS medium with a

Табл. 4. Влияние различных составов модифицированной питательной среды на морфологические показатели оздоровленных микрорастений сорта Солнечный на 28-е сутки выращивания

Table 4. Effects of Different Compositions of the Modified Nutrient Medium on Morphological Parameters of Improved Microplants of the Solnechny Variety on the 28th Day of Cultivation

Experiment option	Weight, g				Lamina surface area, cm^2
	roots	sprout	leaves	stem	
1	0,10 ± 0,004	0,24 ± 0,008	0,11 ± 0,004	0,13 ± 0,006	6,74 ± 0,206
2	0,11 ± 0,004	0,30 ± 0,01***	0,13 ± 0,004**	0,17 ± 0,007***	7,57 ± 0,199**
3	0,12 ± 0,005*	0,30 ± 0,01***	0,13 ± 0,003***	0,17 ± 0,007***	7,52 ± 0,188**
4	0,09 ± 0,04	0,21 ± 0,01**	0,10 ± 0,003	0,11 ± 0,005**	6,95 ± 0,184
5	0,11 ± 0,04*	0,28 ± 0,01**	0,14 ± 0,005***	0,14 ± 0,005	8,23 ± 0,225***
6	,05 ± 0,04***	0,22 ± 0,01	0,06 ± 0,004***	0,16 ± 0,008***	4,87 ± 0,213***

reduced concentration of mineral components, acceleration of rhizogenesis was recorded (see Table 5). In addition, acceleration of rhizogenesis was also noted in the variant with reduced amount of agar-agar. Addition of GAs and IAAs resulted in slowing down the process of root formation. While stimulating stem growth, this modified nutrient medium simultaneously suppressed root growth due to the high concentration of gibberellin and led to a decrease in the leaf size, which is expressed in their low weight in this variant of the experiment[5].

When calculating the cost-effectiveness of the use of modified nutrient media of different composition, the cost of individual components of the nutrient medium, as well as disposable consumables required in the preparation of the media (during the preparation of nutrient medium MS with the addition of GAs and IAAs for sterilization of these components it is additionally necessary to use cold filtration filters, the cost of which is 246 rubles. 84 cop. per 1 pc. Two filters are needed to prepare 1 liter of medium). The cost of individual components is presented in Table 6. Calculation results are given in Table 7. Prices as of October 22, 2021

Табл. 5. Влияние различных составов модифицированной питательной среды на число микрорастений картофеля сорта Солнечный с появившимися корнями на разных сроках культивирования

Table 5. Effects of Different Compositions of the Modified Nutrient Medium on the Number of Potato Microplants of the Solnechny Variety, with Roots Formed at Different Stages of Cultivation

Experiment option	Cultivation time, days				
	3	7	14	21	28
1 (control)	19	70	105	105	105
2	29	82	104	105	105
3	29	85	104	105	105
4	23	52	105	105	105
5	40	81	105	105	105
6	10	58	105	105	105

Табл. 6. Стоимость компонентов питательной среды

Table 6. The Cost of Components of the Nutrient Medium

Nutrient medium component	Cost per 1 kg, roubles.
NH_4NO_3	468
KNO_3	440
$CaCl_2\ 2H_2O$	400
$MgSO_4\ 4H_2O$	300
KH_2PO_4	479
H_3BO_3	173
$MnSO_4 \cdot 4H_2O$	1157
$CoCl_2 \cdot 6H_2O$	2980
$ZnSO_4\ 7H_2O$	243
$CuSO_4\ 5H_2O$	724
$Na_2MoO_4\ 2H_2O$	3448
KI	5516
$Fe_2SO_4\ 7H_2O$	318
Na_2–EDTA $2H_2O$	700
Thiamine – HCl	41167
Pyridoxin – HCl	466078
IAA	65496
GA	1484306
Saccharose	586
AC-K	2552
Agar-agar	5700

Табл. 7. Стоимость различных вариантов модифицированной питательной среды

Table 7. The Cost of Different Compositions of Modified Nutrient Medium

Nutrient conditions variant	Cost per 1 l, roubles.
Control	61,96
MS medium with 1/2 content of mineral components	60,94
MS medium with 1/3 content of mineral components	60,60
MS medium with increased content of agar-agar (10 g/l)	79,07
MS medium with reduced agar-agar content (4 g/l)	44,87
MS medium with 3 mg/l GA and 1 mg/l IAA	557,97

[5] Timofeeva O.A., Nevmerzhitskaya Yu. Yu. Clonal micropropagation of plants: teaching aid. Kazan: Kazan University. 2012. 56 p.

were used for the calculations.

The most expensive components of modified nutrient media are GAs, IAAs, Thiamine - HCl, and Pyridoxine - HCl (see Table 6).

From the considered three variants of nutrient medium composition are cheaper than the control: nutrient medium with 1/2 mineral components (by 1 p.02 for 1 l), nutrient medium with 1/3 mineral components (by 1 p.36 for 1 l) and nutrient medium with decreased agar-agar content (by 17 p.09 for 1 l) (See Table 7).

CONCLUSION

The use of a modified nutrient medium with a reduced amount of mineral components (1/2 and 1/3 of MS concentration) for growing potato plants of the Solnechny variety led to an increase in the plant height, increased weight of the root system, leaves and stems of plants, as well as an increase in the surface area of leaf plates of the plants. Cultivation of healthy potato plants on modified nutrient medium with an increased content of agar-agar (10 g/l) led to a decrease in the height of plants and stem weight. The use of a modified nutrient medium MS with a lower content of agar-agar (4 g/l) caused an increase in the root weight, leaf weight and total surface area of leaf plates of potato plants of the Solnechny cultivar. In the variant with the modified nutrient medium with the addition of GAs and IAAs, a significant increase in the plant height, as well as a decrease in the weight of the root system, leaves and the total surface of the leaf plates were observed. In addition, in this variant, an increase in the weight of plant stems was recorded.

When calculating the cost of a modified nutrient medium of different compositions, the modified nutrient medium with the addition of GAs and IAAs was found to be the most expensive variant of those studied; the medium with a reduced amount of agar-agar was found to be the least expensive.

For cultivation of healthy microplants of the Solnechny variety for further cuttings to obtain the maximum number of new plants it is advisable to use a modified nutrient media with a reduced number of mineral components (1/2 and 1/3 parts). When growing plants which are being prepared for further transplanting to aerohydroponic plants to obtain minitubers, a modified nutrient media MS with reduced amounts of mineral components (1/2 and 1/3), as well as with reduced content of agar-agar (4 g/l) are recommended.

СПИСОК ЛИТЕРАТУРЫ

1. *Xhulaj D., Gixhari B.* In Vitro Micropropagation Of Potato (*Solanum tuberosum* L). Cultivars // Agriculture and Forestry. 2018. Vol. 64. N 4. P. 105–112.
2. *Гизатуллина А.Т., Стасевский З., Гимаева Е.А., Сафиуллина Г.Ф.* Картофель (*Solanum tuberosum* L.*) cv.* Особенности формирования микроклубеньков Невского в культуре *in vitro* // Ученые записки Казанского университета. Серия Естественные науки. 2019. Т. 161. № 3. С. 375–384. DOI: 10.26907 / 2542-064X.2019.3.375-384.
3. *Чураков А.А., Попова Н.М., Халипский А.Н., Пирятенец Ю.А.* Способ получения асептических эксплантов картофеля в культуре *in vitro* // Вестник КрасГАУ. 2019. № 5. С. 16–21.
4. *Loyola-Vargas V.M., Ochoa-Alejo N.* An Introduction to Plant Tissue Culture: Advances and Perspectives // Plant Cell Culture Protocols, 4th edition. Серия книг: Methods in Molecular Biology. 2018. Vol. 1815. P. 3–13.
5. *Милехин А.В., Бакулов А.Л., Рубцов С.Л., Дмитриева Н.Н.* Морфологические показатели растений картофеля *in vitro* в зависимости от различных питательных сред // Известия Самарского научного центра Российской академии наук. 2018. Т. 20. № 2 (3). С. 632–636.
6. *Trejo-Tellez I.L., Gomez-Merino C.F.* Nutrient Solutions for Hydroponic Systems // Hydroponics – A Standard Methodology for Plant Biological Researches. 2012. P. 1–22.
7. *Mahler R.L.* Nutrients Plants Require for Growth // University of Idaho Agriculture Experiments Station. 2004. Vol. 1124. P. 20–23.
8. *Кушнаренко С.В., Ромаданова Н.В., Аралбаева М.М., Матакова Г.Н., Бекебаева М.О., Басибекова Д.И.* Создание коллекции *in*

vitro сортов и гибридов картофеля как исходного материала для криоконсервации // Биотехнология. Теория и практика. 2013. № 1. С. 28–33.
9. *Yaser Hassan Dewir, Abdulhakim A. Aldubai, Mafatlal M. Kher, Abdullah A. Alsadon, Salah El-Hendawy, Nasser A. Al-Suhaibani.* Optimization of media formulation for axillary shoot multiplication of the red-peeled sweet potato (Ipomea batatas [L.] Lam.) 'Abees' // Chilean journal of agricultural research. 2020. Vol. 80. Is. 1. C. 3–10.
10. *Мякишева Е.П., Таварткиладзе О.К., Дурникин Д.А.* Новые особенности клонального микроразмножения сорта картофеля селекции Западной Сибири // Биологический вестник Мелитопольского государственного педагогического университета имени Богдана Хмельницкого. 2016. Т. 6. № 1. С. 375–389.
11. *Munoz M., Diaz O., Reinún W., Winkler A., Quevedo R.* Slow growth in vitro culture for conservation of Chilotanum potato germplasm // Chilean journal of agricultural research. 2019. Vol. 79. Is. 1. P. 26–35.
12. *Vettorazzil R.G., Carvalho V.S., Sudre C.P., Rodrigues R.* Developing an in vitro optimized protocol to sweet potato landraces conservation // Acta Scientarium. Agronomy. 2017. Vol. 39. Is. 3. P. 359–367.
13. Bello-Bello J.J., García-García G.G., Iglesias-Andreu L. *In vitro* conservation of vanilla (Vanilla planifolia Jacks.) under slow growth conditions // Revista fitotecnia mexicana. 2015. Vol. 38. Is. 2. P. 165–171.
14. *Романова М.С., Хаксар Е.В., Новиков О.О., Леонова Н.И., Семенов А.Г.* Влияние различных составов питательной среды на развитие микрорастений картофеля сорта Антонина // Сибирский вестник сельскохозяйственной науки. 2020. Т. 50. № 6. С. 26–36. DOI: 10.26898/0370-8799-2020-6-3.
15. *Новиков О.О., Романова М.С., Леонова Н.И., Хаксар Е.В., Чудинова Ю.В.* Изучение влияния различного состава питательных сред на растения картофеля сортов Памяти Рогачева и Кетский в культуре *in vitro* // Инновации и продовольственная безопасность. 2018. № 4 (22). С. 39–45.
16. *Ходаева В.П., Куликова В.И.* Размножение сортов картофеля в культуре *in vitro* на различных питательных средах // Достижения науки и техники АПК. 2016. Т. 30. № 10. С. 66–68.

REFERENCES

1. Xhulaj D., Gixhari B. In Vitro Micropropagation Of Potato (*Solanum tuberosum* L). Cultivars. *Agriculture and Forestry*, 2018, vol. 64, no. 4, pp. 105–112.
2. Gizatullina A.T., Stasevskii Z., Gimaeva E.A., Safiullina G.F. Potato (*Solanum Tuberosum* L.) cv. Nevskij microtuber formation in in vitro culture. *Uchenye zapiski Kazanskogo universiteta. Seriya Estestvennye nauki = Uchenye Zapiski Kazanskogo Universiteta. Seriya Estestvennye Nauki*, 2019, vol. 161, no. 3, pp. 375–384. (In Russian). DOI: 10.26907 / 2542-064X.2019.3.375-384.
3. Churakov A.A., Popova N.M., Khalipskii A.N., Piryatenets Yu.A. The way of obtaining aseptic potato explants in vitro. *Vestnik KrasGAU = Bulletin of KrasGAU*, 2019, no. 5, pp. 16–21. (In Russian).
4. Loyola-Vargas V.M., Ochoa-Alejo N. An Introduction to Plant Tissue Culture: Advances and Perspectives. *Plant Cell Culture Protocols, 4th edition. Book series: Methods in Molecular Biology.* 2018, vol. 1815, pp. 3–13.
5. Milekhin A.V., Bakulov A.L., Rubtsov S.L., Dmitrieva N.N. Morphological parameters of potato plants in vitro depending on various nutrient media. *Izvestiya Samarskogo nauchnogo tsentra Rossiiskoi akademii nauk = Izvestia of RAS SamSC*, 2018, vol. 20, no. 2 (3), pp. 632–636. (In Russian).
6. Trejo-Tellez I.L., Gomez-Merino C.F. Nutrient Solutions for Hydroponic Systems. *Hydroponics – A Standard Methodology for Plant Biological Researches*, 2012, pp. 1–22.
7. Mahler R.L. Nutrients Plants Require for Growth. *University of Idaho Agriculture Experiments Station,* 2004, vol. 1124, pp. 20–23.
8. Kushnarenko S.V., Romadanova N.V., Aralbaeva M.M., Matakova G.N., Bekebaeva M.O., Basibekova D.I. Creation of an in vitro collection of potato varieties and hybrids as a starting material for cryopreservation. *Biotekhnologiya. Teoriya i praktika = Eurasian Journal of Applied Biotechnology*, 2013, no. 1, pp. 28–33. (In Russian).
9. Yaser Hassan Dewir, Abdulhakim A. Aldubai, Mafatlal M. Kher, Abdullah A. Alsadon, Salah

El-Hendawy, Nasser A. Al-Suhaibani. Optimization of media formulation for axillary shoot multiplication of the red-peeled sweet potato (*Ipomea batatas* [L.] Lam.) 'Abees'. *Chilean journal of agricultural research*, 2020, vol. 80, is. 1, pp. 3–10.

10. Myakisheva E.P., Tavartkiladze O.K, Durnikin D.A. Clonal micropropagation of potato varieties by Western Siberia selection – the new features. *Biologicheskii vestnik Melitopol'skogo gosudarstvennogo pedagogicheskogo universiteta imeni Bogdana Khmel'nitskogo = Biological Bulletin of Bogdan Chmelnitskij Melitopol State Pedagogical University*, 2016, vol. 6, no. 1, pp. 375–389. (In Russian).
11. Munoz M., Diaz O., Reinún W., Winkler A., Quevedo R. Slow growth in vitro culture for conservation of Chilotanum potato germplasm. *Chilean journal of agricultural research*, 2019, vol. 79, is. 1, pp. 26–35.
12. Vettorazzil R.G., Carvalho V.S., Sudre C.P., Rodrigues R. Developing an in vitro optimized protocol to sweet potato landraces conservation. *Acta Scientarium. Agronomy*, 2017, vol. 39, is. 3, pp. 359–367.
13. Bello-Bello J.J., García-García G.G., Iglesias-Andreu L. *In vitro* conservation of vanilla (*Vanilla planifolia* Jacks.) under slow growth conditions. *Revista fitotecnia Mexicana,* 2015, vol. 38, is. 2, pp. 165–171.
14. Romanova M.S., Khaksar E.V., Novikov O.O., Leonova N.I., Semenov A.G. The effect of different compositions of growth media on the development of microplants of the Antonina potato variety. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2020, vol. 50, no. 6, pp. 26–36. (In Russian). DOI: 10.26898/0370-8799-2020-6-3.
15. Novikov O.O., Romanova M.S., Leonova N.I., Khaksar E.V., Chudinova Yu.V. The effect of various nutrient media on plants of potato varieties memory Rogachev and Ket in vitro. *Innovatsii i prodovol'stvennaya bezopasnost' = Innovations and food safety*, 2018, no. 4 (22), pp. 39–45. (In Russian).
16. Khodaeva V.P., Kulikova V.I. Reproduction of potato cultivars in vitro on different nutrient media. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC*. 2016, vol. 30, no. 10, pp. 66–68. (In Russian).

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БИОЛОГИЧЕСКАЯ ОЦЕНКА КОСТРЕЦА БЕЗОСТОГО В РАЗЛИЧНЫХ АГРОКЛИМАТИЧЕСКИХ ЗОНАХ ЯКУТИИ

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Представлены результаты биологической оценки сортообразцов костреца безостого в разных агроклиматических зонах Якутии. В исследованиях использованы 143 коллекционных сортообразца костреца безостого из генетической коллекции ВИР, других научно-исследовательских учреждений, а также местные дикорастущие образцы. Изучаемые сортообразцы обладают высокой зимостойкостью, селекционные номера в большей степени. Дана оценка засухоустойчивости сортообразцов, выращиваемых в трех зонах Якутии. Установлена тесная взаимосвязь признаков зимостойкости и засухоустойчивости (водоудерживающей способности) у костреца безостого. Коэффициент корреляции в среднем составил 0,74. Дана оценка интенсивности транспирации у сортообразцов костреца безостого. Анализ дневной динамики транспирации выявил, что в начальной фазе развития генеративных побегов (выход в трубку) минимальная интенсивность транспирации происходила в вечернее время, максимальная – в утренние и дневные часы. В фазе колошения и цветения интенсивность транспирации зависит от погодных условий. Установлено, что высокая зимостойкость костреца безостого обусловливает высокую урожайность сена; низкий процент водоудерживающей способности – зимостойкость и получение максимального урожая сена в условиях криолитозоны Якутии. Коэффициенты корреляции между параметрами зимостойкости, засухоустойчивости с урожайностью сена при разном травостое в среднем составили –0,85…–0,24. Стандартный сорт костреца безостого Камалинский 14 устойчив и высоко адаптирован к условиям Якутии, рекомендуется как родительская форма в селекционном процессе по кострецу безостому. При отборе сортообразцов костреца безостого следует обратить внимание на сортообразцы из местной селекции, а также на популяции экспедиционных сборов по Якутии, которые обладают высокой урожайностью семян.

Ключевые слова: кострец безостый, зимостойкость, засухоустойчивость, семена

BIOLOGICAL EVALUATION OF AWNLESS BROMEGRASS IN DIFFERENT AGRO-CLIMATIC ZONES OF YAKUTIA

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The results of biological evaluation of awnless bromegrass varieties in different agroclimatic zones of Yakutia are presented. A total of 143 collection varieties of awnless bromegrass from the genetic collection of VIR, other research institutions and local wild specimen were used in the research. The varieties studied are highly winter-hardy, the breeding specimen numbers to a greater extent. The drought tolerance of the varieties grown in the three zones of Yakutia is evaluated. A close relationship between winter hardiness and drought tolerance (water retention capacity) in awnless bromegrass was established. The correlation coefficient averaged 0.74. The intensity of transpi-

ration in awnless bromegrass cultivars is evaluated. Analysis of the daily dynamics of transpiration revealed that during the initial development phase of generative shoots (emergence into a tube), the minimum intensity of transpiration occurred in the evening and the maximum in the morning and afternoon hours. During the earing and flowering phase, the intensity of transpiration depends on weather conditions. It has been established that high winter hardiness of awnless bromegrass accounts for high hay yield; low water-holding capacity accounts for winter hardiness and maximum hay yield in the conditions of Yakutia's cryolithozone. The correlation coefficients between winter hardiness, drought tolerance parameters and hay yield at different herbage levels averaged –0,85… –0,24. The standard variety of awnless bromegrass Kamalinsky 14 is stable and highly adapted to the conditions of Yakutia, and is recommended as a seed parent in the selection process for awnless bromegrass. When selecting varieties of awnless bromegrass, attention should be paid to varieties from local breeding, as well as populations of expeditionary collections across Yakutia, which have high seed yields.

Keywords: awnless bromegrass, winter hardiness, drought resistance, seeds.

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INTRODUCTION

Awnless bromegrass (Bromopsis inermis Leyss) is one of the most common perennial grasses. Due to its biological features, it grows in various soil and climatic conditions, including the Far North [1, 2].

Awnless bromegrass is characterized by high yield, drought tolerance and winter hardiness. It is willingly eaten in pastures and as hay by all kinds of livestock. It grows well after mowing or straining. Grows early in spring and yields large quantities of green fodder; thus, it may be used as an early green supplementation instead of winter crops. In Yakutia it survives in grass on fenced plots for 8-9 years. It is widely used in grass mixtures when creating cultivated hayfields and pastures, as well as for sowing in drained bogs and lands subject to water and wind erosion[1] [1-9].

Many literature sources indicate the importance of winter hardiness in the preparation of plants depending on their belonging to the type groups (in relation to negative air temperatures). The following types of crops are distinguished: those resistant to low temperatures of atmospheric air, soil layer and under-snow temperature [10-16]. Awnless bromegrass has many forms, which are united into two types according to biological, ecological, and economic characteristics: northern and southern (see footnote 1) [6, 16].

[1]Efimova A.Z. Agroecological justification of awnless bromegrass (Bromopsis inermis (Leyss.) Holub) cultivation for seeds in Yakutia: Ph.D. in Agricultural sciences. Yakutsk, 2004. 24 p.

In Yakutia, the main limiting factors are severe overwintering conditions and drought conditions during the growing season. The selection of source material adapted to the harsh conditions of Yakutia should be the basis for the creation of varieties with a stable yield of aboveground mass.

The purpose of the study is to evaluate the biological characteristics of awnless bromegrass varieties in different agroclimatic zones of Yakutia.

MATERIAL AND METHODS

Experimental studies were conducted in three scientific field stations of the M.G. Safronov Yakut Scientific Research Institute of Agriculture, which are located in different agroclimatic zones of crop cultivation: Prigorodnaya (Khangalassky ulus), Zarechnaya (Ust-Aldansky ulus) and Northern (Oymyakonsky ulus).

In Khangalassky ulus, the research was conducted in 1989-1993 on a floodplain site located in the middle course of the Lena River. The soil is frozen-floodplain, soddy, light gray sandy loam with neutral and slightly alkaline reaction of soil medium. Salinity type is sulfate-chloride. Humus content in arable layer is 2.14-2.95%, exchangeable potassium is 3.5-19.7 mg/100 g, pH is 7.2-7.4.

In the Ust-Aldan ulus, the research was conducted on the thermokarst alas Bedi in 2006-2008. The alas is flat and belongs to the basin-valley type. The site is located on alas xeromorphic solonets, which are widespread in alas meadows of the studied region. This soil type occupies 47.4% of the area of the main bottom of Badi alas, which is 672.7 ha [17].

The microrelief of the experimental plot is flat, with a slight slope from north to south, from the periphery of the alas to the center. The humus content at the depth of 0-20 cm is very high (8.9%) with decreasing down the profile to 1.9%. Provision of nitrate nitrogen is very high - 46-48 mg/kg of soil, phosphorus content is very low - 58 mg/kg, potassium at 0-20 cm depth is very high - 305 mg/kg, 20-40 cm is high - 159 mg/kg. Salinity is weak, sulfate-chloride at 0-20 cm horizon and hydrocarbonate at 20-40 cm horizon. According to the observations of R. Desyatkin [17], permafrost during the growing season drops to 2.0-2.5 m.

In the Oymyakonsky ulus the research was conducted in 1998-2001. The site is located on the floodplain of the Yuchyugei River. The soil is permafrost north taiga podzolized. The soil profile is subjected to permafrost cryoturbations, gleyed, and has thixotropy on soils of heavy texture. By mechanical composition, the soils are light, medium and heavy loamy on ancient alluvial deposits, underlain by sand and pebbles from below. The humus content is 2.11-2.47%, the reaction of the aqueous solution of the soil medium is neutral, pH 6.4-7.7. The content of phosphorus and potassium is high. In the upper layers (0-20 cm), the phosphorus content is 29.9-31.78 mg/100 g of soil, exchangeable potassium is 25.6-26.4 mg/100 g.

Meteorological conditions during the years of research were characterized by very harsh winters (temperature dropped to -57 °C in Khangalassky and Ust-Aldansky uluses and lower to -62 °C in Oymyakonye) and more favorable conditions during the growing season.

Hydrothermal coefficient (HTC) in the first site for 1989-1993 was from 1.2 to 2.7. The dry period was 1989 (HTC 1.20), 1993 (HTC 1.53), humid - 1990, 1991 (HTC 2.07 and 1.62, respectively). The year 1992 was humid (GTC 2.7).

At the second site in 2006-2008 the meteorological conditions of the growing season can be divided into dry (2007) and wet (2006, 2008) according to the hydrothermal coefficient. Weather conditions of vegetation period 2007 were characterized by relatively low air temperature and deficit of atmospheric precipitation. During the first and second ten-day periods of July, the weather was dry and hot, while rains started only from the third ten-day period. The HTC was 0.55. The sum of active temperatures above 10°C was 1,295°C, and precipitation totaled 71.4 mm during the period.

At the third test site, the HTC was 1.65 in 2000 and 1.23 in 2001.

Field experiments, biometric measurements and observations were carried out according to the methodological guidelines of VIR (1985)

and VNIIK (1985, 1993). Daily transpiration rate was determined according to N. Gusev's method "Some methods of plant water regime research" (1966). Mathematical processing of the research results was carried out according to B.A. Dospekhov (1985) using the software package Sandor (2009) and Microsoft Office Excel 2007.

143 collection variety samples of awnless bromegrass from the genetic collection of VIR and other research institutions, as well as local wild specimens were used in the studies: 40 variety samples in Khangalass Ulus, 90 variety samples in Oymyakonsky Ulus, and 13 samples in Ust-Alansky Ulus. The standard is a zoned variety Kamalinskiy 14.

RESULTS AND DISCUSSION

When determining the selection features of awnless bromegrass, important biological traits: winter hardiness, drought tolerance and water retention capacity were taken into account. According to the developed farming technique of this crop in the conditions of Yakutia, sowing was carried out by wide-row method in the summer period [2, 12]. Good adaptability of awnless bromegrass under Yakutian conditions is observed with such sowing.

In Khangalassky and Oymyakonsky uluses, experimental plots were used for winter grazing of horses during the winter period. As a result, winter-hardy and drought-resistant varieties were identified.

In Khangalassky ulus, in the standard variety Kamalinsky 14 winter hardiness in the first 2 years of plant life is generally good, which becomes excellent with age.

When evaluating awnless bromegrass cultivars for drought tolerance, it was determined that the water-holding capacity is well manifested in vegetative shoots. Generative shoots in dry year are less stable than vegetative ones in water-holding capacity. In this connection, the specimens were studied during the tillering phase.

Water loss from the total weight of plants was recorded in the first year of vegetation of plants in the variety Kamalinsky 14 at 4.5%, in local samples - from 2 to 3%. In subsequent years of herbage use, it was noted that water retention capacity reached 5% in variety Kamalinsky 14 and up to 4% in local populations, except for hybrid number G-18. It showed homeostasis effect and did not change its water-holding capacity from the third to the fourth year of plant life (at the level of 2%).

Hay yields were 14.4 to 33.3 c/ha for Kamalinsky 14 on the bogara depending on HTC of the year and the first point of research. The first life year of awnless bromegrass coincided with a moderately humid year (HTC 0.81). Hay yield reached 33.3 c/ha. In the second year of awnless bromegrass life (HTC 1.03) hay yield was 21.1 c/ha. In the third year of life this indicator was 14.4 c/ha, which is associated with the age of the herbage and a very dry summer (HTC 0.59). In the fourth year of life in a more favorable year (HTC 1.09) the hay yield was 21.98 c/ha.

Thanks to agrotechnological methods, the variety Kamalinskiy 14 adapted well in the cryolithozone. Negative correlation was noted both between yield and winter hardiness (up to -0.6), and between hay yield and water retention capacity (-0.8) (see Table 1).

A similar agronomic technique with wide-row sowing method was used in the second point of research when studying the VIR collection of awnless bromegrass in the harsh conditions of the cold Pole of Oimyakon.

It was noted that Kamalinskiy 14 adapted well in the cryolithozone. In this variety, the negative relationship between yield with winter hardiness (to -0.5), and between hay yield and water-holding capacity (-0.5) was confirmed.

Local varieties showed themselves differently: a positive correlation between winter hardiness and hay yield and water-holding capacity and hay yield was noted. Correlation coefficients were 0.6-1.0 and 0.6, respectively. In hybrid samples the negative relationship with winter hardiness and hay yield is clearly expressed, indicating homeostasis and inheritance of the parental form of the Kamalinskiy 14 variety (see Table 2).

Peculiarities of winter hardiness of awnless bromegrass and drought tolerance expressed themselves in a certain correlation with forage

Табл. 1. Хозяйственно ценные признаки и определение взаимосвязи с урожайностью сена у сортообразцов костреца безостого в условиях Хангаласского улуса (посев 1989 г., учет 1990–1993 гг.)

Table 1. Economically valuable traits and determination of correlation with hay yield in awnless bromegrass cultivars in Khangalass ulus conditions (seeding 1989, records 1990–1993)

Year of Life	Winter hardiness, score	HTC	Drought tolerance (water retention capacity), %	Hay yield, c/ha
First (1990)	4,5	0,81	4	33,3
Second (1991)	4,5	1,03	4,5	21,1
Third (1992)	5	0,59	5	14,4
Fourth (1993)	5	1,09	5	21,98
Property correlation coefficient with the yield of awnless bromegrass hay	–0,66	0,24	–0,87	1,00

harvesting in the second field point. The correlation coefficient between winter hardiness and waterholding capacity for Kamalinsky 14 variety was 1,00, for Karavaev's bromegrass Э№07-1/37 – 0,82, variety G-18 - 0,58, for bromegrass Э№07-1/51 – 0,58. The average correlation coefficient for the samples was 0.74.

In Ust-Aldansky ulus the sowing was made in the autumn term. Observations of transpiration intensity in awnless bromegrass cultivars were carried out during the second, third and fourth years of life according to plant development phases (emergence of a tube, earing and flowering).

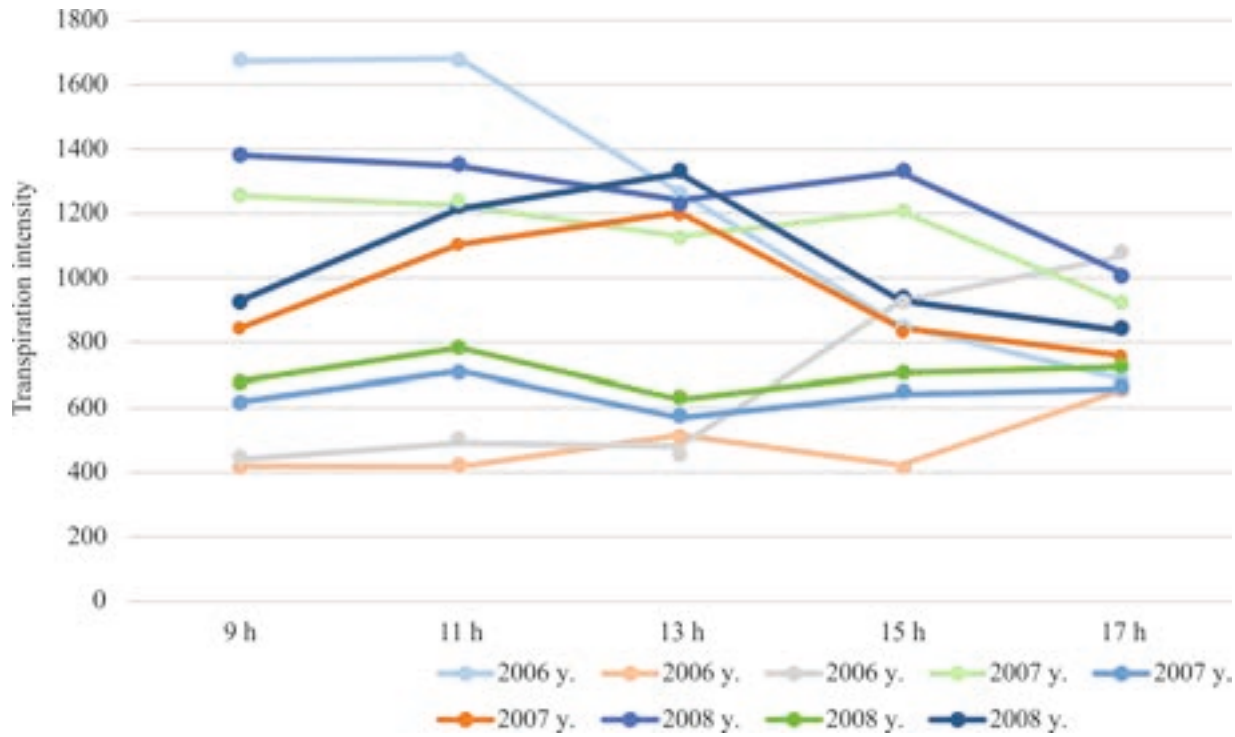
Over the years of research, the daily transpiration rate of awnless bromegrass cultivars is expressed by single- and double-peaked curves shown in the figure.

The analysis of daily dynamics of transpiration revealed that in the initial phase of development of generative shoots (emerging into the tube) the minimum intensity of transpiration occurred in the evening, the maximum - in the morning and afternoon hours. In the earing and flowering phase, the intensity of transpiration depends on weather conditions. In favorable conditions of moisture supply in 2007 and 2008, maximum (11 h) and minimum (13 h) evaporation was recorded during daytime during earing and flowering phases. During flowering, the peak of transpiration intensity fell on daytime (13 h), the minimum value - in the evening (17 h). During unfavorable moisture availability in 2006, the minimum intensity of transpiration was observed at 9 and 11 h, the maximum - in the evening time (17 h). The analysis of transpiration intensity by development phases in awnless bromegrass showed that the maximum evaporation of moisture from leaves occurs in the phase of emerging into a tube. By years this indicator varied from 1149 to 1263 mg/h, considerably less in the earing phase - from 486 to

Табл. 2. Коэффициент корреляции у местных образцов костреца безостого и адаптированного сорта Камалинский 14 (Оймяконский улус, посев 1998 г., учет 1999–2001 гг.)

Table 2. Correlation coefficient in local samples and adapted cultivar Kamalinsky 14 (Oymyakonsky ulus, seeding 1998, records 1999–2001).

Factor relationship	Kamalinsky 14	Karavaev bromegrass E№07-1/37	G-18	Bromegrass E№07-1/51	Average value
Hay winter hardiness and yield	–0,5	1,0	–0,4	0,6	0,2
Water-holding capacity and yield of hay	–0,5	0,6	0,7	0,6	0,4



Среднесуточная интенсивность транспирации сортообразцов костреца безостого (учет 2006–2008 гг.), мг/ч

Average daily transpiration rate of awnless bromegrass cultivars (records 2006–2008), mg/h

704 mg/h, flowering - from 681 to 951 mg/h. Low transpiration coefficient (486-1231 mg/h) was registered in plants during unfavorable heat and moisture deficit vegetation period of 2006.

Among awnless bromegrass cultivars the lowest intensity of transpiration is characterized by varieties Antey and Amethyst. In the booting phase in the third and fourth years of life they had the highest value of transpiration coefficient - 1599 and 1614 mg/h, respectively.

In the third year of life of awnless bromegrass varieties in the booting phase, high rates of transpiration were revealed. In standard Kamalinsky 14 it was 3718 mg/h. With optimal signs of winter hardiness and drought tolerance, bromegrass plants formed a good seed yield during this period (see Table 3).

Due to biological features of awnless bromegrass, it reaches the maximum seed yield in the third and fourth years of plant life. Reliably high seed yield is provided by six varieties: Haptagaisky, Mestny Yakutsky, Ammachaan, K-02-8, E-118, K-02-6, in which the excess over the standard varieties varies from 22 to 49% (see Table 3).

CONCLUSIONS

1. The standard variety of awnless bromegrass Kamalinsky 14 is stable and highly adapted to the conditions of Yakutia, and is recommended as a parent form in the breeding process for awnless bromegrass.

2. Water retention capacity of awnless bromegrass plants in the tillering phase decreases to 5% with age.

3. Correlation coefficients between the parameters of winter hardiness, drought tolerance and hay yield with different herbage on average are at -0,85 ... -0,24.

4. High winter hardiness of awnless bromegrass determines the high yield of hay; low percentage of water-holding capacity - winter hardiness and getting the maximum yield of hay in conditions of Yakutia cryolithozone.

5. Close correlations of winter hardiness and drought tolerance (water retention capacity) in awnless bromegrass were established. The correlation coefficient averaged 0.74.

6. Analysis of daily dynamics of transpiration revealed that in the initial phase of gen-

Табл. 3. Урожайность семян костреца безостого на третьем участке (условия аласа Бэди), посев 2005 г., г/м^2

Table 3. Seed yields of awnless bromegrass in plot 3 (Bedi Alas conditions), seeding 2005, g / m^2

Variety	Year of Life			Average value	% to the standard
	second	third	fourth		
Kamalinsky 14 (standard)	5,3	7,8	15,9	9,7	100
Langepas	4,7	7,5	17,5	9,9	102
Ametist	4,5	8,5	16,6	9,9	102
Antei	6,4	8,9	17,6	11	113
Local Yakut	7,3	8,5	20,1	12	124
Ammachaan	6,8	10,1	21,2	12,7	131
Khaptagai	4,8	8,9	21,6	11,8	122
E-118	6,1	11,8	23,7	13,9	143
K-02-5	4,9	8,7	17,2	10,3	106
K-02-6	7,7	12,2	23,4	14,4	149
K-02-8	6	8,4	23,3	12,6	130
$LSD_{0,5}$	1,7	2,9	3,1	2,1	

erative shoots development (booting stage) the minimum intensity of transpiration occurred in the evening, the maximum - in the morning and daytime hours. In the phase of earing and flowering the intensity of transpiration depends on weather conditions.

7. When selecting varieties of awnless bromegrass, one should pay attention to varieties from local breeding, as well as to populations of expeditionary collections in Yakutia.

СПИСОК ЛИТЕРАТУРЫ

1. *Казарина А.В., Абраменко И.С., Марунова Л.К.* Оценка сортообразцов костреца безостого по хозяйственно ценным признакам и свойствам в лесостепи Самарского Заволжья // Известия Самарского научного центра Российской академии наук. 2019. Т. 21. № 6. С. 131–136.
2. *Ефимов З.Г., Ефимова А.З., Слепцова А.И.* Основы возделывания костреца безостого на семена в условиях Центральной Якутии. Якутск: Издательство СО РАСХН, 2002. 56 с.
3. *Осипова В.В., Конощук Л.Я.* Продуктивное долголетие многолетних злаковых трав в условиях мерзлотных почв Нюрбинского улуса Республики Саха (Якутия) // Вестник Красноярского государственного аграрного университета. 2019. № 1. С. 3–8. DOI: 10.36718/1819-4036-2019-11-3-8.
4. *Банданова А.В., Бутуханов А.Б.* Изменение величины и качества урожая костреца безостого по фазам развития // Вестник Красноярского государственного аграрного университета. 2019. № 9. С. 19–26.
5. *Денисов Г.В.* Кормовые культуры в зоне вечной мерзлоты: монография. М.: Россельхозиздат, 1980. 176 с.
6. *Денисов Г.В., Стрельцова В.С., Нахабцева С.Ф.* Реконструкция и охрана аласных лугов Якутии: монография. Якутск, 1983. 192 с.
7. *Косолапов В.М., Пилипко С.В.* Состояние и перспективы селекции многолетних кормовых культур // Кормопроизводство. 2017. № 3. С. 26–29.
8. *Павлова С.А., Пестерева Е.С., Захарова Г.Е.* Урожайность и качество сеяных злаковых и бобово-злаковых пастбищ аласных лугов Заречной зоны Якутии // Международный сельскохозяйственный журнал. 2020. Т. 63. № 4 (376). С. 46–48. DOI: 10.24411/2587-6740-2020-14070.
9. *Захарова В.И.* Разнообразие сосудистых растений Центральной Якутии: монография. Новосибирск: Наука, 2014. 180 с.

10. *Гончаров Н.П., Гончаров П.Л.* Методические основы селекции растений; изд. 2-е, перераб. и доп.: монография. Новосибирск: Гео, 2009. 435 с.
11. *Гончаров П.Л.* Научные основы травосеяния Сибири: монография. М.: Агропромиздат, 1986. 286 с.
12. *Косолапов В.М., Пилипко С.В.* Состояние и перспективы селекции многолетних кормовых культур // Кормопроизводство. 2017. № 3. (372). С. 8–12.
13. *Кашеваров Н.И., Осипова Г.М., Тюрюков А.Г., Филиппова Н.И.* Исследование особенностей биологических признаков костреца безостого (*Bromopsis inermis* Leyss.) для возделывания в экстремальных условиях // Доклады РАСХН. 2014. № 6. С. 14–17.
14. *Павлов Н.Е., Томская Ф.Г., Софронова Е.П.* Интродукция и селекция кормовых трав в Якутии (пырейник сибирский, кострец безостый, ломкоколосник ситниковый): монография. Новосибирск: Юпитер, 2006. 237 с.
15. *Платонова А.З.* Зимостойкость костреца безостого в Центральной Якутии // Вестник Северо-Восточного федерального университета им. М.К. Аммосова. 2016. № 4 (54). С. 37–40.
16. *Сивцева В.И., Емельянова А.Г., Платонова А.З.* Оценка многолетних злаков сенокосного применения на надпойменной террасе средней Лены // Аграрная Россия. 2016. № 3. С. 16–20.
17. *Десяткин Р.В.* Почвообразование в термокарстовых котловинах – аласах криолитозоны: монография. Новосибирск: Наука, 2008. 324 с.

REFERENCES

1. Kazarina A.V., Abramenko I.S., Marunova L.K. Assessment of awnless bromegrass varieties by economically valuable characters and properties in the forest-steppe of Samara Zavolzhye. *Izvestiya Samarskogo nauchnogo tsentra Rossiiskoi akademii nauk = Izvestia of the Samara Scientific Centre of the Russian Academy of Sciences*, 2019, vol. 21, no. 6, pp. 131–136. (In Russian).
2. Efimov Z.G., Efimova A.Z., Sleptsova A.I. *Fundamentals of cultivation of awnless rump for seeds in the conditions of Central Yakutia*. Yakutsk, Publishing house SB RAAS, 2002, 56 p. (In Russian).
3. Osipova V.V., Konoshchuk L.Ya. Productive longevity of perennial cereal grasses under conditions of frozen soils of Nurbinsk ulus of the Republic of Sakha (Yakutia). *Vestnik Krasnoyarskogo gosudarstvennogo agrarnogo universiteta = Bulletin of KrasGAU*, 2019, no. 1, pp. 3–8. (In Russian). DOI: 10.36718/1819-4036-2019-11-3-8.
4. Bandanova A.V., Butukhanov A.B. Changes in size and quality of awnless bromegrass by development phase. *Vestnik Krasnoyarskogo gosudarstvennogo agrarnogo universiteta = Bulletin of KrasGAU*, 2019, no. 9, pp. 19–26. (In Russian).
5. Denisov G.V. *Forage crops in the permafrost zone*. Moscow, Rossel'khozizdat Publ., 1980, 176 p. (In Russian).
6. Denisov G.V., Strel'tsova V.S., Nakhabtseva S.F. *Reconstruction and protection of alas meadows in Yakutia*. Yakutsk, 1983, 192 p. (In Russian).
7. Kosolapov V.M., Pilipko S.V. State and prospects of breeding perennial forage crops. *Kormoproizvodstvo = Fodder Production*, 2017, no. 3, pp. 26–29. (In Russian).
8. Pavlova S.A., Pestereva E.S., Zakharova G.E. Yield and quality of seeded cereal and bean-cereal pastures of alas grasslands in the Zarechnaya zone of Yakutia. *Mezhdunarodnyi sel'skokhozyaistvennyi zhurnal = International Agricultural Journal*, 2020, vol. 63, no. 4 (376), pp. 46–48. (In Russian). DOI: 10.24411/2587-6740-2020-14070.
9. Zakharova V.I. *Variety of vascular plants in Central Yakutia*. Novosibirsk, Nauka Publ., 2014, 180 p. (In Russian).
10. Goncharov N.P., Goncharov P.L. *Methodological foundations of plant breeding.* Novosibirsk, Geo Publ., 2009, 435 p. (In Russian).
11. Goncharov P.L. *Scientific foundations of Siberian grass growing*. Moskow, Agropromizdat Publ., 1986, 286 p. (In Russian).
12. Kosolapov V.M., Pilipko S.V. State and prospects of breeding perennial forage crops. *Kormoproizvodstvo = Fodder Production,* 2017. № 3. (372). pp. 8–12. (In Russian).
13. Kashevarov N.I., Osipova G.M., Tyrykov A.G., Filippova N.I. Investigation of the features of biological traits of awnless bromegrass (*Bromopsis inermis* Lace.) for cultivation in extreme conditions. *Doklady RASKhN = Reports of the Russian Academy of Agricultural Sciences*, 2014, no. 6, pp. 14–17. (In Russian)
14. Pavlov N.E., Tomskaya F.G., Sofronova E.P. *Introduction and selection of forage grasses*

in Yakutia (Siberian wheatgrass, awnless bromegass, psathyrostachys juncea). Novosibirsk, Yupiter Publ., 2006, 237 p. (In Russian)
15. Platonova A.Z. Winter hardiness of awnless rump in Central Yakutia. *Vestnik Severo-Vostochnogo federal'nogo universiteta im. M.K. Ammosova = Vestnik of North-Eastern Federal University*, 2016, no. 4 (54), pp. 37–40. (In Russian).
16. Sivtseva V.I., Emel'yanova A.G., Platonova A.Z. Evaluation of perennial grasses for hay production on the above-floodplain terrace of the middle Lena. *Agrarnaya Rossiya = Agrarian Russia*, 2016, no. 3, pp. 16–20. (In Russian).
17. Desyatkin R.V. *Soil formation in thermokarst basins – alases of the permafrost zone*. Novosibirsk, Nauka Publ., 2008, 324 p. (In Russian).

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ПОТРЕБНОСТЬ В ПРОДОЛЖИТЕЛЬНОСТИ ЯРОВИЗАЦИИ КОЛЛЕКЦИОННЫХ ОБРАЗЦОВ МЯГКОЙ ОЗИМОЙ ПШЕНИЦЫ

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Потребность в яровизации – определенное по продолжительности влияние низких положительных температур с целью обеспечения перехода растений к генеративному развитию. Если требование по продолжительности яровизации не выполняется, растение не вступает в стадию образования генеративных органов. Определена яровизационная потребность образцов озимой мягкой пшеницы различного географического происхождения. Дана оценка влияния продолжительности периода яровизации на степень выраженности элементов структуры урожая. Материалом исследования служили 15 сортообразцов озимой мягкой пшеницы различного географического происхождения. Образцы проращивали в бумажных рулонах, затем яровизировали в климатической камере при температуре 3–5 ºС на протяжении 60, 50, 40 сут. По окончании яровизации высаживали в теплице по 10 растений каждого образца. Отмечали даты наступления фенологических фаз: выхода в трубку, колошения, цветения. Для определения основных элементов структуры урожая проведен структурный анализ растений. С увеличением периода яровизации отмечено сокращение межфазных периодов от выхода в трубку до цветения. Влияние сроков яровизации отмечено на проявление признака длина колоса. Установлено, что общее количество стеблей и количество продуктивных стеблей почти у всех сортов уменьшается с увеличением периода яровизации. Выявлены существенные различия между коллекционными сортами в потребности яровизации, обусловленные как их географическим происхождением, так и генотипом растений. У всех изучаемых форм с увеличением периода яровизации в различной степени увеличивался темп развития растения, уменьшались общее количество стеблей, продуктивный стеблестой и длина колоса.

Ключевые слова: озимая пшеница, яровизация, сорт, генеративная стадия развития

THE NEED FOR THE VERNALIZATION DURATION OF SOFT WINTER WHEAT COLLECTION SAMPLES

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The need for vernalization is a duration-dependent effect of low, positive temperatures in order to ensure the plants' transition to generative development. If the requirement for the duration of germination is not met, the plant will not enter the stage of forming generative organs. The vernalization requirements of winter soft wheat samples of different geographical origins are determined. An assessment of the vernalization period duration influence on the severity of the elements of the yield structure is given. The research material consisted of 15 cultivars of soft winter wheat of various geographic origin. The samples were germinated in paper rolls, then vernalized in a climatic chamber at a temperature of 3–5 ºC for 60, 50, and 40 days. At the end of vernalization, 10 plants of each sample were planted in a greenhouse. The dates of the onset of phenological phases were noted: tube emergence, earing, flowering. To determine the main elements of the yield structure, a structural analysis of plants was carried out. With an increase in the vernalization period, a decrease in the interfa-

cial periods from tube emergence to flowering was noted. The influence of the timing of vernalization was noted on the manifestation of the spike length trait. It was found that the total number of stems and the number of productive stems in almost all varieties decreases with an increase in the period of vernalization. Significant differences between collection varieties in the need for vernalization, due to both their geographical origin and the genotype of plants are revealed. In all the studied forms, with an increase in the period of vernalization, the rate of plant development increased to varying degrees, the total number of stems, the productive stem and the length of the spike decreased.

Keywords: winter wheat, vernalization, variety, generative stage of development

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INTRODUCTION

In the process of evolutionary development in the species of soft winter wheat Triticum aestivum L., a variety of genetic mechanisms have emerged that allow to control the adaptive reactions regulated by the action of temperature [1, 2]. The duration of the growing season in soft wheat is an important adaptive trait that determines the productivity of the plant and resistance to biotic and abiotic factors: drought, low temperatures, diseases and pests [3]. Genes of sensitivity to vernalization (VRN) are the main genetic systems that determine the duration of the growing season as a whole, as well as the duration of the main stages of organogenesis [4-6]. These genetic systems initiate the transition of wheat plants from the vegetative to the generative stage of development. The requirement for vernalization is a certain in duration effect of low positive temperatures in order to ensure the transition of plants to the generative development [7]. If the requirement for the duration of vernalization is not fulfilled, the plant does not enter the stage of formation of generative organs [8]. The need for low positive temperatures helps to avoid the effects of adverse environmental factors in late autumn and winter and to maximize the use of favorable for growth and development spring and summer vegetation period.

Winter wheat varieties have significant differences in the duration of vernalization - from 15 to 60 days and more [9, 10]. It is believed that varieties of different geographical origin are characterized by a certain need in the duration of vernalization [11]. The longer one is typical for the varieties cultivated in the areas with a long winter period. With the extensive use of local varieties, which have been adapted to certain climatic conditions for decades, an increase in the need for germination when moving from south to north was observed [7]. It was found that differences in the duration of the stage of vernalization affect the length of the period from seedlings to earing, drought-, winter- and frost-resistance, the weight of grain per ear, and yield [11, 12]. Reducing the duration of the ripening stage to 30-40 days contributes to a significant increase in yield, but at the same time leads to a decrease in winter- and frost-resistance of modern varieties [10]. Long-term warming provides high adaptability to harsh natural conditions, but interferes with

the rapid development of plants in the spring [13, 14]. Productivity and adaptability of winter soft wheat varieties are closely related to the resistance of plants to stressful wintering conditions. It, in turn, depends on the rate of passage and duration of organogenesis stages, which are largely due to the influence of genetic systems that control the duration of vernalization period.

The purpose of the study was to determine the vernalization requirements of soft winter wheat samples of different geographical origin and to evaluate the effect of the duration of the vernalization period on the elements of the yield structure.

MATERIAL AND METHODS

The work was carried out in the greenhouse of the Institute of Cytology and Genetics of Siberian Branch of the Russian Academy of Sciences (Novosibirsk) in 2020. The material for the research was 15 varieties of soft winter wheat of different geographical origin obtained from VIR and CIMMYT collections, as well as from own working collection. Samples were germinated in paper rolls and then ripened for 60, 50, 40 days in a climatic chamber at 3-5 °C, humidity 85%, illumination 1,500 lux with duration of illumination 8 hours per day. After the end of germination, 10 plants of each sample were planted in the greenhouse. Plants were grown under the temperature regime of 18-20 ºC, illumination of 4-5 thousand lux on a sunny day, 2-3 thousand lux on a cloudy day, and lighting duration of 16 hours per day. The dates of phenological phases: booting, earing, flowering were recorded.

The duration of vernalization was considered sufficient to meet the vernalization requirement if the plants were completely pruned in 50 days after planting. After harvesting, a structural analysis of plants was carried out to determine the main elements of yield structure according to the method of VIR[1]. Statistical calculations were carried out in the Snedecor program.

RESULTS AND DISCUSSION

The studied samples of winter wheat showed a different need for the duration of vernalization. With its increase the reduction of interphase periods from booting to flowering was noted.

Seven samples out of 15 (Krasnobskaya ozimaya, Novosibirskaya 3, Skipetr, Poema, Lars, Czech 9015-15, Utes) do not suffice 40 days to pass the phase of vernalization, so after this period, they did not go to the generative stage of development (see Table 1). In these samples, the increase of the vernalization period from 50 to 60 days led to insignificant (up to 2-4 days) changes in the rate of development.

Differences in the duration of the interphase periods in the remaining 8 samples, which entered the heading phase after 40 days, were more significant and ranged from 2-3 to 8-10 days. Plants of the variety Banko at all stages of vernalization entered the booting phase simultaneously, and only the flowering phase came two days earlier - at 60 days of vernalization. For the collection sample Volzhskaya, the difference between entering the earing and flowering phase at 40 and 60 days of vernalization was 10 days; the difference in the rate of development after vernalization at 50 and 60 days was negligible and varied from 1 to 2 days.

According to two-factor analysis of variance, the influence of the studied factors is reliable (see Table 2). For all the indicators the interaction of the factors "variety" and "vernalization period" was confirmed. It was the interaction of factors that had the greatest influence - from 39,3% (productive stem) to 58,6% (ear length). The share of the influence of the vernalization period was the greatest in the indicator of the ear length - 31.4%.

The results of structural analysis of winter wheat plants of different dates of vernalization show that both the total number of stems and the number of productive stems in almost all varieties decreased with increasing the period of vernalization (see Table 3). On average, the

[1]Replenishment, live preservation and study of the world collection of wheat, aegiplos and triticale: guidelines. A.F. Merezhko, R.A. Udachin, E.V. Zuev et al., SPb, VIR, 1999. - 82 p.

Табл. 1. Продолжительность межфазных периодов в зависимости от продолжительности периода яровизации озимой пшеницы, сут

Table 1. Duration of interphase periods depending on the duration of the winter wheat vernalization period, days

Variety	Origin	Vernalization duration								
		60	50	40	60	50	40	60	50	40
		Booting			Earing			Flowering		
Novosibirskaya 40	Novosibirsk region	27	30	30	34	33	38	38	38	42
Krasnobskaya ozimaya		29	29	–	38	40	–	42	48	–
Novosibirskaya 3		28	28	–	37	37	–	41	42	–
Skipetr	Moscow region	29	30	–	36	37	–	39	42	–
Poema	Vladimir region	27	29	–	34	35	–	38	38	–
Volzhskaya	Ulyanovsk region	28	27	37	34	33	44	38	38	48
Banko	Germany	24	24	24	33	32	33	36	38	38
Lars		30	35	–	36	41	–	41	45	–
Czech 9015-15	Czech Republic	35	37	–	43	45	–	47	50	–
Co 07 W 245	USA	24	28	31	30	32	38	33	37	41
KS 920-709		26	27	30	31	33	35	36	39	41
Utes		30	30	–	34	35	–	39	41	–
SWW 1-135	Kazakhstan	29	29	32	33	35	39	37	39	43
Jcam/Emu	Turkey	29	30	31	34	34	37	39	39	41
Alpu		26	27	30	32	33	37	35	36	42
$LSD_{0,05}$		1,2	1,0	0,9	1,1	1,2	0,8	1,0	1,2	1,1

Примечание. Прочерк означает, что растения не перешли в генеративную стадию развития.

Табл. 2. Двухфакторный дисперсионный анализ показателей продуктивности коллекционных образцов мягкой озимой пшеницы в зависимости от продолжительности периода яровизации

Table 2. Two-factor analysis of variance indicators of soft winter wheat collection samples productivity depending on the duration of the vernalization period

Factor	Trait								$F_{table\ 0.5}$
	Total number of stems		Productive canopy		Ear length		Grain weight per plant		
	Share of the factor's influence, %	$F_{fact.}$	Share of the factor's influence, %	$F_{fact.}$	Share of the factor's influence, %	$F_{fact.}$	Share of the factor's influence, %	$F_{fact.}$	
General	100		100		100		100		
Variety (A)	12,6	5,3	18,3	15,2	4,6	24,4	11,4	7,1	1,8
Vernalization period (B)	13,8	42,9	15,3	86,4	31,4	1162,7	10,8	46,4	3,0
A × B	43,1	14,7	39,3	18,3	58,6	155,2	44,4	16,4	1,0
Error	30,5		27,1		5,4		33,4		

total number of stems decreased from 8.7 (40 days of vernalization) to 6.74 (60 days). The maximum number of stems was recorded at 40 days of vernalization: 12.8 units in the variety Banko and 12.6 units in the variety Novosibirskaya 40.

The average number of productive stems in the studied genotypes was 6.3 for the duration of vernalization of 60 days and increased to 7.5 for 40 days. The response of varieties on this trait to different terms of vernalization was ambiguous. Significant reduction in productive bushiness with an increase in the period of vernalization to 60 days was observed in the varieties Krasnobskaya ozimaya, Skipetr, Lars, Banko. In samples Poema, Volzhskaya, KS 920-709, Utes productive bushiness is practically comparable at all terms of vernalization.

Varieties Lars, Banko and Poema formed the highest crop (6.9-10.0 units). At the same time, the minimum number of unproductive stems was registered in them.

The influence of the terms of vernalization on the length of the ear was noted. With a reduction of terms of vernalization this feature increased. Significant increase in the ear length was observed in Novosibirskaya 40, Volzhskaya, SWW1-135 with an increase in the period of vernalization from 40 to 60 days. In the samples Krasnobskaya ozimaya, Skipetr, Lars, Utes, when reducing the period of vernalization by 10 days (from 50 to 60), the ear length

Табл. 3. Показатели структурного анализа озимой пшеницы в зависимости от продолжительности периода яровизации

Table 3. Indicators of the structural analysis of winter wheat depending on the duration of the vernalization period

Variety	Vernalization duration, days											
	60	50	40	60	50	40	60	50	40	60	50	40
	Total number of stems, pcs.			Productive canopy, pcs.			Spike length, cm			Grain weight per plant, g		
Novosibirskaya 40 (standard)	4,1	7,0	12,6	4,1	6,9	7,9	7,17	7,67	9,79	3,79	7,31	7,63
Krasnobskaya ozimaya	5,1	12,2	–	5,1	7,8	–	8,51	9,43	–	5,66	8,10	–
Novosibirskaya 3	5,7	6,8	–	5,6	6,6	–	8,95	9,55	–	6,82	8,51	–
Skipetr	5,4	13,8	–	5,4	8,0	–	8,27	9,37	–	7,58	10,89	–
Poema	9,3	9,0	–	9	8,4	–	9,36	10,70	–	9,19	9,49	–
Volzhskaya	6,1	6,3	8,5	6,1	6,3	7,9	5,86	6,71	8,07	4,33	4,69	8,23
Banko	7,0	7,5	12,8	6,9	7,5	9,6	5,41	6,84	7,18	3,67	4,57	6,74
Lars	8,2	10,0	–	7,9	10,0	–	8,65	10,00	–	8,74	13,95	–
Czech 9015-15	11,7	11,2	–	6,3	5,8	–	8,69	9,68	–	6,66	5,07	–
Utes	4,8	6,4	–	4,1	4,7	–	6,97	8,71	–	3,20	4,94	–
Co 07 W 245	6,9	5,8	8,7	6,8	5,8	8,4	6,10	6,37	7,72	5,57	5,36	9,04
KS 920-709	6,5	6,3	6,4	6,3	6,2	6,4	6,35	6,74	6,98	6,03	6,20	5,45
SWW 1-135	6,9	4,8	8,4	6,9	4,8	7,1	6,42	7,52	8,26	7,46	5,04	10,10
Jcam/Emu	6,3	7,8	5,9	6,3	7,7	5,9	6,39	7,02	7,65	6,01	6,33	5,88
Alpu	7,1	5,2	6,5	7,1	4,7	6,5	6,77	7,25	6,13	6,49	3,71	7,98
Average value	6,7	8,0	8,7	6,3	6,8	7,5	7,32	8,24	7,70	6,10	6,94	7,63
LSD (5%)	2,0	3,0	2,7	1,6	1,4	1,8	0,58	0,69	0,59	2,02	2,22	2,20

was significantly increased. In Novosibirskaya 3, Poema, Jcam/Emu, Alpu varieties the ear length practically did not change or increased within the error of experiment.

As the period of vernalization decreased, the increase of productive stem and ear length in a number of samples led to an increase in the productivity of plants. Almost all samples with a requirement of 40 days of vernalization had a significant excess of grain weight per plant compared to 60 days. The exceptions were the samples from Turkey Jcam/Emu, Alpu and the sample from the USA KS 920-709. In the samples with a longer period of vernalization, this trend persisted, grain weight per plant at 50 days of vernalization is higher than at 60 days of vernalization.

Two samples from the USA (Co 07 W 245 and KS 920-709) and two samples from Turkey (Jcam/Emu and Alpu) showed relatively similar values of yield structure elements at all stages of vernalization. This indicates that the plants developed relatively similarly at different duration of vernalization. It can be assumed that these varieties have a low need for vernalization: 40 days are enough for a complete transition to the generative stage of development. At the same time, the rate of development slowed down from 2 (Jcam/Emu) to 8 days (Co 07 W 245) compared with 60 days of vernalization.

Four variety samples Novosibirskaya 40, Volzhskaya, Banko, SWW 1-135 also showed a low need for vernalization. However, in contrast to the previously mentioned samples, their indicators of structural analysis at the time of vernalization of 40 days differed significantly from the results obtained with a longer vernalization. In Novosibirskaya 40 and Banko the total number of stems significantly exceeded the number of productive stems, which can negatively affect the density of crops. In varieties Volzhskaya and SWW 1-135, this difference was almost minimal.

In the remaining samples, we observed a sufficient need for vernalization of 50 days. This period was enough for them to go to the generative stage of development. Samples Novosibirskaya 3, Poema, Utes showed comparable data on the elements of the yield structure in the vernalization of 50 and 60 days: at both dates the plants developed equally well. This confirms the fact that these samples did not significantly slow down in development when changing the terms of vernalization.

The varieties Krasnobskaya ozimaya, Skipetr and Lars with 50 days of vernalization formed elements of the yield structure noticeably higher than with a longer period. The varieties Krasnobskaya ozimaya and Skipetr had formed a large number of unproductive stems at 50-days of vernalization in contrast to the variety Lars, where there were no unproductive stems. The variety Czech 9015-15 needed only 50 days of vernalization to reach the generative stage, but this specimen was very active both at 50 and 60 days of vernalization. In both cases, the productive stems were almost 2 times lower than the total number of stems. This may indicate that the requirement of 50-60 days of vernalization for this sample is not fully consistent for optimal development.

The varieties of Siberian selection Novosibirskaya 3 and Krasnoobskaya winter, in contrast to the variety Novosibirskaya 40 showed different need for vernalization, which may be explained by their origin. Novosibirskaya 3 variety was obtained on the basis of interspecific hybridization using winter triticale. Cytological analysis showed the presence of rye chromosome translocation in the plant genome [14]. This translocation was also noted in the variety Krasnobskaya ozimaya, whose pedigree includes the variety Novosibirskaya 3.

CONCLUSION

The study of the need for vernalization of winter wheat collection samples revealed significant differences between the varieties due to both their geographical origin and plant genotype. In all studied forms with increasing of the period of vernalization the development rate increased to a different extent, the total number of stems, productive stem and ear length decreased. At 60 days of vernalization the productive stalks of the samples were close to the total number of stems. This ratio decreases as the germination period decreases. At long-term

vernalization (up to 60 days) in most samples the grain weight from plants decreased compared with vernalization at 50 and 40 days.

СПИСОК ЛИТЕРАТУРЫ

1. *Файт В.И.* Генетический контроль продолжительности яровизации сортов озимой пшеницы // Экологическая генетика. 2006. Т. 4. № 2. С. 29–36
2. *Файт В.И., Симоненко Л.К., Мокану Н.В., Попова Н.В.* Хромосомная локализация генов контроля продолжительности яровизации (vrd) озимой мягкой пшеницы // Генетика. 2007. Т. 43. № 2. С. 202–208.
3. *Chumanova E.V., Efremova T.T., Kruchinina Y.V., Pershina L.A.* Development and investigation of common wheat lines of winter cultivar Bezostaya 1 with combinations of dominant alleles of VRN-1 loci // Vavilov Journal of Genetics and Breeding. 2018. Vol. 22 (8). P. 951–956. DOI: 10.18699/VJ18.437.
4. *Стельмах А.Ф., Файт В.И.* Разнообразие генотипов современных сортов озимой мягкой пшеницы по потребности в яровизации и фоточувствительности // Молекулярная и прикладная генетика. 2011. Т. 12. С. 15–17
5. *Киселева А.А., Салина Е.А.* Генетические механизмы формирования времени колошения мягкой пшеницы // Генетика. 2018. Т. 54. № 4. С. 381–396. DOI: 10.7868/S001667581804001X.
6. *Пирыч А.В., Булавка Н.В., Юрченко Т.В.* Фотопериодическая чувствительность и яровизационная потребность сортов мягкой пшеницы озимой (*Triticum aestivum* L.) мироновской селекции // Зернові культури. 2018. Т. 2. № 2. С. 261–266. DOI: 10.31867/2523-4544/0034.
7. *Булавка Н.В.* Яровизационная потребность сортов озимой мягкой пшеницы в связи с их морозоустойчивостью // Земледелие и селекция в Беларуси. 2014. № 50. С. 383–392.
8. *Košner J., Pánková K.* Vernalisation Response of Some Winter Wheat Cultivars // Czech Journal of Genetics and Plant Breeding. 2002. Vol. 38. N 3–4. P. 97–103.
9. *Файт В.И.* Изогенные линии озимой пшеницы по генам контроля продолжительности яровизации // Информационный вестник ВОГиС. 2006. Т. 10. № 3. С. 580–587.
10. *Файт В.И.* Эффекты генов контроля продолжительности яровизации (Vrd) по агрономическим признакам в озимой мягкой пшенице // Цитология и генетика. 2007. № 5. С. 18–26.
11. *Булавка Н.В., Голик Л.Н.* Яровизационная потребность современных сортов пшеницы мягкой озимой (*Tritikum aestivum* L.) // Сортовивчення та охорона прав на сорти рослин. 2007. № 2 (6). С. 54–59.
12. *Потокина Е.К., Кошкин В.А., Алексеева Е.А.* Комбинация аллелей генов PPD и Vrn определяет сроки колошения у сортов мягкой пшеницы // Вавиловский журнал генетики и селекции. 2012. Т. 16. № 1. С. 77–86.
13. *Дубинина О.А.* Устойчивость озимой пшеницы к основным стрессовым факторам окружающей среды и погодных условий (обзор) // Зерновое хозяйство России. 2017. № 1. С. 23–26.
14. *Степочкин П.И., Пономаренко В.И., Першина А.А., Осадчая Т.С., Трубачева Н.В.* Использование отдаленной гибридизации для создания селекционного материала озимой пшеницы // Достижения науки и техники АПК. 2012. № 6. С. 37–38.

REFERENCES

1. Fait V.I. Genetic control of vernalization requirement duration of winter wheat cultivars. *Ekologicheskaya genetika = Ecological genetics*, 2006, vol. 4, no. 2, pp. 29–36. (In Russian).
2. Fait V.I., Simonenko L.K., Mokanu N.V., Popova N.V. Chromosomal location of genes for vernalization requirement duration (vrd) in winter bread wheat. *Genetika = Russian Journal of Genetics*, 2007, vol. 43, no. 2, pp. 202–208. (In Russian).
3. Chumanova E.V., Efremova T.T., Kruchinina Y.V., Pershina L.A. Development and investigation of common wheat lines of winter cultivar Bezostaya 1 with combinations of dominant alleles of VRN-1 loci. *Vavilov Journal of Genetics and Breeding*, 2018, no. 22 (8), pp. 951–956. DOI: 10.18699/VJ18.437.
4. Stel'makh A.F., Fait V.I. Variety of genes of modern winter bread wheat cultivars for requirement in vernalization and photosensitivity. *Molekulyarnaya i prikladnaya genetika = Molecular and applied genetics*, 2011, vol. 12, pp. 15–17. (In Russian).
5. Kiseleva A.A., Salina E.A. Genetic regulation of common wheat heading time. *Genetika = Russian Journal of Genetics*, 2018, vol. 54, no. 4, pp. 381–396. (In Russian). DOI: 10.7868/S001667581804001X.
6. Pirych A.V., Bulavka N.V., Yurchenko T.V. Photoperiodic sensitivity and vernalization requirement of winter wheat varieties (Triticum aestivum L.) of Myronivka breeding. *Zernovi*

kul'turi = Grain crops, 2018, vol. 2, no. 2, pp. 261–266. (In Belarus). DOI: 10.31867/2523-4544/0034.
7. Bulavka N.V. Vernalization requirement of winter soft wheat varieties in relation to their winter hardiness. *Zemledelie i selektsiya v Belarusi = Agriculture and selection in Belarus,* 2014, no. 50, pp. 383–392. (In Russian).
8. Košner J., Pánková K. Vernalisation Response of Some Winter Wheat Cultivars. *Czech Journal of Genetics and Plant Breeding*, 2002, vol. 38, no. 3–4, pp. 97–103.
9. Fait V.I. Near- isogenic lines of the genes controlling differences in duration of vernalization in winter common wheat. *Informatsionnyi vestnik VOGiS = Vestnik VOGiS (Information Bulletin of Vavilov Society for Geneticists and Breeding Scientists)*, 2006, vol. 10, no. 3, pp. 580–587. (In Russian).
10. Fait V.I. Effects of genes for controlling the duration of vernalization (Vrd) on agronomic traits in winter soft wheat. *Tsitologiya i genetika = Cytology and genetics*, 2007, no. 5, pp. 18–26. (In Russian).
11. Bulavka N.V., Golik L.N. Vernalization requirement of winter bread wheat modern varieties (Triticum aestivum L.). *Sortovivchennya ta okhorona prav na sorti roslin*, 2007, no. 2 (6), pp. 54–59. (In Belarus).
12. Potokina E.K., Koshkin V.A., Alekseeva E.A. The combination of PPD and Vrn gene alleles determines the heading date in common wheat varieties. *Vavilovskii zhurnal genetiki i selektsii = Vavilov Journal of Genetics and Breeding*, 2012, vol. 16, no. 1, pp. 77–86. (In Russian).
13. Dubinina O.A. Winter wheat resistance to main stress factors of environment and weather (review). *Zernovoe khozyaistvo Rossii = Grain economy of Russia*, 2017, no. 1, pp. 23–26. (In Russian).
14. Stepochkin P.I., Ponomarenko V.I., Pershina A.A., Osadchaya T.S., Trubacheva N.V. Utilization of distant hybridization for development of breeding material of winter wheat. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AICis*, 2012, no. 6. pp. 37–38. (In Russian).

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ПРОДУКТИВНОСТЬ ЕСТЕСТВЕННЫХ ФИТОЦЕНОЗОВ НАМСКОГО АГРОЛАНДШАФТА ЯКУТИИ ПРИ ОРГАНИЧЕСКОМ И МИНЕРАЛЬНОМ РЕЖИМАХ ПИТАНИЯ

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Представлены результаты изучения потенциала продуктивности естественных фитоценозов разного видового состава Намского агроландшафта среднетаежной подзоны Республики Саха (Якутия). Исследования проведены в 2009–2016 гг. Почвы опытного участка мерзлотные с маломощным гумусовым слоем. Изучено влияние минеральных и органических удобрений на продуктивность остепненных лугов. На разнотравно-злаковом, пырейном, остепненном фитоценозах использовали следующие приемы по органоминеральному питанию растений: контроль (без удобрения); перегной 20 т/га; перегной 20 т/га 1 раз в 4 года + $N_{60}P_{60}K_{60}$ ежегодно; $N_{30}P_{30}K_{30}$ ежегодно; перегной 20 т/га ежегодно. Установлены оптимальные нормы внесения органических и минеральных элементов питания для улучшения потенциала продуктивности естественных остепненных лугов. Наиболее высокий потенциал продуктивности в условиях Намского агроландшафта получен при совместном применении органических и минеральных удобрений (перегной 20 т/га 1 раз в 4 года + $N_{60}P_{60}K_{60}$ ежегодно). На разнотравно-злаковом и пырейном фитоценозах урожайность сена достигала 23,0–24,1 ц/га. Сбор с 1 га обменной энергии составил 27,0–22,4 ГДж, кормовых единиц – 1472–1663, сырого протеина – 336–371 кг. Содержание переваримого протеина в 1 к. ед. у разнотравно-злакового равнялось 92 г, пырейного – 102 г. Ежегодное внесение минеральных удобрений в дозе 60 кг/га действующего вещества обеспечивало повышение урожайности естественных фитоценозов в 2 раза в зависимости от агроклиматических условий вегетационного периода. Влияние минеральных удобрений и совместного внесения их с органическими на урожайность естественных фитоценозов статистически достоверно, что свидетельствует о возможности регулирования продуктивности остепненных фитоценозов.

Ключевые слова: органические и минеральные удобрения, естественный фитоценоз, пырейный, разнотравно-злаковый, остепненный агроландшафт

PRODUCTIVITY OF NATURAL PHYTOCENOSES OF THE NAMSKY AGROLANDSCAPE IN YAKUTIA UNDER ORGANIC AND MINERAL NUTRITION REGIMES

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The results of the study of the productivity potential of natural phytocenoses of different species composition in the Namsky agrolandscape of the middle taiga subzone of the Republic of Sakha (Yakutia) are presented. The research was conducted in 2009-2016. The soils of the experimental plot are permafrost soils with a thin humus layer. The effect of mineral and organic fertilizers on the productivity of steppe meadows was studied. On herb-grass, wheatgrass, steppificated phytocenoses the following practices of organo-mineral nutrition of plants were used: control (no fertilizer); humus 20 t/ha; humus 20 t/ha once every 4 years + $N_{60}P_{60}K_{60}$ annually; $N_{30}P_{30}K_{30}$ annually; humus 20 t/ha annually. The optimum rates of organic and mineral nutrients to improve the productivity potential of natural steppe meadows have been established. The highest productivity potential in the Namsky agrolandscape was obtained with the combined application of organic and mineral fertilizers (humus 20 t/ha once every 4 years + $N_{60}P_{60}K_{60}$ annually). On herb-grass and wheatgrass phytocenoses hay yield reached 23.0-24.1 c/ha. Yield per 1 ha of metabolizable energy was 27.0-22.4 GJ, fodder units 1472-1663, crude protein 336-371 kg. The content of digestible protein in 1 fodder unit in herb-grass was 92 g, in wheatgrass - 102 g. The annual application of mineral fertilizers at a dose of 60 kg/ha of the active substance provided a 2-fold increase in the productivity of natural phytocenoses, depending on agroclimatic conditions of the growing season. The influence of mineral fertilizers and their joint application with organic fertilizers on the yield of natural phytocenoses is statistically reliable, which indicates the possibility of regulating the productivity of steppificated phytocenoses.

Keywords: organic and mineral fertilisers, natural phytocenosis, wheatgrass, herb-grass, steppificated agrolandscape

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INTRODUCTION

Improvement of natural forage lands is an important problem of grassland fodder production in the Republic of Sakha (Yakutia). Due to the high cost and complicated logistics of delivering mineral fertilizers, many farms cannot use them. The productivity of natural grasslands depends to a large extent on the climatic conditions of the growing season. To avoid dependence of the yield and productivity of natural grasslands on weather conditions, the use of organic fertilizers is relevant.

Under the conditions of the Namsky agrolandscape on permafrost meadow-chernozem soils, natural meadow steppes respond differently to the nutritional regime. The nutrient supply of meadow plants significantly affects the species composition, economic yield and productivity potential of the natural phytocenoses.

The purpose of the study is to study the effect of mineral and organic fertilizers on the productivity of steppe meadows in the conditions of the Namsky agro-landscape of Yakutia.

The objective of the study is to establish optimal rates of organic and mineral nutrients to improve the productivity potential of natural steppe meadows.

MATERIAL AND METHODS

In the field experiment using the factorial scheme the effectiveness of the influence of or-

ganic and mineral fertilizers in a wide range of doses and combinations on the productivity of phytocenoses was studied. As a result of comprehensive research, new data on the effect of the most important fertilizer systems: mineral, organic and organomineral - on soil fertility and its biological activity were obtained.

The objects of the research were different steppe communities: motley grass-grasses, wheatgrass, and steppe phytocenoses under different feeding regimes under conditions of natural moisture. The studies of the baseline project 2009-2016 were conducted in steppe meadows at the Markhinsky station of the Institute of Biological Problems of the Cryolithozone of the Siberian Branch of the Russian Academy of Sciences. The station is located 13 km from Yakutsk; according to the agrolandscape zoning of the middle taiga subzone of Yakutia, it is located in the Namsky agrolandscape and occupies the sixth agroecological land group. The area of the Namsky agrolandscape is 2,575 thousand ha, or 6.0% of the Lena-Vilyui interfluve [1]. This agro-landscape is an erosion-accumulative gentle-wave plain with absolute altitudes of 300-400 m, formed by Neogene-Quaternary deposits with permafrost taiga paleo- and medium-salty, medium-loam soils, which are covered by larch-motley grass-grasses and lingonberry forests.

The climate of the Namsky agricultural landscape is moderately cold and arid. January air temperature is -41.2 °C, July temperature rises to 17.6 °C. The annual amount of precipitation is 264 mm, of which 123 mm falls during the active vegetation period. The average duration of the frost-free period is 79 days; it varies considerably depending on the location. The soil is suitable for agricultural work from May 17-19. The sum of average daily air temperatures above 10 °C is 1414-1642 °C. Moisture coefficient for the year is 0.90, during the active vegetation period of plants - 0.49, i.e. moisture content of the territory is deficient and acutely deficient [2].

The sixth agro-ecological group of lands of the Namsky agro-landscape is represented by saline lands of the Lena River floodplain terraces and occupies an area of 0.15 thousand m2 [3]. The dominant soils are permafrost meadow-chernozem solonetzic soils. The soils under steppe meadows are characterized by high dryness and relatively intensive heating of the root zone. The upper horizons of these soils are acidified, only in the lower strata alkalinization is noted, the pH of aqueous suspension reaches 7.4. The spring humidity of permafrost sod soil is characterized as insufficient for the initial vegetation of meadow grasses, so steppe meadows are characterized by low biological productivity.

The soils of the study area at the “Marikhinsky” station are permafrost floodplain meadow-chernozem soils. The content of humus in the 0-20 cm arable layer is 2.5%, mobile phosphorus is 279 mg/kg of soil, and exchangeable potassium is 104 mg/kg [4]. The weather conditions of the vegetation periods 2009-2016 differed from each other and included all the features of agroclimatic conditions of the Middle Lena valley. The amount of precipitation of 161-170 mm is considered optimal for growth and development of perennial grasses in the conditions of the Namsky agrolandscape during the growing season. The driest and hottest growing season was 2015 (HTC 0.50) with 121 mm of precipitation while the norm was 161 mm. The wettest period was 2013 (HTC 0.90). Heavy rains occurred in spring and in the first half of summer, and the amount of precipitation during the growing season reached 234 mm. The year 2014 was variable-humidity year (HTC 0.70) with dry spring and rainy summer. 2016 was the most favorable by temperature regime and the amount of precipitation (HTC 0.80).

Different in temperature and precipitation weather conditions of 2009-2016 influenced the growth and development of plants, the passage of phenological phases, the formation of yield and development of the root system of steppe plants in the station "Marikhinsky" [5].

Motley grass-grasses, wheatgrass, and steppe phytocenoses used the following methods for organomineral nutrition of plants: control (no fertilizer); humus 20 t/ha; humus 20 t/ha once every 4 years + $N_{60}P_{60}K_{60}$ annually; $N_{30}P_{30}K_{30}$ annually; humus 20 t/ha annually.

The studies used generally accepted methods for meadow science and grassland management. All records and observations were made according to the methods [1,2], statistical processing of yield data was carried out by the method of variance analysis according to B.A. Dospekhov[3]. The chemical composition of hay forage (crude fiber, fat, crude ash, nitrogen, phosphorus, calcium) was determined in the biochemistry laboratory of the Yakutsk Research Institute of Agriculture. Energy fluxes in meadow phytocenoses were evaluated according to the method[4].

RESULTS AND DISCUSSION

For the first time under the conditions of the Namsky agricultural landscape on permafrost meadow-chernozem soils, the productivity potential of meadow steppes with different species composition was evaluated.

According to the VNIIK methodology, the productivity potential of meadow ecosystems is determined by the collection of metabolizable energy, fodder units and crude protein from 1 hectare. It is established in our studies that the productivity potential of meadow steppes depending on fertilizers is conditioned by weather conditions of vegetation periods, biological features of meadow plants and nutrition regime.

In the conditions of the Namsky agrolandscape, a natural herb-grass phytocenosis without fertilization with the content of cereals in the herbage up to 65.2% ensured the productivity from 1 ha in terms of the collection of exchange energy up to 8.8 GJ, fodder units - 595, crude protein - 99 kg. The content of digestible protein in 1 fodder unit was 53 g, which is 1.9 times lower than the zootechnical norm (see Table 1).

Under the conditions of motley grass-grasses phytocenosis the joint use of organic and mineral fertilizers (humus 20 t/ha once in 4 years + N60P60K60 annually) ensured the increase of productivity by 2.2 times with the yield of 23.0 c/ha of hay of 1st class with raw protein content up to 14.6%. The optimum yield of 27 GJ of metabolizable energy, 1472 fodder units, and 336 kg of crude protein per 1 ha was formed. At the same time, the content of digestible protein in 1 fodder unit in herb-grass meadow reached 92 g when the norm was 105 g.

Under this nutritional regime, the dominance of cereal species (Elytrígia répens, Koeleria pyramidata (Lam.) P. Beauv., Poa stepposa (Kryl.) Roshev.) in motley grass-grasses phytocenosis was noted. The content of wild cereals was up to 93.1%, herbs - up to 6.9% of DM, indicating the responsiveness of cereal species to nitrogen fertilizers.

The annual application of mineral fertilizers at a dose of $N_{60}P_{60}K_{60}$ in motley grass-grasses phytocenosis with the content of wild grains up to 87.0% ensured productivity per 1 ha in terms of metabolizable energy harvesting 18.8 GJ, fodder units - 1327, crude protein - 278 kg. According to the content of digestible protein in 1 k. unit. (79 g) the herb-grass phytocenosis did not meet the zootechnical standards [6].

When mulch 20 t/ha was applied once in 4 years + 20 t/ha annually, motley grass-grasses phytocenosis with cereals 66,2-86,4% CB ensured productivity per ha in terms of metabolizable energy collection 12,5-12,5 GJ, fodder units - 847-725, crude protein - 153-154 kg.

A natural wheatgrass phytocenosis without fertilizers containing 87.5% CB in the grass of wheatgrass (Elytrigia repens) had an average productivity of 13.5 GJ, fodder units - up to 927, crude protein - 179 kg from 1 ha of harvested metabolizable energy. At the same time the provision of 1 fodder unit (66 g) of digestible protein. (66 g) of digestible protein was insufficient. The mineral dietary regime of wheatgrass phytocenosis at the dose of $N_{60}P_{60}K_{60}$ annually resulted in increased productivity per hectare in raw protein collection - 403 kg and high provision of 1 k. unit of digestible protein - 105 г.

[1]Methodology of experiments in hayfields and pastures. M., 1971. P. 1. 229 p.

[2]Methodology of experiments in hayfields and pastures. M., 1971. P. 2. 174 p.

[3]Dospekhov B.A. Methodology of field experience. Moscow: Agropromizdat, 1985. 375 p.

[4]Methodological Guide for the Assessment of Energy Flows in Meadow Agroecosystems. Moscow: VNIIK named after V.R. Williams, 2007.

Табл. 1. Потенциал продуктивности естественных фитоценозов разного состава при органоминеральном режиме питания (среднее за 2009–2016 гг.)
Table 1. Productivity potential of natural phytocenoses of different composition under organo-mineral nutritional regime (average for 2009–2016)

Dietary pattern	Content of wild species, %			Yield, c/ha DM	Production per 1 ha			Content of digestible protein in 1 f.u., g
	Cereals	Legumes	Forbs		exchange energy, GJ/ha	f. u.	crude protein, kg	
Motley grass-grasses phytocenosis								
Control (without fertilizer)	65,2	15,2	19,7	10,1	8,8	595	99	53
Mould 20 t/ha once every 4 years	66,2	20,1	13,7	14,6	12,5	847	153	55
Mould 20 t/ha once every 4 years + $N_{60}P_{60}K_{60}$ annually	93,1	–	6,9	23,0	27,0	1472	336	92
$N_{60}P_{60}K_{60}$ annually	87,0	0,8	10,8	21,4	18,8	1327	278	79
$N_{30}P_{30}K_{30}$ annually	82,1	0,9	17,1	15,7	13,9	973	179	67
Mould 20 t/ha annually	86,4	1,1	12,6	14,5	12,5	725	154	69
LSD_{05}				3,4				
Agropyron phytocenosis								
Control (without fertilizer)	87,5	3,9	8,6	15,2	13,5	927	179	66
Mould 20 t/ha once every 4 years	90,5	2,3	7,3	16,7	14,7	1052	225	81
Mould 20 t/ha once every 4 years + N60P60K60 annually	92,0	0,8	7,2	24,1	22,4	1663	371	102
$N_{60}P_{60}K_{60}$ annually	93,2	0,6	6,3	20,0	18,2	1360	403	105
$N_{30}P_{30}K_{30}$ annually	90,4	0,0	9,7	17,3	15,5	1124	263	93
Mould 20 t/ha annually	85,0	3,2	11,9	15,7	14,6	958	195	67
LSD_{05}				4,0				
Steppificated phytocenosis								
Control (without fertilizer)	19,8	13,1	67,1	7,0	6,0	420	58	39
Mould 20 t/ha once every 4 years	36,8	18,1	45,2	9,0	8,0	567	76	46
Mould 20 t/ha once every 4 years + N60P60K60 annually	45,6	0,4	54,1	17,1	16,0	1197	214	82
$N_{60}P_{60}K_{60}$ annually	45,5	1,4	53,2	14,7	13,0	911	157	64
$N_{30}P_{30}K_{30}$ annually	31,5	1,5	67,1	13,1	11,4	799	139	65
Mould 20 t/ha annually	47,0	9,3	43,8	12,6	10,8	668	94	45
LSD_{05}				3,3				

The natural steppe phytocenosis without fertilizers with herbs and cereals up to 67.1 and 19.8% DM, respectively, had the lowest productivity potential with an average yield of 7.0 c/ha DM. The content of digestible protein in 1 f.u. was 39 g, which is significantly lower than the zootechnical norm. Productivity of the phytocenosis without fertilizers in terms of metabolizable energy collection was 6.0 MJ/ha, fodder units - 420, crude protein - 58 kg/ha.

With a combination of organic and mineral fertilizers (mulch 20 t/ha 1 time in 4 years + $N_{60}P_{60}K_{60}$ annually) the productivity potential of this phytocenosis increased: the collection of metabolic energy to 16.0 GJ, fodder units - to 1197, crude protein - to 214 kg/ha. The content of digestible protein in 1 fodder unit increased to 82 g, which is lower than the zootechnical norm.

A combined application of organic and mineral fertilizers (mulch 20 t/ha once in 4 years + $N_{60}P_{60}K_{60}$ annually) proved to be most effective in the meadow steppes of the Namsky agrolandscape, which led to a 2-fold increase in the yield with good quality hay forage. The exchange energy per 1 ha was 27.0-22.4 GJ, fodder units 1472-1663, crude protein 336-371 kg. By the content of digestible protein in 1 fodder unit herb-grass and wheat grass phytocenosis with the content of cereals from 88 to 93% corresponded to zootechnical norms (93-105 g). On these phytocenoses the 1st class hay yield reached 23.0-24.1 c/ha. The content of digestible protein in 1 cfu was 92 g in motley grass-grasses phytocenosis, 102 g in wheat grass phytocenosis, 82 g in steppe grass phytocenosis.

It is important to note the effectiveness of annual application of mineral fertilizers at a dose of 60 kg/ha, which provides an increase in the yield of natural phytocenoses by about 2 times [7-9]. At the same time, a significant variation of economic yield of phytocenoses by years of research was noted. This pattern was particularly evident in the wheatgrass phytocenosis. The most effective was the joint application of organic and mineral fertilizers (mulch 20 t/ha once in 4 years + $N_{60}P_{60}K_{60}$ annually), which provided a hay yield of wheatgrass phytocenosis up to 24.1 c/ha.

Long-term results of our experiments indicate that in the conditions of the sixth agroecological group of lands of the Namsky agrolandscape the most effective is the joint application of organic and mineral fertilizers (mulch 20 t/ha once in 4 years + $N_{60}P_{60}K_{60}$ annually). This application formed the maximum yield of herb-grass, wheatgrass and steppe phytocenoses regardless of the species composition and the degree of moisture of the growing season. On average for the years of research the combined application of organic and mineral fertilizers provided the yield of motley grass-grasses phytocenosis 23.0 c/ha, wheatgrasses - 24.1, steppe - 17.1 c/ha (see Table 2).

Табл. 2. Урожайность естественных фитоценозов при внесении удобрений (среднее за 8 лет), ц/га
Table 2. Productivity of natural phytocenoses with fertilization (average over 8 years), c / ha

Experiment variant	Phytocenosis		
	steppificated	motley grass-grasses	agropyron
Control (without fertilizer)	6,9	10,1	15,1
Mould 20 t/ha once every 4 years	9,4	14,6	16,7
Mould 20 t/ha once every 4 years + N60P60K60 annually	17,0	23,0	24,1
$N_{60}P_{60}K_{60}$ annually	14,6	21,4	20,0
$N_{30}P_{30}K_{30}$ annually	12,6	15,7	17,3
Mould 20 t/ha annually	12,2	14,5	15,7
Confidence interval	1,7	3	4,4
Proportion of the influence of the factor "Year" *	8	21	55
Proportion of the influence of the factor "Fertilizer"	21	21	9

*Процент от общей вариации признака.

CONCLUSION

In the Namsky agro-landscape, the highest productivity potential was obtained with the combined application of organic and mineral fertilizers (mulch 20 t/ha once in 4 years + N60P60K60 annually). On motley grass-grasses and wheatgrass phytocenoses hay yield reached 23,0-24,1 c/ha with exchange energy 27,0-22,4 GJ, fodder units 1472-1663, crude protein 336-371 kg per 1 ha. The content of digestible protein in 1 fodder unit of motley grass-grasses phytocenosis was 92 g, that of wheat grass - 102 g. The influence of mineral fertilizers and their coapplication with organic fertilizers on the productivity of natural phytocenoses is statistically reliable, which indicates the possibility of regulating the productivity of steppe phytocenoses. Meanwhile, the efficiency of mineral fertilizers and their coapplication with organic fertilizers significantly depended on the weather conditions of the growing season, which was most clearly manifested in the couch grass phytocenosis. At the same time on low-productive steppe phytocenoses with insufficient moisture application of organic and combined organic and mineral fertilizers positively affects the yield of fodder mass.

СПИСОК ЛИТЕРАТУРЫ

1. *Иванова Л.С.* Адаптивно-ландшафтные системы земледелия Лено-Амгинского междуречья: монография. Новосибирск, 2004. 131 с.
2. *Барашкова Н.В., Данилова А.А., Аржакова А.П., Мартынова Л.В., Устинова В.В., Иванова Л.С.* Продуктивность и средообразующий потенциал луговых фитоценозов в условиях среднетаежной подзоны Якутии: монография. Новосибирск: Издательство СО РАН, 2020. 218 с.
3. *Иванова Л.С.* Агроландшафтное районирование и агроэкологическая группировка земель среднетаежной подзоны Якутии для проектирования адаптивно-ландшафтных систем земледелия: монография. Новосибирск, 2018. 113 с.
4. *Чевычелов А.П., Барашкова Н.В., Захарова О.Г., Устинова В.В., Аржакова А.П.* Влияние длительного применения удобрений на урожайность растений и изменение свойств мерзлотной лугово-черноземной почвы // Агрохимический вестник. 2018. № 3. С. 26–31.
5. *Абрамов А.Ф.* Эколого-биохимические основы производства кормов и рационального использования пастбищ в Якутии: монография. Новосибирск: Издательство СО РАСХН, 2000. 205 с.
6. *Степанов А.И., Мерзлая Г.Е.* Агроэкологическая эффективность органических удобрений в условиях мерзлотных почв // Российская сельскохозяйственная наука. 2018. № 1. С. 35–38.
7. *Кислицына А.П., Фигурин В.А.* Влияние извести и минеральных удобрений на агрохимические показатели почвы и продуктивность лядвенце-тимофеечной травосмеси // Аграрная наука Евро-Северо-Востока. 2021. № 22 (3). С. 367–375.
8. *Иванова Н.Н., Капсамун А.Д., Павлючик Е.Н.* Эффективность возделывания пастбищных травостоев в условиях осушаемых земель Нечерноземья // Кормопроизводство. 2021. № 4. С. 4–8.
9. *Шайкова Т.В., Дятлова М.В., Волкова Е.С.* Влияние минеральных и комплексных удобрений на зерновую продуктивность озимой ржи в условиях Северо-Запада России // Кормопроизводство. 2020. № 9. С. 19–23.

REFERENCES

1. Ivanova L.S. *Adaptive-landscape systems of agriculture in the Lena-Amga* interfluve. Novosibirsk, 2004. 131 p. (In Russian).
2. Barashkova N.V., Danilova A.A., Arzhakova A.P., Martynova L.V., Ustinova V.V., Ivanova L.S. *Productivity and habitat-forming potential of meadow phytocenoses in the middle taiga subzone of Yakutia*. Novosibirsk, SB RAS Publ., 2020, 218 p. (In Russian).
3. Ivanova L.S. *Agrolandscape zoning and agroecological grouping of lands in the middle taiga subzone of Yakutia for the design of adaptive landscape farming systems*. Novosibirsk, 2018. 113 p. (In Russian).
4. Chevychelov A.P., Barashkova N.V., Zakharova O.G., Ustinova V.V., Arzhakova A.P. The effect of long-term use of fertilizers on crop yields and changes in the properties of permafrost meadow-chernozem soil. *Agrokhimicheskii vestnik = Agrochemical Herald*, 2018, no. 3, pp. 26–31. (In Russian).
5. Abramov A.F. *Ecological and biochemical foundations of fodder production and rational*

use of pastures in Yakutia. Novosibirsk, SB RAAS Publ., 2000. 205 p. (In Russian).
6. Stepanov A.I., Merzlaya G.E. Agroecological efficiency of organic and mineral fertilizers under conditions of frozen soil. *Rossiiskaya sel'skokhozyaistvennaya nauka = Russian Agricultural Sciences*, 2018, no. 1, pp. 35–38. (In Russian).
7. Kislitsyna A.P., Figurin V.A. The effect of lime and mineral fertilizers on agrochemical characteristics of soil and productivity of birdsfoot trefoil and timothy grass mixture. *Agrarnaya nauka Evro-Severo-Vostoka = Agricultural Science Euro-North- East*, 2021, no. 22 (3), pp. 367–375. (In Russian).
8. Ivanova N.N., Kapsamun A.D., Pavlyuchik E.N. Cultivation of grassland ecosystems on drained lands of the non-chernozem region. *Kormoproizvodstvo = Fodder Production*, 2021, no. 4, pp. 4–8. (In Russian).
9. Shaikova T.V., Dyatlova M.V., Volkova E.S. Impact of mineral and complex fertilizers on grain yield of winter rye in northwest Russia. *Kormoproizvodstvo = Fodder Production*, 2020, no. 9, pp. 19–23. (In Russian).

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ЗАЩИТА РАСТЕНИЙ НОВОГО СОРТА ЯРОВОЙ ПШЕНИЦЫ МАРСИАНКА

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Представлены результаты изучения воздействия протравителей семян и гербицидов на урожайность и экономическую эффективность нового сорта яровой пшеницы Марсианка. Закладку опыта, наблюдения и учеты проводили по общепринятым методикам. В фазе кущения пшеницы распространенность корневой гнили была на 22% меньше в посевах с применением протравленных семян. В опыте более высокая сохранность урожая от болезни 77,5% и прибавка 0,38 т/га получены в варианте с препаратом Максим Плюс, ВСК с нормой 1,5 л/т. С помощью препаратов Максим Плюс, ВСК и Виал ТрасТ, ВСК (0,4 л/т) натура зерна возросла до 799 г/л, стекловидность – до 65,4%, масса 1000 семян – до 38,6 г, содержание белка – до 16,2%, количество клейковины в зерне – до 36,0%. Виал ТрасТ, ВСК обеспечил лучшие экономические показатели: чистый доход возрос на 23,3%, себестоимость 1 т зерна снизилась на 9,1% и рентабельность повысилась на 20,2%. Обработка посевов в фазу кущения баковой смесью гербицидов Ластик ТОП, МКЭ (доза 0,4 л/га) и Магнум, ВДГ (0,008 кг/га) позволила получить наивысшую в опыте урожайность 3,63 т/га при улучшенном качестве зерна (натурная масса 798 г/л, стекловидность 67,9%, белковость зерна 17,3%). Гербицид Ланцелот 450, ВДГ и баковая смесь Пума Супер 100, КЭ + Секатор Турбо, МД обеспечили массу 1000 зерен 38,1 г и количество клейковины 34,7%. Посевы, обработанные гербицидом Ланцелот 450, ВДГ, баковыми смесями Ластик ТОП, МКЭ + Магнум, ВДГ и Балерина, СЭ + Мортира, ВДГ, обеспечили наибольший чистый доход 15 200–15 300 р./га. Максимальная рентабельность 116,9% и минимальная себестоимость 3688,66 р./т получены от применения препарата Грэнери, ВДГ.

Ключевые слова: пшеница мягкая яровая (*Triticum aestivum* L.), сорт, средство защиты, химический препарат, продуктивность, качество зерна, рентабельность

PLANT PROTECTION OF A NEW VARIETY OF SPRING WHEAT MARSIANKA

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The results of the study of the effect of seed dressers and herbicides on the yield and economic efficiency of the new variety of spring wheat Marsianka are presented. The experimentation, observations and registrations were carried out according to generally accepted methods. In the tillering phase of wheat, the incidence of root rot was 22% lower in crops with dressed seed. In the experiment a higher retention of yield from the disease 77.5% and an increase of 0.38 t/ha were obtained in the variant with

the preparation Maxim Plus, VSK with the rate of 1.5 l/t. Using the preparations Maxim Plus, VSK and Vial TrasT, VSK (0.4 l/t), grain unit increased to 799 g/l, vitreousness - to 65.4%, 1000 seed weight - to 38.6 g, protein content - to 16.2%, gluten content in grain - to 36.0%. Vial TrasT, VSK provided better economic performance: net income increased by 23.3%, the cost per tonne of grain decreased by 9.1% and profitability increased by 20.2%. Crop treatment in tillering phase with a tank mixture of herbicides Lastik TOP, MKE (dose 0.4 l/ha) and Magnum, VDG (0.008 kg/ha) resulted in the highest yield in the experiment 3.63 t/ha with improved quality of grain (natural weight 798 g/l, vitreousness 67.9%, grain protein content 17.3%). The herbicide Lancelot 450, VDG and the tank mixture Puma Super 100, KE + Pruner Turbo, MD ensured a weight of 38.1 g and a gluten content of 34.7%. Crops treated with the herbicide Lancelot 450, VDG, the tank mixtures Lastik TOP, ME + Magnum, VDG and Balerina, SE + Mortira, VDG provided the highest net income of 15,200-15,300 p/ha. A maximum profitability of 116.9% and a minimum cost of 3,688.66 p/t were obtained from the use of Greneri, VDG.

Keywords: spring soft wheat (*Triticum aestivum L.*), cultivar, protective agent, chemical preparation, productivity, grain quality, profitability

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INTRODUCTION

Wheat is the most important crop cultivated almost all over the Russian Federation and forms the basis of the country's grain complex, which development directly affects its food security [1].

Spring wheat in Eastern Siberia is the main grain crop grown for vegetable protein. This is due to its high technology and productivity, as well as the demand for its consumption by the population [2]. The task of crop cultivation technologies, including spring wheat, is to ensure high crop yields while optimizing labor and material and financial costs per unit of quality products[1]. It is possible to realize the potential of new wheat varieties in the formation of high quality grain yields by including in its production system the technologies that ensure the effective use of agricultural intensification means (organic and mineral fertilizers, biological preparations and plant protection agents against weeds, pests and diseases), which guarantee environmental safety [3]. Modern farming methods have significantly increased yields over the past 50 years, including through chemical control of plant pests and the use of new varieties and hybrids [4].

Among the factors that negatively affect the yield and quality of crops, including wheat, plant diseases stand out [5]. Root rot of various etiologies is a harmful disease of cereal crops worldwide. Fungi of genera *Rhizoctonia*, *Pythium*, and *Fusarium* are most often noted as causative agents of common root rot in the works of foreign scientists studying the control of this disease [6, 7]. In the Irkutsk region, root rot also annually causes serious damage to spring wheat crops. Its main causative agents are *Bipolaris sorokiniana* (Sacc.) *Shoemaker*. Syn.: *Helminthosporium sativum* Pammel, C.M. King et Bakke, *Helminthosporium sorokinianum* Sacc., *Drechslera sorokiniana* (Sacc.) Subram. Et P.C. Jain.; species of the genus *Fusarium* (F. *culmo-*

[1]Innovative technologies in farming and crop production in the Irkutsk region. Scientific and production recommendations. Irkutsk: FSBEI HE "Irkutsk State Agrarian University", 2021. 216 p.

rum (W.G.Sm.) Sacc. var. *culmorum*, F. *avenaceum* (Fr.) Sacc. var. *avenaceum*, F. *oxysporum* Schltdl. var. *oxysporum*, F. *graminearum* Schwabe, etc.). Species of the genus *Alternaria* (*A. alternata* species complex, etc.) are found in the root part of the stem, roots, and rhizosphere of wheat [8].

The formation of clusters in the district for the production of environmentally safe quality grain products demanded in the world market is possible on the basis of integrated chemicalization, including herbicidal and fungicidal plant protection [9]. The role of varietal characteristics in the development of root rot and leaf spot diseases was manifested in the lower incidence of root rot in mid-maturing varieties at tillering and milk-ripening stages of grain (by 31.0 and 23.4%, respectively) compared to mid-late ones [10]. Foreign researchers note the economic benefit of seed dressing with fungicides [11]. In Russia, the economic feasibility of expanding the volume of the rational system of protection of grain crops is confirmed by the effectiveness of the use of pesticides according to the indicator of the saved yield from pests, diseases and weeds (32.1%) of the potentially possible level of prevention of yield losses. At the same time, a relatively high level of profitability is achieved (67.7%) compared to the general indicators of grain production (24.9%) [12]. The use of chemical protection agents allows to stabilize the phytosanitary situation in agrocenosis by 70-95%, reducing yield losses from diseases, and ensure high crop productivity [13, 14].

In the soil and climatic conditions typical for the forest-steppe zone of Western Siberia, the use of fungicide seed dressing agents on fallow forecrop provides a reliable increase in wheat yield by 2.5%, from dressing agents and insecticides - by 14.4%, from the complex of phytosanitary agents - by 24.4% [15]. Manufacturers improve the range of fungicides, releasing to the market environmentally safe preparations, which at the same time have high efficiency against the target objects [16].

The purpose of the study was to study the effect of fungicides and herbicides on productivity, grain quality and economic efficiency of cultivation of the new variety of spring wheat Marsianka.

MATERIAL AND METHODS

Studies were performed in 2019, 2020 in the experimental field of the Irkutsk Research Institute of Agriculture. The object of the research is a new variety of spring wheat (*Triticum aestivum* L.) Marsianka. The influence factors of seed dressing and herbicide treatment were studied.

The experiment on fungicide application had the following scheme:

- Control (without seed treatment);
- BisolbiSan, L at the rate of 1 l/t;
- Oplot Trio, WSC - 0.5 l/t;
- Grandsil Ultra, SC - 0.5 l/t;
- Maxim Plus, WSC - 1.5 l/t;
- Vial TrasT, WSC - 0.4 l/t.

The experiment scheme for herbicide treatment of crops contained the following options for the use of preparations:

- Control (no herbicides);
- Granery, WDG at a rate of 0.025 kg/ha;
- Lancelot TM 450, WDG - 0.033 kg/ha;
- Lastik TOP, ME - 0,5 l/ha;
- Lastik TOP, ME - 0,4 l/ha + Magnum, WDG - 0,008 kg/ha;
- Ballerina, SE - 0,4 l/ha + Mortira, WDG - 0,015 kg/ha;
- Puma Super 100, EC - 0.6 l/ha + Secator Turbo, MD - 0.05 l/ha;
- Puma Plus, EC - 1.5 l/ha.

Field experiments were laid on clean fallow. Soil of the experimental plot (according to its granulometric composition) contained 4.5-4.9% of humus in the tilled layer (20-22 cm), 0.27% of total nitrogen (according to Kjeldahl), 11.2-11.9 mg of labile phosphorus and 7.9-8.6 mg of exchangeable potassium per 100 g of soil (according to Kirsanov), pH 4.6-4.9.

Wheat varieties were sown on May 10 with seeding rate of 7 million germinated seeds/ha. The area of plots was 75 m^2, and the repetition was three times. Plots were arranged systematically with an offset in each repetition. Experiment setting, observations and recordings were

made according to the approved methodology[2]. We counted weeds according to the method of the All-Russian Plant Protection Institute[3] before herbicide treatment in the phase of tillering of wheat varieties and 25 days after it on fixed trial plots (0.25 m^2) with four replications per plot in each replication. Yields in the phase of full grain ripeness were recorded after recalculation to 14% moisture content and 100% purity.

Meteorological conditions during the years of observations differed significantly from the mean annual values. Precipitation was 9.8% lower than normal during hot and dry growing seasons, while the sum of active air temperatures exceeded the mean annual values by 29.7%.

RESULTS AND DISCUSSION

The results of field experiments on the use of fungicides confirmed that the studied preparations markedly restrained the defeat of root rot, favorably affecting the growth and development of wheat plants. In the tillering phase, the disease incidence in the control variant (without seed dressing) was quite high and amounted to 80.1% with a disease development index of 1.4 points.

After seed treatment, the preparation Maxim Plus, WSC at a dose of 1.5 l / t was the most effective of all, reducing the incidence and index of disease development by 3.6 and 3.5 times, respectively. Chemical disinfectants Grandsil Ultra, SC, 0.5 l/t and Oplot Trio, WSC, 0.5 l/t were slightly inferior to it with the rates of 25.6 and 28.2%, respectively (see Table 1). Biological preparation BisolbiSan, L reduced the degree of disease lesion only by 22.6%.

Disease prevalence at full ripeness of wheat exceeded 98% and was not affected by the studied preparations. A relatively better effect was produced by Maxim Plus, WSC (95.9%).

The results of the field studies revealed that the most effective means of plant protection against weeds was a tank mixture of herbicides Lastik TOP, ME and Magnum, WDG (81.9%). By a statistically insignificant value it was inferior to the herbicide Puma Plus, EC and a mixture of Ballerina, SE + Mortira, WDG. The most ineffective was herbicide

Табл. 1. Показатели корневой гнили в растениях нового сорта яровой пшеницы Марсианка при воздействии биологического препарата и химических протравителей, %

Table 1. Indicators of root rot in plants of a new spring wheat variety Marsianka affected by the biological preparation and chemical dressers, %

Prevalence of root rot by vegetation phase	Dressing agent (biological and chemical preparations)					
	Control (without treatment)	BisolbiSan, L, 1 l/t	Oplot Trio, WSC - 0.5 l/t	Grandsil Ultra, SC - 0.5 l/t	Maxim Plus, WSC - 1.5 l/t;	Vial TrasT, WSC - 0.4 l/t.
Occurrence						
Tillering	80,1	62,0	28,2	25,6	22,5	46,0
Full ripeness	97,0	97,2	98,0	96,4	95,9	98,1
Average by the experiment	88,6	79,6	63,1	61,0	59,2	72,1
Development index						
Tillering	1,4	1,0	0,3	0,4	0,4	0,6
Full ripeness	1,6	1,4	1,6	1,5	1,8	1,7
Average by the experiment	1,5	1,2	1,0	1,0	1,1	1,2

[2]Methodology of State Variety Testing of Agricultural Crops. Moscow: State Commission on Crop Variety Testing, 1989. 195 p.

[3]Methods of accounting for pests. Recommendations of VIZR // Plant Protection and Quarantine. 2002. № 2, 3. pp. 49-54.

Lastik TOP, ME, 0.5 l/ha outside the tank mixture (see Table 2).

Preservation of yield from diseases due to the action of biological and chemical preparations allows us to obtain an increase compared to the control in the amount of 0.07 t/ha, or 2.5% - BisolbiSan, L to 0.38 t/ha, or 13.6% - Maxim Plus, WSC. Biological preparations gave the lowest yield increase. Chemical seed dressers provided a reliable increase in the gross grain yield (see Table 3).

The improvement of safety of the yield at seeding with treated seeds was accompanied by the increase of some grain quality indices: natural grain weight - by 3-15 g/l, vitreousness - by 0,4-1,9%, thousand-kernel weight - by 0,1-1,1 g, protein content - by 0,1-1,0% and the quantity of gluten in grain - by 0,3-2,9%. This range of variation of values is due to the different effects of the studied plant protection products, of which Vial TrasT, WSC and Maxim Plus, WSC were the most effective.

Табл. 2. Уровень засоренности посевов нового сорта яровой пшеницы Марсианка при обработке гербицидами и их баковыми смесями

Table 2. The level of weediness in crops of the new spring wheat variety Marsianka when treated with herbicides and their tank mixtures

Herbicide and tank mixture, dose	Number of weeds, pcs. /m^2		Biological efficiency, %
	before treatment	after treatment	
Control (without herbicides)	74	80	–
Granery, WDG, 0.025 kg/ha	72	14	80,5
Lancelot 450, WDG - 0.033 kg/ha	75	14	81,3
Lastik TOP, ME - 0,5 l/ha	74	35	52,7
Lastik TOP, ME - 0,4 l/ha + Magnum, WDG - 0,008 kg/ha	72	13	81,9
Ballerina, SE - 0,4 l/ha + Mortira, WDG - 0,015 kg/ha	76	14	81,6
Puma Super 100, EC - 0.6 l/ha + Secator Turbo, MD - 0.05 l/ha	74	15	79,7
Puma Plus, EC - 1.5 l/ha	71	13	81,7
Average value	73,5	24,8	

Табл. 3. Урожайность и качество зерна нового сорта яровой пшеницы Марсианка при воздействии биологических препаратов и химических протравителей

Table 3. Yield and grain quality of the new spring wheat variety Marsianka affected by biological preparations and chemical disinfectants

Dressing agent (biological and chemical preparations), dosage	Yield, t/ha	Grain unit, g/l	Vitreousness, %	Thousand-kernel weight, g	Content, %	
					protein	crude gluten
Control (without herbicides)	2,79	784	63,5	37,5	15,2	33,1
BisolbiSan, L, 1 l/t	2,86	787	63,9	37,6	15,3	33,4
Oplot Trio, WSC, 0.5 l/t	3,03	794	64,8	38,1	15,9	35,3
Grandsil Ultra, SC, 0.5 l/t	3,07	795	65,0	38,3	16,0	35,6
Maxim Plus, WSC, 1,5 l/t	3,17	798	65,3	38,6	16,2	35,8
Vial TrasT, WSC, 0,4 l/t	3,15	799	65,4	38,6	16,1	36,0
Average value	3,00	792	64,6	38,1	15,8	34,7
LSD	0,27	66,1	5,74	0,74	1,28	2,45

Treatment of wheat crops with herbicides and their tank mixtures helps to preserve the harvest to a greater extent and contributes to achieving higher productivity of the variety and grain quality (see Table 4).

Application of the tank mixture Lastik TOP, ME and Magnum, WDG, as well as the preparation Puma Plus, ME resulted in the highest yield increases of 0.43 and 0.42 t/ha, respectively, or 13.4 and 13.1%. Grain quality indicators show that the values of bulkiness (798 g/l), vitreousness (67,9%) and grain protein content (17,3%) were the best in the variant with the bath mixture Lastik Top, ME + Magnum, WDG. By weight of 1000 grains with the same value of 38.1 g Lancelot 450 herbicide, WDG and a tank mixture of Puma Super 100, ME + Secator Turbo, MD, stood out with the latter also having the best content of crude gluten (34.7%).

Economic benefit from the pre-sowing treatment of wheat seeds of the Marsianka variety by the studied preparations was confirmed not only by the increase of the profitability level from 98,9 to 118,9%, depending on the preparation used, but also by the increase of the net income from 11 100 to 13 690 rubles/ha and the decrease of the cost of production from 4021,5 to 3654,0 rubles/ton. Significantly higher economic indicators have chemical seed dressers. And the best values of all presented economic indicators provided the preparation Vial TrasT, WSC with the rate of 0.4 l / t (see Table 5). Biological means of protection BisolbiSan, L brought the lowest in the experiment net income 11540 r./ha (4.0% higher than the control), profitability (+ 2.9% to the control) and the cost of 1 ton of grain 3965.0 r.

Despite the increase in production costs of growing grain due to the use of chemical means of weed control, the revenue received from the increase in yield justifies the costs incurred and provides an increase in economic performance.

The highest net income (15.2-15.3 thousand rubles/ha) was obtained when treating crops with herbicide Lancelot 450, WDG, tank mixtures Lastik TOP, ME + Magnum, WDG and Balerina, SE + Mortira, WDG. With regard to the maximum profitability of production (116,9%) and the minimum cost of 1 ton

Табл. 4. Урожайность и качество зерна нового сорта яровой пшеницы Марсианка при обработке посевов гербицидами и их баковыми смесями

Table 4. Yield and grain quality of the new spring wheat variety Marsianka in crops affected with herbicides and their tank mixtures

Name of herbicide or herbicide tank mixture, dose	Yield, t/ha	Grain unit, g/l	Vitreousness, %	Thousand-kernel weight, g	Content, %	
					protein	crude gluten
Control (without herbicides)	3,20	787	65,8	36,9	15,9	32,6
Granery, WDG, 0.025 kg/ha	3,44	792	66,7	37,8	16,5	33,8
Lancelot 450, WDG - 0.033 kg/ha	3,54	794	66,5	38,1	16,7	33,9
Lastik TOP, ME - 0,5 l/ha	3,51	789	66,2	37,7	16,4	32,8
Lastik TOP, ME - 0,4 l/ha + Magnum, WDG - 0,008 kg/ha	3,63	798	67,9	37,8	17,3	34,6
Ballerina, SE - 0,4 l/ha + Mortira, WDG - 0,015 kg/ha	3,58	791	67,2	38,0	16,9	34,4
Puma Super 100, EC - 0.6 l/ha + Secator Turbo, MD - 0.05 l/ha	3,49	793	67,6	38,1	17,1	34,7
Puma Plus, EC - 1.5 l/ha	3,62	796	66,9	37,9	17,0	34,8
Average value	3,00	792	64,6	38,1	15,8	34,7
LSD	0,29	63,7	5,5	1,0	1,3	2,8

Табл. 5. Экономическая эффективность протравливания семян нового сорта яровой пшеницы Марсианка

Table 5. Economic efficiency of seed treatment for the new spring wheat variety Marsianka

Dressing agent (biological and chemical preparations), dose	Conditional net income, r./ha	Cost price of 1 ton of grain, r.	Breakeven level, %
Control (without treatment)	11 100	4021,5	98,9
BisolbiSan, L, 1 l/t	11 540	3965,0	101,8
Oplot Trio, WSC, 0.5 l/t	12 570	3851,5	107,7
Grandsil Ultra, SC, 0.5 l/t	13 040	3752,4	113,2
Maxim Plus, WSC, 1,5 l/t	13 260	3817,0	109,6
Vial TrasT, WSC, 0,4 l/t	13 690	3654,0	118,9
Average value	12 533	3843,6	108,4

Табл. 6. Экономическая эффективность обработки посевов нового сорта яровой пшеницы Марсианка гербицидами и их баковыми смесями

Table 6. Eonomic efficiency of dressing the crops of the new spring wheat variety Marsianka with herbicides and their tank mixtures

Name of herbicide or herbicide tank mixture, dose	Conditional net income, r./ha	Cost price of 1 ton of grain, r.	Breakeven level, %
Control (without herbicides)	13 176	3882,50	106,1
Granery, WDG, 0.025 kg/ha	14 831	3688,66	116,9
Lancelot 450, WDG - 0.033 kg/ha	15 233	3696,89	116,4
Lastik TOP, ME - 0,5 l/ha	13 984	4015,95	99,2
Lastik TOP, ME - 0,4 l/ha + Magnum, WDG - 0,008 kg/ha	15 227	3805,23	110,2
Ballerina, SE - 0,4 l/ha + Mortira, WDG - 0,015 kg/ha	15 343	3714,25	115,4
Puma Super 100, EC - 0.6 l/ha + Secator Turbo, MD - 0.05 l/ha	13 246	4204,58	90,3
Puma Plus, EC - 1.5 l/ha	13 820	4182,32	91,3
Average value	14 358	3898,80	105,7

of grain (3688,66 rubles) the preparation Granery, WDG stood out due to the lowest cost of its purchase (see Table 6).

CONCLUSIONS

1. The intensity of plant growth and development, productivity, grain quality and economic efficiency of cultivation of the new variety of spring wheat Marsianka largely depends on the use of protective agents (seed dressers and herbicides). Chemical disinfectants are twice as effective as biological preparations in terms of effectiveness (degree of reduction of disease incidence and preservation of plants for harvesting).

2. The biological efficacy of the tank mixture Lastik TOP, ME + Magnum, WDG in wheat crops was 81.9%. Its superiority over the tank mixture Balerina, SE + Mortira, WDG and herbicides Puma Plus, ME is statistically insignificant.

3. The highest harvest of quality grain (3.15 and 3.17 t/ha) was obtained with pre-sowing dressing of seeds with Maxim Plus, WSC with the rate of 1.5 l / t and Vial TrasT, WSC - 0.4 l / t. The growth of productivity was accompanied by improvement of the quality of grain: grain size increased to 15 g/l, vitreousness - by 0,4-1,9%, weight of 1000 seeds - by 0,1-1,1 g, protein content - by 0,1-1,0% and gluten content

in grain - by 0,3-2,9%. The treatment of crops in the phase of tillering with a tank mixture of herbicides Lastik Top, ME, 0.4 l / ha and Magnum, WDG at a dose of 0.008 kg / ha led to the highest in the experiment yield 3.63 t / ha with improved quality of grain: natural weight - 798 g / l, vitreousness - 67,9% and protein content in grain - 17.3%. The highest indicators of the weight of 1000 grains (38.1 g) and the amount of gluten (34.7%) in wheat were observed in variants with the herbicide Lancelot 450, WDG and a tank mixture of Puma Super 100, EC + Secator Turbo, MD.

4. The economic advantage of pre-sowing treatment of wheat seeds of the Marsianka variety with investigated chemical means of protection is proved by reliable growth of net income by 23,3%, reduction of production costs by 9,1% and increased profitability by 20,2%. The best values of all noted economic indicators provided the preparation Vial TrasT, WSC with the rate of 0.4 l / t. The excess of the indicator of net income over the control variant from the use of the biological preparation BisolbiSan, L was only 4.0%.

5. Chemical means of weed control provide additional profits from increasing yields and obtaining quality products. The greatest net income (15.2-15.3 thousand roubles/ha) was obtained from the crops treated with Lancelot 450 herbicide, WDG, tank mixtures of Lastik TOP, ME + Magnum, WDG and Balerina, SE + Mortira, WDG. Preparation Granerie, WDG maximized profitability to 116.9% and made the production of 1 ton of grain cheaper to 3688.66 roubles due to the lower cost.

СПИСОК ЛИТЕРАТУРЫ

1. *Милащенко Н.З., Трушкин С.В.* Резервы производства высококачественного зерна пшеницы в российском земледелии // Земледелие. 2018. № 7. С. 30–33.
2. *Келер В.В., Хижняк С.В.* Аспекты повышения продуктивности и рентабельности производства зерна яровой пшеницы в Красноярском крае // Вестник КрасГАУ. 2019. № 6 (147). С. 28–34.
3. *Журавлева Е.В., Милащенко Н.З., Сапожников С.Н., Трушкин С.В.* Система увеличения производства высококачественного зерна пшеницы // Достижения науки и техники АПК. 2020. Т. 34. № 3. С. 7–10.
4. *Ramakrishna W., Yadav R., Li K.* Plant growth promoting bacteria in agriculture: Two sides of a coin // Applied Soil Ecology, 2019, no. 138, pp. 10–18.
5. *Санин С.С.* Адаптивная защита растений – важнейшее звено современного растениеводства // Защита и карантин растений. 2019. № 2. С. 3–8.
6. *Mavrodi O.V., Walter N., Elateek S., Taylor C.G., Okubara P.A.* Supression of *Rhizoctonia* and *Pythium* root rot of wheat by new strains of *Pseudomonas* // *Biological Control*, 2012, vol. 62, no. 2, pp. 93–102.
7. *Wang L.-Y., Xie Y.-S., Cui Y.-Y., Xu J., He W., Chen H.-G., Guo J.-H.* Conjunctively screening of biocontrol agents (BCAs) against fusarium root rot and fusarium head blight caused by *Fusarium graminearum* // *Microbiological Research*, 2015, vol. 177, pp. 34–42.
8. *Разина А.А., Дятлова О.Г.* Сидеральный пар – агроприем для снижения распространения корневой гнили // Сибирский вестник сельскохозяйственной науки. 2016. № 6. С. 5–12.
9. *Першукевич П.М., Тю Л.В., Гриценко Г.М.* Проблемы и перспективы развития зерновой отрасли и рынка зерна в Сибирском федеральном округе // Достижения науки и техники АПК. 2019. Т. 33. № 10. С. 5–8.
10. *Власенко Н.Г., Егорычева М.Т., Иванова И.А.* Влияние технологии возделывания на пораженность болезнями новых сортов яровой пшеницы // Сибирский вестник сельскохозяйственной науки. 2017. Т. 47. № 1. С. 56–63.
11. *Jarroudi M.E., Kouadio L., Beyer M., Junk J., Hoffmann L., Tychon B., Maraite H., Bock C.H., Delfosse Ph.* Economics of a decision-support system for managing the main fungal diseases of winter wheat in the Grand-Duchy of Luxembourg // Field Crops Research, 2015, vol. 172, pp. 32–41.
12. *Захаренко В.А.* Экономическая целесообразность системы защиты зерновых культур в России // Достижения науки и техники АПК. 2018. Т. 32. № 7. С. 5–8.
13. *Санин С.С., Сандухадзе Б.И., Мамедов Р.З., Карлова Л.В., Корнева Л.Г., Рулева О.М., Санин Ст.С.* Технологии интенсивного зернопроизводства и защита растений // Защита и карантин растений. 2021. № 5. С. 9–16.

14. *Кекало А.Ю., Немченко В.В., Заргарян Н.Ю., Филиппов А.С., Козлова Т.А.* Современный подход к вопросу защиты пшеницы от болезней и вредителей // Земледелие. 2020. № 5. С. 41–45.
15. *Слободчиков А.А.* Эффективность защиты сортов яровой пшеницы от вредных организмов // Земледелие. 2019. № 2. С. 45–47.
16. *Глазунова Н.Н., Безгина Ю.А., Устимов Д.В., Мазницына Л.В.* Биологическая эффективность фунгицидов в посевах озимой пшеницы в условиях зоны неустойчивого увлажнения Ставропольского края // Вестник АПК Ставрополья. 2018. Т. 3. № 31. С. 66–70.

REFERENCES

1. Milaschenko N.Z., Trushkin S.V. Reserves of production of high-quality wheat grain in Russian agriculture. *Zemledelie = Zemledelie*, 2018, no. 7, pp. 30–33. (In Russian).
2. Keler V.V., Khizhnyak S.V. The aspects of productivity and profitability increasing in spring wheat grain production in Krasnoyarsk region. *Vestnik KrasGAU = Bulletin of KrasGAU*, 2019, vol. 147, no. 6, pp. 28–34. (In Russian).
3. Zhuravleva E.V., Milashchenko N.Z., Sapozhnikov S.N., Trushkin S.V. System for increasing the production of high-quality wheat. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2020, vol. 34, no. 3, pp. 7–10. (In Russian).
4. Ramakrishna W., Yadav R., Li K. Plant growth promoting bacteria in agriculture: Two sides of a coin. *Applied Soil Ecology*, 2019, no. 138, pp. 10–18.
5. Sanin S.S Adaptive plant protection is the most important link in modern crop production. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine*, 2019, no. 2, pp. 3–8. (In Russian).
6. Mavrodi O.V., Walter N., Elateek S., C.G. Taylor, Okubara P.A. Supression of *Rhizoctonia* and *Pythium* root rot of wheat by new strains of *Pseudomonas. Biological Control*, 2012, vol. 62, no. 2, pp. 93–102.
7. Wang L.-Y., Xie Y.-S., Cui Y.-Y., Xu J., He W., Chen H.-G., Guo J.-H. Conjunctively screening of biocontrol agents (BCAs) against fusarium root rot and fusarium head blight caused by *Fusarium graminearum. Microbiological Research,* 2015, vol. 177, pp. 34–42.
8. Razina A.A., Dyatlova O.G. *G*reen-manured fallow is an agricultural technique for reducing root rot propagation. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2016, no. 6, pp. 5–12. (In Russian).
9. Pershukevich P.M., Tyu L.V., Gritsenko G.M. Problems and prospects for the development of the grain industry and the grain market in the Siberian Federal District. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2019, vol. 33, no. 10, pp. 5–8. (In Russian).
10. Vlasenko N.G., Egorycheva M.T., Ivanova I.A. Influence of cultivation technology on affection of new spring wheat varieties with diseases. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2017, vol. 47, no. 1, pp. 56–63. (In Russian).
11. Jarroudi M.E., Kouadio L., Beyer M., Junk J., Hoffmann L., Tychon B., Maraite H., Bock C.H., Delfosse Ph. Economics of a decision-support system for managing the main fungal diseases of winter wheat in the Grand-Duchy of Luxembourg. *Field Crops Research*, 2015, vol. 172, pp. 32–41.
12. Zakharenko V.A. Economic expediency of the system of grain crop protection in Russia. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2018, vol. 32, no. 7, pp. 5–8. (In Russian).
13. Sanin S.S., Sandukhadze B.I., Mamedov R.Z., Karlova L.V., Korneva L.G., Ruleva O.M., Sanin St.S. Technologies of intensive grain production and plant protection. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine*, 2021, no. 5, pp. 9–16. (In Russian).
14. Kekalo A.Yu., Nemchenko V.V., Zargaryan N.Yu., Filippov A.S., Kozlova T.A. A modern approach to the wheat protection from diseases and pests. *Zemledelie = Zemledelie*, 2020, no. 5, pp. 41–45. (In Russian).
15. Slobodchikov A.A. Efficiency of protection of spring wheat varieties from pests. *Zemledelie = Zemledelie*, 2019, no. 2, pp. 45–47. (In Russian).
16. Glazunova N.N., Bezgina Yu.A., Ustimov D.V., Maznitsyna L.V. Biological efficiency of fungicides in winter wheat sows in the conditions of the zone of the unstable humidification of the Stavropol territory. *Vestnik APK Stavropol'ya = Agricultural Bulletin of Stavropol Region,* 2018, vol. 31, no. 3, pp. 66–70. (In Russian).

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РЕЗУЛЬТАТЫ ИЗУЧЕНИЯ СОРНО-ПОЛЕВОЙ ФЛОРЫ ПРИМОРСКОГО КРАЯ В 2016–2020 гг.

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Представлены результаты изучения сорного компонента агроценозов сои, ранних зерновых культур и кукурузы в Приморском крае. Всего в 2016–2020 гг. обнаружено 111 видов сорных растений, относящихся к 35 семействам. По сравнению с результатами обследований посевов сельскохозяйственных культур, проведенных в 2006–2015 гг., общее количество выявленных видов увеличилось на 23. Наибольшее количество видов принадлежит семействам Asteraceae (24), Poaceae (15), Polygonaceae (11), Fabaceae (9), Brassicaceae (8), Caryophyllaceae (7) и Lamiaceae (5). Остальные 26 семейств представлены 1–3 видами каждое. Впервые обнаружены сорняки-представители семейств Scrophulariaceae, Violaceae, Lythraceae, Onagraceae, Asclepiadaceae и Boraginaceae. Наибольшим оказался флористический состав соевых агроценозов – 108 сорных видов 31 семейства. В посевах зерновых культур и кукурузы разнообразие сорняков отмечено менее значительным – 75 видов 22 семейств и 72 вида 25 семейств соответственно. Сорная растительность во всех указанных культурах представлена 62 видами 19 семейств. Основными сорными видами, которые произрастали на 97–99% обследуемой территории при достаточно высокой средней густоте стояния (21–61 шт./м^2), оказались амброзия полынолистная, ежовник обыкновенный (просо куриное) и амброзия полыннолистная. Также более чем на половине обследованных посевов сои, зерновых культур и кукурузы присутствовали шерстняк мохнатый, осот полевой, пырей ползучий, марь белая, виды полыни, хвощ полевой, бодяк щетинистый, коммелина обыкновенная и щетинник малорослый. Практические мероприятия по защите от сорных растений в Приморском крае должны быть в первую очередь нацелены на контролирование этих видов.

Ключевые слова: сельскохозяйственная культура, обследование посевов, засоренность, сорное растение, вид, видовой состав, встречаемость, плотность засорения

RESULTS OF THE STUDY OF THE WEED-FIELD FLORA OF PRIMORSKY TERRITORY IN 2016-2020

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The results of the study of the weed component of soybean, early grain crops and maize agrocenoses in Primorsky Territory are presented. In total, 111 species of weeds belonging to 35 families were found during the period from 2016 to 2020. Compared with the results of crop surveys conducted in 2006-2015, the total number of species detected has increased by 23. The largest number of species belongs to the families Asteraceae (24), Poaceae (15), Polygonaceae (11), Fabaceae (9), Brassicaceae (8), Caryophyllaceae (7) and Lamiaceae (5). The remaining 26 families were represented by 1-3 species each. For the first time weeds-representatives of the families Scrophulariaceae, Violaceae, Lythraceae, Onagraceae, Asclepiadaceae and Boraginaceae have been discovered. The floristic composition of soybean agrocenoses was the highest with 108 weed species from 31 families. In cereal and maize crops, weed diversity was less significant, with 75 species in 22 families

and 72 species in 25 families, respectively. Weed vegetation in all the above crops is represented by 62 species of 19 families. The main weed species that grew on 97-99% of the surveyed territory with a sufficiently high average density of standing (21-61pcs/m^2) were Asian copperleaf, cockspur grass and common ragweed. Also, more than half of the surveyed crops of soybeans, cereals and corn were hairy cupgrass, perennial sow thistle, common couch-grass, common lamb's quarters, wormwood species, field horsetail, yellow thistle, dayflower and yellow foxtail. Practical measures to protect against weeds on the Primorsky Territory should be primarily aimed at controlling these species.

Keywords: agricultural crop, crops inspection, weed contamination, weed plant, species, species composition, occurrence, density of contamination

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INTRODUCTION

The Far Eastern Federal District (FEFD) covers 36% of the area of the Russian Federation. The southern territories of the FEFD include the Amur Region, the Jewish Autonomous Oblast, the Khabarovsk Territory and the Primorsky Territory, where 77% of the Far Eastern agricultural land and 92% of the arable land are located [1]. In the Primorsky Territory over the last 5 years the sown area has increased by 26.6 thousand hectares and reached 449.2 thousand hectares in 2020. In 2020, almost 62% of the Territory is sown with soybeans, 7.6% with spring cereals and 15.7% with corn[1].

The pace of development of agricultural production in Primorye still does not meet the growing needs for food and raw materials. A serious obstacle in obtaining high and stable yields of cultivated crops is a significant weed infestation of the fields, determined by the peculiarities of the local monsoon climate.

The main harm caused by weeds is a sharp decrease in the crop yield and deterioration of the quality of products as a result of interspecific competition for the main factors of life - water, light and nutrients [2]. For example, according to the data of the All-Russian Institute of Oil Crops, removal of nutrients by ragweed above ground mass (20 pcs. /m^2, or 5 t/ha) amounts to: nitrogen - 135 kg/ha, phosphorus - 40 kg/ha, potassium - 157 kg/ha [3]. In Russia, the potential risks of reducing the yield of grain crops from weeds annually average 15.5%, soybeans - 16.5%. In 2017-2019, yield losses from the spread of weeds in agroecosystems averaged 16.1% in the country [4].

Scientific and informational basis for the development and implementation of practical measures to protect plants are the results of phytosanitary monitoring in combination with diagnosis and prediction of development and spread of pests in agrocenoses. Monitoring studies provide the agricultural sector with relevant phytosanitary information, including data on the weed infestation of crops [5, 6].

The species composition of weeds, their number and distribution in agrocenoses are in constant dynamics determined by climatic changes, and directly depend on seasonal weather conditions and a number of anthropogenic factors. On the territory of the agroecosystem or crop rotation there are many weed spe-

[1]Sown areas of agricultural crops in the Primorsky Territory: Statistical collection. Primorskstat. Vladivostok, 2021. 99 p.

cies, which under the influence of the features of cultivation technologies manifest themselves differently in different crops, consistently cultivated on the same field contour. Thus, the weed infestation of crops is determined by a number of factors, among which the main ones are the features of cultivation technology and soil and climatic conditions [7].

At present, herbological studies in Russia are carried out on a regular basis mainly in the Moscow, Leningrad, Novgorod, Pskov, Chelyabinsk oblasts, Krasnodar, and Primorsky territories. We study the succession of weeds in agrophytocenoses of the most important agricultural crops and find out the connections of these processes with the implemented agricultural technologies and the soil and climatic conditions characteristic of the regions. The most common and (or) harmful, economically important weed species are identified and ways of their effective control are proposed [8-15].

The purpose of the study is to herbologically assess the current state of the main agricultural crops in the Primorsky Territory.

MATERIAL AND METHODS

Monitoring surveys were conducted annually in 2016-2020 in ten administrative districts of the Primorsky Territory in accordance with the approved instructions[2]. Crop surveys with a total area of about 20 thousand ha were conducted for the first time in a season during the mass emergence of major weed species (II-III decades of June). Each field was passed diagonally, evenly overlapping accounting frames with the area of 0.25 m^2, within which the number of weeds of each species was counted separately. Species affiliation of weeds was determined according to the publications [16, 17]. The second time during the season, the crops were examined in August to confirm the data of the first survey and to obtain the final information on the weed component of agrophytocenoses.

The degree of general weed infestation was determined according to the scale proposed by V.V. Isayev: the number of weeds up to 5 pcs/m^2 - very weak; 5.1-15.0 - weak; 15.1-50.0 - medium; 50.1-100.0 - strong and more than 100 pcs/m^2 - very strong [18].

The occurrence of each weed species was calculated using the formula

$$V = \frac{a \times 100\%}{n},$$

where V is the species occurrence in the surveyed territory, a is the number of surveyed habitats where the species was registered, n is the total number of surveyed habitats [19]. Weed species differing in frequency of detection were divided into groups. The predominant weed species with high occurrence in the entire surveyed area and (or) in the crops of individual crops were singled out.

Average weed density (weed stand density) was calculated taking into account the total area of the surveyed crops according to the formula

$$\mathrm{AD} = \frac{\Sigma_{i=1}^{n} Pi \times Si}{\Sigma_{i=1}^{n} Si},$$

where AD is the average species density, Pi is the density of plants of this species per field (pieces per square meter of sowing), Si is the area of the surveyed field, n is the total number of surveyed fields[3].

RESULTS AND DISCUSSION

Phytosanitary monitoring of crops in the Primorsky Territory, conducted in 2016-2020, revealed a high level of general weed infestation in soybeans, early grains (wheat, barley, oats) and corn (see Table 1).

The main characteristic of the weed flora is the botanical spectrum of its constituent species. Previously, as a result of research conducted by FERIPP staff in 2006-2015 in four

[2]Instruction for determining fields, perennial plantations, cultivated hayfields and pastures. Moscow: Agropromizdat, 1986. 15 p.

[3]Vostrikova S.S., Morokhovec V.N., Morokhovec T.V., Basaj Z.V., Shterbolova T.V. Dynamics of soybean agrocenosis component in the Primorsky Territory. Scientific support of soybean production: problems and prospects Blagoveshensk: IPK "ODEON" LLC, 2018. pp. 131-140.

natural-climatic zones of the Primorsky Territory, 88 species of weeds of 29 families were registered in crops of major agricultural crops (soybean, spring cereals, and corn). In soybean crops, 80 species were detected. In agrocenoses of early cereals and maize, 73 and 52 species were recorded, respectively. The most frequent weeds annually registered on 70-100% of the surveyed areas were barnyard grass *Echinochloa crusgalli* (L.) Beauv, copper leaf *Acalypha australis* L, field sow thistle *Sonchus arvensis* L., common lamb's quarters *Chenopodium album* L., ragweed *Ambrosia artemisiifolia* L., and yellow thistle *Cirsium setosum* (Willd.) Bieb[4]. The same species were characterized by high density of growth, occurring in the surveyed fields in the maximum quantities, and were most widely and abundantly represented in the crops of all crops [15].

In 2016-2020, 111 species of weeds belonging to 33 botanical families were found in the surveyed areas. The largest number of species (24) belongs to the family Asteraceae Dumort. Then, in descending order by the number of species represented, the families of bluegrass Poaceae Barnhart (15 species), knotgrass Polygonaceae Juss. (11), beans Fabaceae Lindl. (9), cabbage Brassicaceae Burnett (8), carnation Caryophyllaceae Juss. (7), mint family Lamiaceae Lindl. (5), the bindweed Convolvulaceae Juss., and the pink Rosaceae Juss. - three species each. Primulacea Vent. and Malvaceae Juss. were represented by two species each, the other 22 families by one species.

The species composition of weeds largely depends on the biology and cultivation technology of crops. The floristic composition of soybean agrocenoses was the widest - 108 weed species of 31 families. In grain and maize crops the diversity of weeds was less considerable: 75 species in 22 families and 72 species in 25 families, respectively. All these crops were infested with plants of 62 species of 19 families.

When considering the ratio of weed groups, we found that dicotyledonous plants significantly outnumbered monocotyledonous plants - 92 species (84% of the total recorded number) against 19. Among dicotyledonous weeds, 55 species were short-lived plants and 37 were perennial. Monocotyledonous weeds were represented by 10 short-lived and 9 perennial species. Minor dicotyledonous species were the predominant group in soybean, spring grain crops, and corn cenoses. In particular, the ratio of minor and perennial dicotyledonous species in soybean crops was 54: 35, in early cereal crops 39: 25, and in maize 37: 26. In soybean agrocenoses, 10 perennial and 9 perennial monocotyledonous weed species were observed. Grain crops and maize were infested by 6 species of small annual weeds and by 5 and 3 perennial annual weeds, respectively.

The main weeds that grew in 97-99% of the surveyed area at a fairly high average standing density (21-61 pcs/m^2) were copper leaf, barnyard grass (barnyard millet), and ragweed (see Table 2). Taken together without other weeds 3 plant species formed a strong (on average - 73,6 pcs. /m^2) weed infestation of maize and very strong (120,3-150,6 pcs. /m^2) - of cereals and soybean. In soybean crops, copper leaf and

Табл. 1. Общая засоренность сельскохозяйственных культур в Приморском крае (среднее за 2016–2020 гг.), % от обследованной площади

Table 1. Total weed contamination of agricultural crops in Primorsky Territory (average for 2016–2020), % of the area studied

Crop	Degree of weediness				
	very weak	weak	medium	strong	very strong
Soy	0,8	–	4,3	22,6	72,3
Early ripening grain crops	–	–	9,5	17,8	72,7
Corn	–	–	16,5	35,5	48,0
The entire survey area	0,6	–	6,0	26,8	66,6

[4]Morokhovets T.V., Morokhovets V.N., Vostrikova S.S., Basay Z.V., Shterbolova T.V. Evaluation of weed frequency in crops of the Primorsky Territory. Protection of grain crops from diseases, pests, weeds: achievements and problems. Bolshiye Vyazemi, 2016. pp. 141-156.

barnyard grass dominated quantitatively. Cereal crops were most densely infested by ragweed. The minimum total weed infestation of copper leaf, barnyard grass and ragweed was detected in corn crops.

Also, in the whole surveyed area with high occurrence (on average, more than 50%) were found hairy cupgrass *Eriochloa villosa* (Thunb. ex Murray) Kunth, field thistle, wheatgrass *Elytrigia repens* (L.) Nevski, common lamb's quarters, wormwood species (common *Artemisia vulgaris* L., red-footed *A. rubripes* Na-Kai, Sivers *A. sieversiana* Willd.), field horsetail *Equisetum arvense* L., yellow thistle, dayflower *Commelina communis* L., and bristle grass *Setaria pumila* (Poir.) Schult. (S. glauca (L.) Beauv.) Practically all listed species are widespread in soybean, cereal crops and corn. Only field horsetail in early cereals (48%) and bristle grass in maize (48%) were found with frequency of occurrence below 50%. Average abundance of most species of this group in crops was 1.51-13.03 units/m^2. In the quantity of less than 1 pc/m^2 we recorded yellow thistle on early cereals and wormwood (species) - in crops of maize.

Velvetleaf *Abutilon theophrasti* Medik., curly sorrel *Rumex crispus* L., rough hedge woundwort *Stachys aspera* Michx., clover species (meadow or red *Trifolium pratense* L., lupin *T. lupinaster* L., field *T. campestre* Schreb., creeping or white *T. repens* L., hybrid (pink or Swedish) *T. hybridum* L., arable *T. arvense* L.), trailing hollyhock *Hibiscus trionum* L., swamp plantain *Plantago uliginosa* F.W. Schmidt, green bristle grass *Setaria viridis* (L.) Beauv., pyrethrum *Tripleurospermum inodorum* (L.) Sch. Bip., spotted knotweed *Persicaria maculosa* S.F. Gray, marsh cress *Rorippa palustris* (L.) Bess., siegesbeckia *Sigesbeckia pubescens* Makino, common reed *Phragmites australis* (Cav.) Trin. ex Steud, bur beggare *Bidens tripartita* L., wild soybean *Glycine soja* Siebold et Zucc., cat pea *Vicia cracca* L., and Mongolian dandelion *Taraxacum mongolicum* Hand-Mazz. Crop infestation density by species from this group was insignificant and averaged less than one plant per square meter of crop in 5 years. In some years, average abundance of 3 to 5 plants/m^2 was recorded for curly sorrel, marsh cress, and siegesbeckia in soybean crops, for hibiscus trifoliate, green bristle grass, and for clover and curly sorrel in early cereal crops. The maximum quantity of the bur beggare (2 pcs/m^2) was observed in soybean crops. The same amount of the marsh cress in corn crops, trailing hollyhock and Velvetleaf in maize crops were recorded in some years with the same abundance.

Average 5-year occurrence of field dodder *Cuscuta campestris* Yunck., eastern knotgrass *Persicaria orientalis* (L.) Spach, doorweed *Polygonum aviculare* L., redroot amaranth *Amaranthus retroflexus* L., radiant chickweed *Fimbripetalum radians* (L.) Ikonn, Siberian cocklebur *Xanthium sibiricum* Patrin ex Widd., waterpepper smartweed *Persicaria hydropiper* (L.) Spach, hemp nettle *Galeopsis bifida* Boenn., elsholtzia *Elsholtzia pseudocristata* Levl. et Vaniot, field mint *Mentha arvensis* L., common spurry *Spergula arvensis* L. were 11-19% with a stand density less than 1 pc/m^2. Some of these species were more widespread in individual crops. For example, field dodder, redroot amaranth and radiant chickweed Fimbripetalum radians (L.) Ikonn were more common in soybean crops than in other crops. Hemp nettle was the most frequent in early cereal crops, while eastern knotgrass, doorweed and Siberian cocklebur were more common in maize crops.

The following 11 species of weed plants (bladder campion *Oberna behen* (L.) Ikonn., Siberian crane's bill *Geranium sibiricum* L., Japanese hop *Humulus japonicus* Siebold et Zucc. Love, climbing buckwheat *Fallopia convolvulus* (L.) A. Love, common shepherd's purse *Capsella bursa-pastoris* (L.) Medik., rock jasmine *Androsace filiformis* Retz., annual knawel *Scleranthus annuus* L., rocket cress *Barbarea arcuata* (Opiz ex J. et C. Presl) Reichb, Canada fleabane *Conyza canadensis* (L.) Cronq., black nightshade *Solanum nigrum* L., wartwort *Gnaphalium uliginosum* L.) were found in 5-10% of agricultural areas, mostly with an average number of less than 1 pc/m^2. Only for the rock jasmine and annual knawel average abundance values were registered slightly higher - 4.99 and 1.02 pcs/m^2, respectively. Standing density of the rock jasmine in 2019 and 2020

Табл. 2. Основные засорители посевов сельскохозяйственных культур в Приморском крае (среднее за 2016–2020 гг.)
Table 2. The main weeds of crops in Primorsky Territory (average for 2016-2020)

Weed plant	Occurrence, %				Abundance, pcs. /m2			
	in all crops	including in the crops of			in all crops	including in the crops of		
		soy	early ripening grain crops	corn		soy	early ripening grain crops	corn
Copper leaf	99	99	98	100	60,74	70,44	36,14	32,26
Barnyard grass	98	97	100	100	52,08	59,52	52,90	23,18
Ragweed	97	90	98	100	20,87	20,64	31,27	18,12
Hairy cupgrass	86	85	79	68	9,05	9,47	5,51	9,61
Field sow thistle	83	85	85	76	4,60	5,27	5,84	2,44
Wheatgrass	77	84	63	67	13,03	15,09	2,98	9,38
Common lamb's quarters	75	77	67	71	7,06	8,78	5,25	1,59
Wormwood, species	69	75	55	58	1,51	1,74	0,94	0,20
Field horsetail	69	70	48	82	5,55	8,13	3,56	7,19
Yellow thistle	69	67	58	80	2,01	1,82	0,69	3,50
Dayflower	62	59	58	77	2,40	1,84	2,71	4,39
Bristle grass	54	54	61	48	2,29	1,64	5,23	1,22
Velvetleaf	48	49	53	36	0,74	0,71	0,59	0,87
Curly sorrel	43	45	34	40	1,72	2,10	0,84	0,68
Rough hedge woundwort	37	36	37	41	0,70	0,82	0,35	0,53
Clover, species	37	38	53	16	0,39	0,45	1,04	0,08
Trailing hollyhock	32	28	29	44	1,05	0,67	1,95	1,16
Swamp plantain	32	33	41	22	0,53	0,57	0,37	0,18
Green bristle grass	31	32	48	14	0,49	0,48	1,22	0,24
Pyrethrum	30	31	36	18	0,37	0,40	0,34	0,39
Spotted knotweed	28	27	25	40	0,42	0,43	0,27	0,48
Marsh cress	28	30	18	19	1,17	1,42	0,52	0,17
Siegesbeckia	28	33	19	16	1,04	1,35	0,37	0,19

Ending table. 2

Common reed	27	33	14	12	0,70	0,73	0,23	0,63
Bur beggare	26	26	29	22	0,72	0,80	0,39	0,50
Wild soybean	26	32	13	14	0,64	0,83	0,43	0,11
Cat pea	23	23	35	14	0,24	0,26	0,27	0,14
Mongolian dandelion	20	23	3	22	0,43	0,55	0,01	0,21
Field dodder	19	26	5	4	0,15	0,18	0,05	0,08
Eastern knotgrass	18	16	16	32	0,49	0,42	0,25	0,91
Doorweed	18	14	13	41	0,15	0,09	0,12	0,35
Redroot amaranth	17	22	5	8	0,93	1,27	0,01	0,06
Radiant chickweed	17	20	3	10	0,42	0,57	0,01	0,09
Siberian cocklebur	15	13	7	34	0,21	0,17	0,06	0,42
Water-pepper smartweed	14	12	15	20	0,23	0,21	0,45	0,22
Hemp nettle	12	11	23	6	0,24	0,28	0,26	0,08
Elsholtzia pseudocristata	12	13	8	4	0,32	0,41	0,16	0,08
Field mint	12	14	7	13	0,34	0,45	0,38	0,14
Common spurry	11	10	16	5	0,89	0,89	1,45	0,77
Bladder campion	9	10	10	4	0,16	0,11	0,71	0,07
Siberian crane's bill	9	9	7	8	0,04	0,04	0,03	0,04
Japanese hop	8	8	11	4	0,07	0,09	0,01	0,01
Climbing buckwheat	8	4	9	27	0,15	0,03	0,05	0,72
Common shepherd's purse	8	9	5	2	0,59	0,84	0,05	0,02
Rock jasmine	8	10	2	3	4,99	8,39	0,07	2,04
Annual knawel	7	7	10	7	1,02	1,12	1,78	0,60
Rocket cress	7	6	8	11	0,07	0,06	0,01	0,04
Canada fleabane	6	9	4	–	0,12	0,16	0,02	–
Black nightshade	6	6	2	8	0,09	0,11	0,004	0,10
Wartwort	5	4	9	2	0,74	0,72	2,20	0,01

in soybean crops was equal or exceeded 21 pcs/m^2, and the abundance of annual knawel in 2016 in early cereal crops reached 8.71 pcs/m^2.

The group of rare weeds with occurrence of more than 1% and less than 5%, density of growth not more than 0.35 pcs/m^2 included 25 species: shining hoarhound *Lycopus lucidus* Turcz. ex Benth., American sloughgrass *Beckmannia syzigachne* (Steud.) Fern., carrot *Daucus carota* L., small-flower galinsoga *Galinsoga parviflora* Cav, narrow-leaved hawkmoth *Crepis tectorum* L., bindweed *Calystegia inflatata* Sweet, common thymothy *Phleum pratense* L., oatgrass *Avena fatua* L., sedge *Carex* sp., trailing bindweed *Convolvulus arvensis* L., common evening primrose *Oenothera biennis* L, common chickweed, satinflower *Stellaria media* (L.) Vill., sanguinary *Achillea millefolium* L., field buttercup *Ranunculus acris* L., purple sandwort *Spergularia rubra* (L.) J. et C. Presl, silverweed cinquefoil *Potentilla anserina* L., ball mustard *Neslia paniculata* (L.) Desv., common burdock *Arctium lappa* L., umbrella rock jasmine *Androsace umbellata* (Lour.) Merr, Japan metaplexis *Metaplexis japonica* (Thunb.) Makino, prickly grass *Echinochloa oryzoides* (Ard.) Fritsch, bluegrass *Poa pratensis* L., field pennycress *Thlaspi arvense* L., clammy smartweed *Persicaria viscofera* (Makino) H. Gross ex Nakai, fleabane *Phalacroloma annuum* (L.) Dumort.

The group of extremely rare weeds included 29 species detected in less than 1% (0.22-0.78%) of the surveyed areas: willow-leaf inula *Inula salicina* L., knotweed Bungea mountaineer *Persicaria bungeana* (Turcz.) Nakai ex Mori, common purslane *Portulaca oleracea* L, silvery cinquefoil *Potentilla argentea* L., Aleppo geum *Geum aleppicum* Jacq., blue bottle flower *Centaurea cyanus* L., Tartary buckwheat *Fagopyrum tataricum* L., *Hieracium umbellatum* L, cattail *Typha latifolia* L., yellow cress *Erysimum cheiranthoides* L., lovegrass *Eragrostis* sp., Siberian morning glory *Ipomoea sibirica* (L.) Pers, wild radish *Raphanus raphanistrum* L., field violet *Viola arvensis* Murr., oxtongue *Picris* sp., common or linear crabgrass *Digitaria ischaemum* (Schreb.) Muehl., large crabgrass *Digitaria sanguinalis* (L.) Scop., cereal chickweed *Stellaria graminea* L., spreading knotweed *Persicaria lapathifolia* (L.) S.F. Gray, long-bristle knotweed *Persicaria longiseta* (De Bruyn) Kitag, small-flowered beggar-ticks *Bidens parviflora* Willd., clump speedwell *Veronica longifolia* L., squirreltail critesion *Critesion jubatum* (L.) Nevski, killweed *Lythrum salicaria* L., Tartar prickly lettuce *Mulgedium tataricum* (L.) DC., water plantain, plantain *Alisma plantago-aquatica* L., viper's bugloss *Echium vulgare* L., field mustard *Sinapis arvensis* L., groundnut peavine *Lathyrus tuberosus* L. These weed species are mainly found in soybean crops with a maximum density of one plant per 4 m^2, most often one plant per 1000-10 000 m^2.

CONCLUSION

Monitoring surveys 2016-2020 showed that the species composition of plants infesting soybean, early grain crops and corn is very diverse and represented by 111 species of 33 families. Compared with the results of the crop surveys conducted in 2006-2015, there was an increase in the total number of species detected. For the first time weed representative of figwort, violet, lythrum, evening primrose (willowherb), milkweed and borage families were found. Prevalence and density of some weed species increased. On the surveyed areas there was a 10-58% increase in occurrence of barnyard grass, wormwood species, field horsetail, dayflower, curly sorrel, wild soybean, field dodder and bird's knotweed. In crops of soybean, early cereal crops and maize the prevalence of couch grass increased by 1.4-4.6 times in 5 years, and of hairy cupgrass by 1.7-3.2 times. Average weed infestation of crops by hairy cupgrass, curly sorrel, scurfy woundwort, marsh cress, wild soybean, bird's knotweed and common spurry increased by 1.5-3.0 times. Less common and in smaller numbers were lamb's quarters, yellow thistle, China jute, Siguezbeekia velvet, bur beggare, Mongolian dandelion and hemp nettle. In 2016-2020, the composition of weed species prevailing in crops was observed to be almost the same. The occurrence rates, abundance of each species, determining its specific place in the dominant group of weeds, var-

ied every year. The most widespread and prevalent weed species in the Primorsky Territory are the Southern copper leaf, barnyard grass and ragweed against which effective control must be provided by the implemented protective measures.

СПИСОК ЛИТЕРАТУРЫ

1. *Ким Л.В., Вдовенко А.В., Назарова А.А., Емельянова Е.А.* Проблемы и перспективы отрасли растениеводства в Дальневосточном федеральном округе // Дальневосточный аграрный вестник. 2019. № 3 (51). С. 20–26. DOI: 10. 24411/1999-6837-2019-13031.
2. *Власенко Н.Г., Власенко А.Н., Кулагин О.В.* Влияние технологий возделывания яровой пшеницы на почвенный банк семян сорняков // Сибирский вестник сельскохозяйственной науки. 2018. Т. 48. № 3. С. 5–13. DOI: 10.26898/0370-8799-2018-3-1.
3. *Лукомец В.Н., Бочкарёв Н.И., Тишков Н.М., Пивень В.Т., Семеренко С.А., Бушнева Н.А., Кривошлыков К.М.* Защита сои // Защита и карантин растений. 2019. № 1. С. 38 (2)–75(39).
4. *Захаренко В.А.* Современное состояние и перспективы экономики применения пестицидов в агроэкосистемах России // Агрохимия. 2021. № 5. С 68–83. DOI: 10.31857/ S0002188121050148.
5. *Захаренко В.А*. Мониторинг фитосанитарного состояния агроэкосистем как инструмент повышения эффективности защиты растений // Защита и карантин растений. 2018. № 6. С. 14–17.
6. *Захаренко В.Н.* Элементы ИТ-технологий на службе фитосанитарного мониторинга // Защита и карантин растений. 2018. № 11. С. 17–19.
7. *Булавин Л.А., Булавина Т.М., Гвоздов А.П., Скируха А.Ч., Власов А.Г., Сорока С.В.* Агротехнические приемы защиты посевов в Беларуси // Защита и карантин растений. 2020. № 9. С. 13–19.
8. *Мысник Е.Н., Закота Т.Ю.* Структура видового состава сорных растений в посевах кукурузы степной зоны Краснодарского края // Вестник защиты растений. 2018. № 4(98). С. 50–53. DOI: 10.31993/2308-6459-2018-4(98)-50-53.
9. *Лунёва Н.Н., Фёдорова Ю.А.* Фитосанитарное районирование сорных растений на макроуровне на примере Северо-Западного региона России // Вестник защиты растений. 2019. № 2 (100). С. 15–23. DOI: 10.31993/2308-6459-2019-2(100)-15-23.
10. *Лунёва Н.Н.* Прогноз распространения видов сорных растений в агрофитоценозах полевых культур сплошного сева и пропашных на территории Ленинградской области // Защита и карантин растений. 2020. № 10. С. 26–29. DOI: 10.47528/1026-8634_2020_10_26.
11. *Лунёва Н.Н., Закота Т.Ю.* Видовой состав сорных растений и количественные показатели засоренности посевов пшеницы озимой степной зоны Краснодарского края // Вестник защиты растений. 2018. № 1 (95). С. 45–52.
12. *Спиридонов Ю.Я., Калимуллин А.Т., Абубикеров В.А., Босак Г.С.* О некоторых особенностях развития сорной растительности центрального Нечерноземья в посевах подсолнечника // Агрохимия. 2018. № 3. С. 43–49. DOI: 10.7868/ S0002188118030067.
13. *Шпанев А.М.* Фитосанитарное состояние посевов озимой ржи на агроэкологическом стационаре Меньковского филиала Агрофизического научно-исследовательского института // Вестник защиты растений. 2018. № 3 (97). С. 67–72.
14. *Шаталина Л.П., Анисимов Ю.П., Калюжина Е.Л.* Ассоциации сорных растений в агрофитоценозах яровой пшеницы // Российская сельскохозяйственная наука. 2020. № 2. С. 25–29. DOI: 10.31857/ S 2500-2627-2020-2-25-29.
15. *Мороховец Т.В., Мороховец В.Н., Вострикова С.С., Басай З.В., Штерболова Т.В.* Оценка обилия сорных растений в посевах сельскохозяйственных культур Приморского края // Успехи современной науки. 2017. № 11. С. 233–244.
16. Сосудистые растения Советского Дальнего Востока: монография в 8 т. Л.: Наука, 1985–1996. Т. 1–8.
17. Флора Российского Дальнего Востока: Дополнения и изменения к изданию «Сосудистые растения Советского Дальнего Востока»: монография. Владивосток: Дальнаука, 1985–1996. Т. 1–8. 456 с.
18. *Исаев В.В.* Принципы прогнозирования и методы учета засоренности полей // Прогноз и картографирование сорняков. М.: Агропромиздат, 1990. С. 5–23.
19. *Мысник Е.Н.* К вопросу об интегрированной оценке встречаемости и обилия сорных растений // Вестник защиты растений. 2012. № 2. С. 66–67.

REFERENCES

1. Kim L.V., Vdovenko A.V., Nazarova A.A., Emel'yanova E. A Problems and prospects of the plant growing industry in the Far Eastern Federal District. *Dal'nevostochnyi agrarnyi vestnik. = Far East Agrarian Bulletin,* 2019, no. 3 (51), pp. 20–26. (In Russian). DOI: 10.24411/1999-6837-2019-13031.
2. Vlasenko N.G., Vlasenko A.N., Kulagin O.V. Influence of the technology of cultivation of spring wheat on the soil bank of weed seeds. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2018, vol. 48, no. 3, pp. 5–13. (In Russian). DOI: 10.26898/0370-8799-2018-3-1.
3. Lukomets V.N., Bochkarev N. I., Tishkov N.M., Piven' V.T., Semerenko S.A., Bushneva N.A., Krivoshlykov K.M. Soybean protection. *Zashchita i karantin rastenii. = Board of Plant Protection and Quarantine,* 2019, no. 1, pp. 38 (2) – 75(39). (In Russian).
4. Zakharenko V.A. The current state and prospects of the economics of the use of pesticides in the agroecosystems of Russia. *Agrokhimiya = Agricultural Chemistry*, 2021, no. 5, pp. 68–83. (In Russian). DOI: 10.31857/ S0002188121050148.
5. Zakharenko V.A. Monitoring the phytosanitary state of agroecosystems as a tool to improve the efficiency of plant protection. *Zashchita i karantin rastenii. = Board of Plant Protection and Quarantine,* 2018, no. 6, pp. 14–17. (In Russian).
6. Zakharenko V.N. Elements of IT technology in the service of phytosanitary monitoring. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine,* 2018, no. 11, pp.17–19. (In Russian).
7. Bulavin L.A., Bulavina T.M., Gvozdov A.P., Skirukha A.Ch., Vlasov A.G., Soroka S.V. Agrotechnical methods of crop protection in Belarus. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine,* 2020, no. 9, pp.13–19. (In Russian).
8. Mysnik E.N., Zakota T.Y. Structure of species composition of weed plants in crops of corn on the territory of steppe zone of Krasnodar territory. *Vestnik zashchity rastenii = Plant Protection News,* 2018, no. 4 (98), pp. 50–53. (In Russian). DOI: 10.31993/2308-6459-2018-4(98)-50-53.
9. Luneva N.N., Fedorova Y.A. Phytosanitary zoning of weeds at the macro level: a case study of the north-western region of Russia. *Vestnik zashchity rastenii = Plant Protection News,* 2019, no. 2 (100), pp. 15–23. (In Russian). DOI: 10.31993/2308-6459-2019-2(100)-15-23.
10. Luneva N.N. Forecast of the distribution of weed species in agrophytocenoses of field crops of solid sowing and tilled crops on the territory of the Leningrad region. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine,* 2020, no. 10, pp. 26–29. (In Russian). DOI: 10.47528/1026-8634_2020_10_26.
11. Luneva N.N., Zakota T.Y. Weed species composition and quantitative parameters of weed infestation of winter wheat crops in the steppe zone of Krasnodar territory. *Vestnik zashchity rastenii = Plant Protection News,* 2018, no. 1(95), pp. 45–52. (In Russian).
12. Spiridonov Yu.Ya., Kalimullin A.T., Abubikerov V.A., Bosak G.S. Some Features of Weed Development in Sunflower Crops in Central Non-Chernozem Region. *Agrokhimiya = Agricultural Chemistry*, 2018, no. 3, pp. 43–49. (In Russian). DOI: 10.7868/ S0002188118030067.
13. Shpanev A.M. Phytosanitary Condition of winter rye crops at agroecological stationary of Menkovo branch of Agrophysical Research institute. *Vestnik zashchity rastenii = Plant Protection News,* 2018, no. 3 (97), pp. 67–72. (In Russian).
14. Shatalina L.P. Anisimov Yu.P., Kalyuzhina E.L. Associations of Weed Plants in Agrophytocenoses of Spring Wheat. *Rossiiskaya sel'skokhozyaistvennaya nauka = Russian Agricultural Science*, 2020, no. 2, pp. 25–29. (In Russian). DOI: 10.31857/ S 2500-2627-2020-2-25-29.
15. Morokhovets T.V., Morokhovets V.N., Vostrikova S.S., Basai Z.V., Shterbolova T.V. Assessment of the abundance of weeds in crops of agricultural crops in the Primorsky Territory. *Uspekhi sovremennoi nauki = Advances in modern science,* 2017, no. 11, pp. 233–244. (In Russian).
16. *Vascular Plants of the Soviet Far East*. In 8 vol. Saint Petersburg, Nauka Publ., 1985–1996, vol. 1–8. (In Russian).
17. *Flora of the Russian Far East: Addenda and corrigenda to "Vascular plants of the Soviet Far East"*. Vladivostok, Dalnauka Publ., 1985–1996, vol. 1–8, 456 p. (In Russian).
18. Isaev V.V. Forecasting principles and methods of accounting for contamination of fields. *Weed forecast and mapping*, Moscow, Agropromizdat Publ., 1990, pp. 5–23. (In Russian).
19. Mysnik E.N. To the question of an integrated assessment of the occurrence and abundance of weeds. *Vestnik zashchity rastenii = Plant Protection News,* 2012, no. 2, pp. 66–67. (In Russian).

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ВЛИЯНИЕ КОРМОВОЙ ДОБАВКИ БИОПРОТЕКТИН-КД НА МОЛОЧНУЮ ПРОДУКТИВНОСТЬ КОРОВ И КОРРЕКЦИЮ МИКРОБИОТЫ ТЕЛЯТ

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Приведены результаты испытаний новой комбинированной кормовой добавки Биопротектин-КД на основе экстракта расторопши пятнистой с добавлением комплекса бактерий рода *Lactobacillus* и *Bifidobacterium* для восстановления кишечной микробиоты животных. Доклинические исследования эффективности кормовой добавки проводили на мышах с экспериментальным антибиотико-ассоциированным дисбактериозом. Исследования кишечной микробиоты мышей выявили неодинаковую степень влияния разных доз кормовой добавки на восстановление резидентной микрофлоры. Полученные результаты доклинических исследований доказали безвредность, отсутствие токсичности и эффективность кормовой добавки. Клинические испытания добавки проведены на продуктивных животных. Изучено ее влияние на продуктивность коров черно-пестрой породы в условиях животноводческого хозяйства Белгородской области. Применение функциональной кормовой добавки Биопротектин-КД положительно повлияло на молочную продуктивность коров черно-пестрой породы. У коров опытных групп, получавших кормовую добавку, удой за лактацию увеличился на 209,41–499,01 кг по сравнению с контрольными животными, что составило 4,01–8,78%. Повысились качественные показатели молока. Исследован состав микрофлоры у опытных (получавших кормовую добавку) и контрольных телят. Установлено, что в кишечнике молодняка контрольной группы количественный состав пробиотической флоры на протяжении опыта практически не менялся. У опытных животных количество индигенной микрофлоры (лактобациллы и бифидобактерии) увеличилось. Содержание молочнокислых микроорганизмов у опытных телят начало возрастать на 6-й день применения кормовой добавки и достигло физиологической нормы на 30-й день. Рассчитан индекс безопасности продукта. Применение функциональной кормовой добавки Биопротектин-КД в условиях животноводческого комплекса позволило улучшить такие производственные показатели, как сохранность телят, их среднесуточные привесы, а также молочную продуктивность коров в опытных группах животных по сравнению с контрольными.

Ключевые слова: антибиотикорезистентность, дисбактериоз, функциональные кормовые добавки, пробиотик, гепатопротектор, расторопша пятнистая, *Lactobacillus, Bifidobacterium*

THE EFFECT OF THE FEED ADDITIVE BIOPROTECTIN-KD ON THE PRODUCTIVITY OF DAIRY COWS AND THE CORRECTION OF THE MICROBIOTA OF CALVES

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The results of tests of a new combined feed additive Bioprotektin-KD based on milk thistle extract with the addition of a complex of bacteria of the genus *Lactobacillus* and *Bifidobacterium* to restore intestinal microbiota of animals are presented. Preclinical studies on the effectiveness of the feed additive were conducted on mice with experimental antibiotic-associated dysbacteriosis. Studies on the intestinal microbiota of mice revealed varying degrees of effect of different doses of feed additive on the recovery of resident microflora. The results of pre-clinical studies have proven the harmlessness, non-toxicity and efficacy of the feed additive. Clinical trials of the additive were carried out on productive animals. Its effect on the productivity of black-motley breed cows in a livestock farm in the Belgorod region was studied. The use of the functional feed additive Bioprotectin-KD had a positive effect on the milk productivity of black-motley breed cows. Cows in the experimental groups that received the feed additive had increased their milk yield per lactation by 209.41-499.01 kg compared to the control animals, which was 4.01-8.78%. The quality indicators of milk have increased. The composition of the microflora of the experimental (feed supplement recipients) and control calves was studied. It was found that the quantitative composition of probiotic flora in the intestines of young calves of the control group remained practically unchanged throughout the experiment. The number of indigeneous microflora (lactobacilli and bifidobacteria) increased in the experimental animals. The content of lactic acid microorganisms in the experimental calves began to increase on day 6 of feed supplementation and reached physiological norm on day 30. The safety index of the product has been calculated. The use of the functional feed additive Bioprotektin-KD in conditions of a livestock complex has improved such production indicators as calf survival, average daily weight gain, and milk productivity of cows in the experimental groups of animals as compared to the control ones.

Key words: Antibiotic resistance, disbacteriosis, functional feed additives, probiotics, hepatoprotectors, milk thistle extract, *Lactobacillus, Bifidobacterium*.

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INTRODUCTION

Intensification of livestock breeding and the annual increase in the number of productive animals lead to a deterioration of the environmental and epizootic situation, since the risk of transmission of infectious and parasitic diseases increases. The main preventive measures aimed at reducing the risk of contamination of productive animals with infectious diseases, in addition to improving living conditions and feeding rations include vaccination and the use of antimicrobial agents. The irrational use of antibiotics in animal husbandry is a major factor in the emergence and spread of antibiotic-resistant microorganisms, which leads to an increased risk of zoonosis and difficulties in antibiotic therapy [1, 2] [1-3].

At present, the search for alternative approaches to the therapy of infectious diseases is underway worldwide. In the applied aspect, it seems important to justify the treatment of animals with the use of combined feed additives of pre- and probiotic composition. These supplements have a positive effect on the indigene microflora: they prevent gut dysbiosis, correct the intestinal microbiota, stimulate humoral immunity, as well as synthesize vitamins B and C and produce a large number of biologically active substances [4-6]. When antibiotics are rejected at the subtherapeutic level, combined functional feed additives, which include pro-, prebiotics and hepatoprotectors of plant origin, are one of the means to enhance immunity, improve the functioning of organs and systems, and correct gastrointestinal and hepatobiliary pathologies[3] [7].

Biological activity of functional feed additives is high and based on more stable preservation and adhesive activity of immobilized microorganisms, while sorbents and hepatoprotective component quickly and efficiently relieve intoxication and accelerate reparative process [8].

One of the biologically active natural hepatoprotectors is the medicinal plant milk thistle (Silybum marianum). Milk thistle meal and extract have detoxifying properties, which affects the external secretory function of the liver, providing antispasmodic and slight anti-inflammatory effect. The main component of the milk thistle meal and extract is silimar (silibinin), which is a mixture of three main isomeric compounds - silibinin, silicristin and silidianin [4, 5].

In the mechanism of hepatoprotective action of milk thistle the main property is stabilization of cell and subcellular membranes. The antioxidant effect of milk thistle is due to the interaction of its components with free radicals in the liver and their transformation into less toxic compounds [6-8] [9].

Recent research in nutrition science suggests that it is possible to maintain the health of the animal body with functional feedstuffs. Genomics and proteomics methods have revealed that probiotic strains can radically affect the gene expression of both other bacterial strains of the intestine and the intestinal

[1]Vasilevskaya E.R. Development of a feed additive based on biologically active substances from raw materials of animal origin: Ph. D. in Engineering Sciences, M., 2019.

[2]O'Neill J. The Review on antimicrobial resistance. Tackling a crisis for the health and wealth of nations. December, 2014. [E- resource]: Available from: http://amr-review.org/

[3]Panina T.V. Application of probiotic - hepatoprotector "Hepopro" in toxic lesions of the liver in dogs: Ph. D. in Veterinary Sciences, M., 2009.

[4]Sadovnikova V.V., Sokolova K.Ya., Ivanova N.L. Studying the effect of probiotic from lacto- and bifidobacteria on the liver of rats with toxic hepatitis. Probiotic microorganisms: current status of the issue and prospects for use: materials of the 2nd international scientific and practical conference. M., 2002. pp. 26-27.

[5]Saratikov A.S., Vengerovsky A.I. Effect of hepatoprotectors containing phospholipids on cytochrome P 450 independent antitoxic liver function in experimental toxic hepatitis. Bulletin of Experimental Biology and Medicine. 1998. № 4. pp. 392-394.

[6]Pyatova L.G. Evaluation of the effectiveness of drugs for the correction of intestinal microflora in combination with silymar in patients with acute viral hepatitis A and B: Ph. D. in Medical Sciences. M., 2008. 160 p.

[7]Modestova L.V., Akovantseva N.V. Composition of bile at different physiological state of digestive system. Diseases of liver and pancreas. M., 1984. pp. 105-113.

[8]Khursa R.V., Mesnikova I.L., Miksha Y.S. Intestinal microflora: the role in health maintenance and pathology development, correction possibilities: tutorial. Minsk, 2017. pp. 5-11.

epithelial cells themselves, turning on and off hundreds of genes relevant to the implementation of the immune response and metabolic reactions [10].

The aim of the work is to study the effectiveness of a new combined feed additive Bioprotektin-KD based on milk thistle extract on the productivity of cows in livestock farming conditions and to determine its effect on the restoration of intestinal microbiota in dysbiosis of calves.

MATERIAL AND METHODS

This work was performed as part of a doctoral training program; the topic "Development of a biologically active feed additive for productive animals" was approved at the Department of Internal Medicine, Moscow State University of Food Production.

Preclinical studies of a functional feed additive Bioprotektin-KD based on milk thistle extract with addition of a complex of bacteria of the genus *Lactobacillus* and *Bifidobacterium* were conducted on white nonlinear mice. Scientific experiment was carried out from 2010 to 2011 in the experimental farm "Manikhino" of the All-Russian State Center for the Quality and Standardization of Medicines for Animals and Feed. Harmlessness, acute and chronic toxicity and effectiveness of the feed additive were studied.

Clinical tests of the functional feed additive Bioprotektin-KD were carried out in the conditions of the livestock complex of the Belgorod region and the Belgorod interregional veterinary laboratory. Experimental samples of functional feed additive are made from milk thistle extract and a complex of probiotic bacteria of the genus *Lactobacillus* and *Bifidobacterium* 5 × 107 lg CFU/g.

In clinical experiments 80 animals of black and white breed were used: 40 cows and 40 calves. Four groups were formed of cows and young calves: one control and three experimental groups (n = 10). Calves and cows were fed according to the developed rations. Animals of experimental groups received functional feed additive in different doses per 1 kg of live weight as part of the diet. Animals of control groups received only the basic diet.

Group Diet

Control Basic diet (BD)

1-st experimental BD + 27 mg Bioprotectin-KD per 1 kg of live weight

2-nd experimental BD + 54 mg Bioprotectin-KD per 1 kg of live weight

3-rd experimental BD + 108 mg Bioprotectin-KD per 1 kg of live weight

Dairy productivity was evaluated based on control milkings, which were performed once a month. The amount of fat and protein by months of lactation was determined by calculation.

Organoleptic evaluation of milk was carried out according to the method of V.P. Shidlovskaya. Chemical composition of milk was estimated according to its content (by acid method according to GOST R ISO 2446-2011, 5867-90 and on the device " Klever 2"), protein - by formol titration method according to GOST 25179-90 and on the device "Klever 2", casein and whey proteins - by refractometric method on milk analyzer, fractions of casein - by K. Butkus and V. Butkene method (2011), NMS (nonfat milk solids) - according to GOST 3626-73 and on "Klever 2" device, lactose - according to GOST R 51259-99 on photoelectric colorimeter, calcium - by complexometric method, phosphorus - by spectrophotometric method according to GOST 31584-2012, ash - by ashing according to N.Yu. Alexeev et al. method (1986). The number and diameter of fat globules were estimated by microscopic examination and counting in the Goryaev chamber according to the method of P.V. Kugenev (1988). The density in milk was determined by areometric method according to GOST 3625-84, titratable acidity - according to GOST 3625-84. The calculation of the energy value was carried out according to the VIZh formula.

Microbiological analysis was carried out according to the following indicators: the number of QMA&OAMO according to GOST R 53430-2009, coliform bacteria, staphylococci, yeast-like and mold fungi by sowing on selective media.

The digestibility of nutrients in diets, nitrogen balance and energy metabolism were studied according to the method of balance experiments on three animals from each group based on the results of chemical analysis of feed, their residues, feces and urine according to generally accepted methods (Lebedev P.T., Usovich A.T., 1976). When studying the energy metabolism, we used the regression equation proposed by A.P. Kalashnikov et al. (1985), N.G. Grigoriev et al. (1989).

Animal fecal samples were examined by quantitative group analysis according to the methodological recommendations of the USSR Ministry of Health "Intestinal dysbacterioses. Application of bacterial biological preparations in the practice of treatment of patients with intestinal infections, diagnosis and treatment of intestinal dysbacterioses" (1988). The number of microorganisms was calculated in lg CFU/g according to the conventional method.

RESULTS AND DISCUSSION

As a result of clinical studies on harmlessness it was proved that a single intragastric administration of Bioprotectin-KD at a dose of 135 mg/kg did not cause death of mice during a 5-day observation period. The acute toxicity study revealed that one individual died on the first day of intragastric administration of this feed additive. Moreover, the LD50 was in the range of 38 to 63 g/kg live weight and was about 50.5 g/kg live weight, which exceeds the proposed dose of the feed additive for clinical trials on productive animals. Chronic toxicity studies on mice receiving a daily dose of Bioprotectin-KD of 500 mg/kg for 30 days resulted in all animals remaining alive. Studies of the effectiveness of the analyzed feed additive were conducted on experimental antibiotic-associated dysbacteriosis in mice using gentamicin in a dosage higher than the therapeutic one. The level of resident microflora of the genus Lactobacillus decreased at the end of antibiotic application and was 5,45 ± 0,50 lg CFU/g in the 1st experimental group, 5,65 ± 0,55 in the 2nd group, 5,66 ± 0,33 in the 3rd group, 5,34 ± 0,22 lg CFU/g in the control group. Studies of the intestinal microbiota of mice obtained in the dynamics of Bioprotectin-KD use revealed varying degrees of influence on the recovery of resident microflora. Thus, only on the 4th day of supplementation the level of lactobacilli increased and amounted to 6,45 ± 0,25; 6,55 ± 0,25l; 6,88 ± 0,44l lg CFU/g in experimental groups 1-3 respectively. In the control group this indicator was 4.88 ± 0.22 lg CFU/g. The maximum increase of lactobacilli in the experimental groups with Bioprotectin-KD was recorded on the 10th day of the study and reached 7,99 ± 0,43; 8,17 ± 0,33; 8,58 ± 0,33 lg CFU/g, while in the control group the lactobacilli level increased slightly - 6,55 ± 0,22 lg CFU/g.

The results of preclinical studies have proven harmlessness, lack of toxicity, as well as the effectiveness of the feed additive Bioprotectin-KD, which made it possible to proceed to the second stage - clinical studies on productive animals.

Application of functional feed additive had a positive effect on milk productivity of black-and-white breed cows (see Table 1).

The animals of the experimental groups that received the feed additive increased the milk yield per lactation by 209.41-499.01 kg, which was 4.01-8.78% ($p < 0.001$) compared to the cows of the control group. The highest coefficient of milk yield was also observed in cows of experimental groups. The maximum value was in the animals of the 3rd experimental group: they surpassed the animals of the 1st group by 85,7 kg, the 2nd group by 48,06 kg, and the control group by 87,5 kg.

The use of Bioprotectin-KD supplement in cows' diets had a positive effect not only on the amount of milk, but also on its qualitative composition. Due to the increased content of nutrients, the milk of the experimental group cows had a higher energy value. The milk of the cows of the 3-rd experimental group exceeded the parameters of the control group by 1,86%, and of the 2nd group - by 1,17% ($p < 0,01$). The milk of the cows from the 3rd experimental group showed slight increases of

Табл. 1. Влияние кормовой добавки Биопротектин-КД на молочную продуктивность коров черно-пестрой породы (n = 10)

Table 1. Effect of Bioprotectin-KD feed additive on milk productivity of black-motley breed cows (n = 10)

Indicator	Group			
	control	experiment		
		1-st	2-nd	3-rd
Milk yield per lactation, kg	2950,15 ± 32,01	2990,58 ± 65,12	3159,60 ± 51,10	3339,16 ± 14,45
Milk yield ratio, %	514,45 ± 12,91	516,25 ± 13,25	553,89 ± 13,70	601,95 ± 15,05
Mass fraction of fat, %	3,15 ± 0,035	3,19 ± 0,025	3,22 ± 0,030	3,25 ± 0,015
Quantity of milk fat, kg	95,99 ± 1,250	108,12 ± 3,550	118,74 ± 2,110	121,12 ± 1,25
Protein mass fraction, %	3,10 ± 0,05	3,11 ± 0,01	3,13 ± 0,05	3,15 ± 0,01
Amount of milk protein, kg	85,45 ± 0,050	95,03 ± 2,215	103,48 ± 0,650	105,81 ± 1,050

phosphorus and calcium content - by 18,2% and 4,75% respectively (p <0,01) as compared to the control.

The introduction of functional feed additive into the diet increased the quantitative indicators of fat in milk. The best indicators were observed when using a probiotic supplement at a dose of 108 g per 1 kg of live weight of the animal. Qualitative analysis of proteins showed a slight increase in the content of albumin and globulin in the milk of the experimental group cows, which was in the range of 0,01-0,02% (p <0,05). At the same time, the ratio of fractions (α, β) tended to increase in all three experimental groups. Microbiological parameters of milk were within the normative parameters laid down in the TR CU 033/2013 "Technical Regulations on the safety of milk and dairy products". The highest ability to digest nutrients of feed was observed in the cows of the experimental groups who received a functional feed additive in the diet.

The coefficients of digestibility of nutrients in diets show that the control group animals were 1.9-3.5% less than the experimental group animals in digestibility of dry matter, 1.25-2.15 % less than the experimental group animals in digestibility of organic matter, 0.75-1.55% less than the experimental group animals in digestibility of crude protein, 2.00% less than the experimental group animals in digestibility of crude fiber, 0.75-1.78% less than the experimental group animals in digestibility of NFES (nitrogen-free extractive substances). Higher rates of bioconversion of nutrients and energy were observed in cows of experimental groups.

According to the yield of protein and fat in milk, the cows of the control group were inferior to the animals of the 1st experimental group by 9.58 and 12.13 kg, the 2nd - by 18.03 and 22.75, the 3rd - by 20.36 and 25 .13 kg respectively.

The growth of energy output indicators in all three experimental groups of cows exceeded those of the control group: in the 1st experimental group - by 4.99%, in the 2nd - by 10.95, in the 3rd - by 20.5%. This recorded a significant level of bioconversion of nutrients and energy into protein and, as a result, an increase in dairy production of cows. The biochemical composition of the serum, hematocrit and hematological parameters of the blood of cows were within the physiological norm.

Preservation of experimental animals was 100%, but in the 2nd experimental group dysbiotic phenomena were observed. The gain of live weight in the 1st experimental group was 10,19 kg, in the 2nd - 11,84, in the 3rd - 11,54 kg, while in the control - 6,72 kg, which is almost 2 times less than in the 1st experimental group.

Subsequently, safety, live weight gain and composition of microflora in calves of control and experimental groups were taken into account (see Tables 2, 3).

Табл. 3. Влияние кормовой добавки Биопротектин-КД на количественное и качественное соотношение лакто- и бифидобактерий кишечной микробиоты телят (n = 10), lg КОЕ/г

Table 3. Effect of Bioprotectin-KD feed additive on the quantitative and qualitative ratio of lacto- and bifidobacteria in the intestinal microbiota of calves (n = 10), lg КОЕ/g

Indicator	Group			
	control	experiment		
		1-st	2-nd	3-rd
		On the 3rd day		
Bifidobacterium	0	0	6,16 ± 0,83	6,78 ± 0,68
Lactobacillus	5,16 ± 0,86	5,43 ± 0,47	6,31 ± 0,34*	6,33 ± 0,75*
		On the 10th day		
Bifidobacterium	6,16 ± 0,55	7,34 ± 0,82**	8,14±0,77***	9,12 ± 0,35***
Lactobacillus	6,75 ± 0,55	7,01 ± 0,53	7,25 ± 0,68**	8,14 ± 0,56***
		On the 30th day		
Bifidobacterium	8,04 ± 0,55	8,99 ± 0,78**	9,38 ± 0,99**	10,01 ± 0,45***
Lactobacillus	7,13 ± 0,58	7,99 ± 0,48	8,58 ± 0,50**	8,89 ± 0,55**

Significant in relation to the control group.
*p < 0,10.
**p < 0,05.
***p < 0,01.

Табл. 2. Влияние кормовой добавки Биопротектин-КД на сохранность и прирост живой массы телят (n = 10)

Table 2. Effect of Bioprotectin-KD feed additive on calf survival and live weight gain (n = 10)

Indicator	Group			
	control	experiment		
		1-st	2-nd	3-rd
Livability , %	100	100	100	100
Live weight, kg: at birth	24,12 ± 1,55	24,27 ± 1,13	24,16 ± 1,25	24,99 ± 1,21
on the 10th day	35,13 ± 1,67	35,01 ± 1,47	34,99 ± 1,16	34,48 ± 1,23
on the 30th day	51,04 ± 1,58	52,88 ± 1,09	52,25 ± 1,32	52, 22 ± 1,12

The average live weight of calves of experimental groups was 52.45 kg, the control group - 51.04 kg. The relative increase in live weight during the study period of experimental groups in relation to the control group was 2.68%.

In the intestines of control group calves, the quantitative composition of probiotic flora throughout the experiment remained virtually unchanged. In the three experimental groups, the quantitative index of indigene microflora (lactobacilli and bifidobacteria) increased. The content of lactic acid microorganisms in all the experimental groups began to increase at the 6th day of supplementation and reached the physiological norm at the 30-th day: bifidobacteria in the 1st group - 8,99 ± 0,79, in the 2nd - 9,38 ± 0,99, in the 3rd - 10,01 ± 0,45 lg CFU/g; lactobacilli - 7,99 ± 0,48; 8,58 ± 0,50; 8,89 ± 0,55 lg CFU/g respectively.

CONCLUSIONS

1. The use of the functional feed additive Bioprotektin-KD had a positive effect on the milk productivity of black-and-white breed cows. The milk yield of experimental animals that received the additive increased by 209,41-499,01 kg per lactation as compared to the cows of the control group, which was 4,01-8,78% (p <0,001). The highest milking ratio was also observed in the cows of the experimental groups.

2. The use of Bioprotektin-KD supplement in cows' diets had a positive effect not only on the amount of milk, but also on its qualitative composition. Due to the increased content of nutrients, milk of the experimental group cows had a higher energy value, increased fat and protein content.

3. Microbiological parameters of milk of the animals receiving the feed additive were within the normal range. Biochemical composition of serum, hematocrit and hematological blood parameters of cows were within the physiological norm.

4. In the intestines of control group calves, the quantitative composition of probiotic flora throughout the experiment remained virtually unchanged. In the three experimental groups, the quantitative index of indigene microflora (lactobacilli and bifidobacteria) increased. The content of lactic acid microorganisms in all experimental groups began to increase on the 6th day and reached the physiological norm on the 30th day of feeding.

СПИСОК ЛИТЕРАТУРЫ

1. *Chattopadhyay M.K.* Use of antibiotics as feed additives: a burning question // Frontiers in Microbiology. 2014. Vol. 5. P. 334–337. DOI: 10.3389/fmicb.2014.00334
2. *Данилов А.И., Жаркова Л.П.* Антибиотикорезистентность: аргументы и факты // Клиническая фармакология и терапия. 2017. № 26 (5). С. 6–7.
3. *Панин А.Н., Комаров А.А., Куликовский А.В., Макаров Д.А.* Проблема резистентности к антибиотикам возбудителей болезней, общих для человека и животных // Ветеринария, зоотехния и биотехнология. 2017. № 5. С. 18–24.
4. Дисбиоз кишечника. Руководство по диагностике и лечению / под ред. Е.И. Ткаченко, А.Н. Суворова: монография. СПб.: СпецЛит, 2007. 238 с.
5. *Ткаченко Е.И., Успенский Ю.П.* Питание, микробиоценоз и интеллект человека: монография. СПб.: СпецЛит, 2006. 590 с.
6. *Успенский Ю.П., Барышникова Н.В.* Эффективность применения пробиотиков на фоне антибактериальной терапии // Фарматека для практикующих врачей. 2015. № 2. С. 78–82.
7. *Севастьянова Т.В., Уша Б.В.* Функциональные кормовые добавки для сельскохозяйственных животных и их влияние на показатели продуктивности // Аграрная наука. 2021. № 4. С. 99–103. DOI: 10.32634/0869-8155-2021-347-4-99-103.
8. *Ahasan ASML., Agazzi A., Invernizzi G., Bontempo V., Savoini G.* The beneficial role of Probiotics in monogastric animal nutrition and health // Journal of Dairy, Veterinary & Animal Research. 2015. Vol. 2. Issue 4. P. 116–121. DOI: 10.15406/JDVAR.2015.02.00041.
9. *Хазанов А.И., Румянцев О.Н., Калинин А.В.* Особенности лекарственных и вирусных поражений печени // Кремлевская медицина. Клинический вестник. 2000. № 1. С. 44–47.
10. *Фадеенко Г.Д., Куринная Е.Г., Вовченко М.Н.* Нутригеномика и нутригенетика: возможности практического применения // Соучастна гастроэнтерология. 2015. №. 6 (86). С. 7–12.

REFERENCES

1. Chattopadhyay M.K. Use of antibiotics as feed additives: a burning question. *Frontiers in Microbiology*, 2014, vol. 5, pp. 334–337. DOI: 10.3389/fmicb.2014.00334.
2. Danilov A.I., Zharkova L.P. Antibiotic resistance: arguments and facts. *Klinicheskaya Farmakologiya i Terapiya = Clinical Pharmacology and Therapy*, 2017, no. 26 (5), pp. 6–7. (In Russian).
3. Panin A.N., Komarov A.A., Kulikovsky A.V., Makarov D.A. Problem of antimicrobial resistance of zoonotic bacteria. *Veterinariya, Zootechniya i Biotechnologiya = Veterinary, Zootechnics and Biotechnology*, 2017, no. 5, pp. 18–24. (In Russian).
4. *Intestinal dysbiosis*. *Manual on diagnosis and treatment* / edited by E.I. Tkachenko, A.N. Su-

vorov. SPb., SpetsLit Publ., 2007. 238 p. (In Russian).
5. Tkachenko E.I., Uspensky Yu.P. *Nutrition, microbiocenosis and human intelligence.* SPb., SpetsLit Publ., 2006, 590 p. (In Russian).
6. Uspensky Y.P., Baryshnikova N.V. The effectiveness of the use of probiotics against the background of antibacterial therapy. *Pharmateca for Practicing Physicians*, 2015, no. 2, pp. 78–82. (In Russian).
7. Sevastianova T.V., Usha B.V. Functional feed additives for farm animals and their impact on productivity indicators. *Agrarnaya Nauka = Agricultural science*, 2021, no. 4, pp. 99–103. (In Russian). DOI: 10.32634/0869-8155-2021-347-4-99-103.
8. Ahasan ASML., Agazzi A., Invernizzi G., Bontempo V., Savoini G. The beneficial role of Probiotics in monogastric animal nutrition and health. *Journal of Dairy, Veterinary & Animal Research*, 2015, vol. 2, issue 4, pp. 116–121. DOI: 10.15406/JDVAR.2015.02.00041.
9. Khazanov A.I., Rumyantsev O.N., Kalinin A.V. Features of medicinal and viral liver lesions. *Kremlevskaya meditsina. Klinicheskij Vestnik = Kremlin medicine journal*, 2000, no. 1, pp. 44–47. (In Russian).
10. Fadeenko G.D., Kurinnaya E.G., Vovchenko M.N. Nutrigenomics and nutrigetics: possibilities of practical application. *Souchastna gastroenterologia = Modern gastroenterology*, 2015, no. 6 (86), pp. 7–12. (In Ucraina).

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МОЛОЧНАЯ ПРОДУКТИВНОСТЬ КОРОВ-ПЕРВОТЕЛОК В ЗАВИСИМОСТИ ОТ ИНТЕНСИВНОСТИ ИХ ВЫРАЩИВАНИЯ

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Представлены результаты исследований молочной продуктивности коров черно-пестрой породы в зависимости от возраста первого осеменения и живой массы при первом отеле в условиях Иркутской области. Изучена динамика выращивания телок по годам, молочная продуктивность коров по 1-й и 3-й лактациям в зависимости от интенсивности их развития. Эксперимент проведен по материалам хозяйства Иркутской области с использованием общепринятых зоотехнических, аналитических, вариационно-статистических методов исследований с 2016 по 2020 г. Живая масса телок во все возрастные периоды соответствовала требованиям классов элита и элита-рекорд. Анализ данных показал, что скорость роста животных в период исследований возросла (6,0; 6,8; 2,3 и 4,8% соответственно при достоверной разнице $p \geq 0{,}90$). С увеличением интенсивности выращивания телок отмечено повышение уровня их удоя за 305 дней 1-й лактации. Наибольшая молочная продуктивность отмечена по 1-й (5309–5476 кг) и 3-й (5418–5817 кг) лактациям у коров, возраст первого плодотворного осеменения которых составил 13–14 мес. Наименьший удой по 1-й и 3-й лактациям получен от коров, осемененных в возрасте 20 мес и старше. Наибольшую молочную продуктивность в 1-ю и 3-ю лактации получили от коров с живой массой при первом отеле 541–550, 551 кг и выше (5197–5164, 5436–5545 кг соответственно). Наименьшая молочная продуктивность получена от коров с живой массой при первом отеле до 500 кг (4567–5122, 4943–5009 кг). Полученные результаты позволяют выявить влияние интенсивности выращивания телок на продуктивные качества коров.

Ключевые слова: рост и развитие, молочная продуктивность, возраст первого осеменения, живая масса при первом отеле

MILK PRODUCTIVITY OF FIRST-CALF COWS DEPENDING ON THE INTENSITY OF THEIR BREEDING

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The paper presents the results of studies of milk productivity of black-and-white cows depending on the age of the first insemination and live weight at the first calving in the conditions of the Irkutsk region. The dynamics of heifer rearing by year, milk productivity of cows in the 1st and 3rd lactations depending on the intensity of their development has been studied. The experiment was conducted on farm materials from the Irkutsk Region using generally accepted zootechnical, analytical, variation and statistical research methods from 2016 to 2020. Live weight of heifers at all ages met the requirements of the elite and elite-record classes. Analysis of the data showed that the growth rate of the animals increased during 5 years (6.0%, 6.8, 2.3 and 4.8% respectively with a significant difference $p \geq 0.90$). With the increased intensity of heifer rearing, an increase in milk yield over 305 days of the first lactation was observed. The highest milk production was noted in the 1st (5309-5476 kg) and 3rd (5418-5817 kg) lactations in cows with the first fruitful insemination at 13-14 months. The lowest 1st and 3rd lactation yields are obtained from cows inseminated at 20

months of age or older. Higher milk production in the first and third lactations was obtained from cows with a live weight at first calving of 541-550 kg, 551 kg and higher (5197-5164, 5436-5545 kg respectively). Less milk production was obtained from cows with a live weight at first calving of up to 500 kg (4567-5122, 4943-5009 kg). The results obtained make it possible to reveal the influence of the intensity of rearing heifers on the productive qualities of cows.

Keywords: growth and development, milk productivity, first insemination age, live weight at first calving

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INTRODUCTION

Milk productivity of cows is the main economic and breeding trait in cattle breeding. The formation of milk productivity occurs during the growth and development of the animal [1-7]. Intensive breeding of replacement heifers and bred heifers, determination of optimal age and live weight at the beginning of their economic use are important elements of highly productive dairy cattle breeding with annual cow productivity of 6-10 thousand kg. Obtaining this level of productivity from the first lactation of cows is an urgent task of herd management and increasing economic efficiency of business activities in dairy cattle breeding [8, 9].

Determination of optimal age and live weight at first calving is of great importance in herd selection [10]. Some scientists believe that early heifer mating (13-15 months) under optimal feeding and housing conditions does not adversely affect the subsequent milk productivity of cows. Other authors believe that the optimal period for the first fertile insemination of heifers should be at least 18, 19 months [11, 12].

The problem of studying the growth and development of heifers is of great economic importance, since the indicators of full development and readiness of animals for the first insemination largely determine the efficiency of further production use of cows [13]. In this connection, the issues of peculiarities of growth and development dynamics of heifers are considered. Dairy productivity depends on many paratypical factors, but the main one is the age of heifers at the first insemination [14, 15]. The age of the first fruitful insemination and calving, the live weight at the first calving have a certain influence on the subsequent productivity and the manifestation of the main breeding traits.

The purpose of the study is to identify the dependence of milk productivity of first heifers on the intensity of their rearing in the conditions of the Irkutsk region.

Research objectives:

– determine the effect of heifer rearing intensity on their future dairy productivity;

– determine the effect of live weight at first calving on milk productivity of cows.

MATERIAL AND METHODS

The information database of the SELEX pedigree accounting program of the highly productive herd of black and white cattle in "Okinsky" SEC of the Irkutsk region served as the research materials. The experiment was conducted from 2016 to 2020. The animals (949 heads) that were evaluated according to growth and development indices, and subsequently according to milk productivity for the 1st and 3rd

lactations were chosen as the object of research.

When performing this work, generally accepted research methods were used: zootechnical, analytical, variation and statistical. All obtained results were processed on the basis of private methods of population genetics and mathematical statistics on a personal computer using Microsoft Excel, Snedecor V5.

RESULTS AND DISCUSSION

Among modern problems in dairy cattle breeding, early maturity deserves attention. Timely use of replacement heifers for herd reproduction is of great production importance because it affects not only zootechnical but also economic issues.

It is known that the productive period of cows begins with calving. The formation and level of the reproductive ability manifestation in adult heifers is determined not only by heredity but also by the intensity of breeding of replacement heifers.

The main indicators of heifer growth intensity, which characterize the growth and development of animals in different age periods of rearing, are absolute and average daily gain. The characteristics of growing heifers are presented in Table 1.

Heifers with the age of the first fruitful insemination at 13-15 months had the highest average daily gains at different ages. At 0-6 months of age (with an average daily gain of 754 g) and 6-12 months (759 g), the first insemination age was 15 months; 0-6 months (778 g), 6-12 months (810 g), 14 months; 0-6 months (808 g), 6-12 months (901 g), 13 months ($p \geq 0.95$). Absolute gains at 0-6 months of age were 136, 140, 145 kg; at 6-12 months, 136, 146, 162 kg, respectively. The highest age of the first fruitful insemination was observed for heifers at 19, 20 months and older, with average daily gains of 722 and 677 g during the 0-6 months breeding period, respectively. During the rearing period of 6-12 months, the average daily gains were also minimal (632 and 665 g, respectively).

Dairy productivity of cows during the first lactation depends largely on how heifers are prepared for insemination, the determining factors are age and live weight [1].

Tables 2, 3 show the dynamics of milk productivity of cows depending on the age of the first calving.

Analysis of Table 2 makes it possible to determine the desirable age of the first insemination, at which the greatest amount of milk can be obtained. Heifers first inseminated at the age of 13 and 14 months with an average live weight of 370-374 kg gave the highest milk productivity in the first lactation (5309-5476 kg, respectively, milk fat content 3.74%). The lowest milk productivity in the 1st lactation was obtained from cows whose age of first insemination was 20 months and older (5036 kg, 3.75%). The heifers inseminated at 15, 16, 17,

Табл. 1. Влияние интенсивности роста телок на возраст первого осеменения
Table. 1. Influence of heifer growth rate on the age of first insemination

Age of the first insemination, months	Heifers, heads.	Absolute weight gain per month on average, kg			Average daily weight gain, g	
		Rearing period			Rearing period	
		0–6 months	6–12 months	6 months before the insemination	0–6 months	6–12 months
13	11	145 ± 4,2	162 ± 3,0	32 ± 3,3	808 ± 73,5	901 ± 16,5
14	150	140 ± 1,5	146 ± 1,2	56 ± 1,1	778 ± 8,4	810 ± 6,9
15	153	136 ± 1,2	136 ± 1,3	75 ± 1,0	754 ± 6,7	759 ± 7,1
16	162	130 ± 1,2	130 ± 1,2	93 ± 1,1	720 ± 6,9	724 ± 6,9
17	151	130 ± 1,4	126 ± 1,5	106 ± 1,6	726 ± 7,5	701 ± 8,3
18	157	128 ± 1,5	121 ± 1,5	120 ± 1,4	714 ± 8,1	674 ± 8,4
19	66	130 ± 1,8	119 ± 2,0	131 ± 2,5	722 ± 9,8	665 ± 11,1
20 and older	99	121 ± 2,2	113 ± 2,4	148 ± 2,8	677 ± 12,1	632 ± 13,1

18, 19 months of age had yields of 5226, 5198, 5147, 5225, 5067 kg, respectively.

The best productivity indices in the 3rd lactation were also observed in heifers inseminated at the age of 13, 14, 15 months (5418, 5817, 5510 kg). The lowest yields in the 1st and 3rd lactations were obtained from animals inseminated at the age of 20 months and older.

Studies conducted in various regions of Russia have proven that heifers with a constant growth rate at all periods have high fertility; young heifers with a high growth rate during pregnancy have a higher mass at calving, which leads to fewer complications during calving, as well as greater productivity in the first lactation. Heifers should have optimum live weight by the time of calving.

Tables 4, 5 show the dynamics of milk production as a function of live weight at first calving.

The highest milk productivity in the 1st and 3rd lactations in "Okinsky" SEC was obtained from cows with live weight at first calving of 541-550, 551 kg and higher (5197-5164, 5436-5545 kg respectively) with a reliable difference $p \geq 0.90$) (see Tables 4, 5). The lowest milk production was obtained from cows with live weight at first calving up to 500 kg (4567-5122, 4943-5009 kg).

Табл. 2. Молочная продуктивность коров по 1-й лактации в зависимости от возраста первого осеменения

Table. 2. Milk productivity of cows in the 1st lactation depending on the age of first insemination

Age of the first insemination, months	Cows, heads.	Live weight at the first productive insemination, kg	Milk productivity			
			Milk yield, kg	Fat, %	Fat, kg	Protein, %
13	9	370	5309 ± 79	3,74 ± 0,002	198,6 ± 2,9	3,11 ± 0,001
14	149	374	5476 ± 33	3,74 ± 0,003	204,8 ± 1,2	3,11 ± 0,001
15	160	378	5226 ± 35	3,74 ± 0,004	195,4 ± 1,3	3,11 ± 0,002
16	168	384	5198 ± 32	3,74 ± 0,004	194,4 ± 1,2	3,12 ± 0,002
17	151	394	5147 ± 28	3,74 ± 0,004	192,4 ± 1,1	3,11 ± 0,002
18	161	405	5125 ± 35	3,74 ± 0,004	191,7 ± 1,3	3,12 ± 0,002
19	70	421	5067 ± 39	3,73 ± 0,005	190,0 ± 1,5	3,12 ± 0,003
20 and older	102	426	5036 ± 50	3,75 ± 0,006	188,9 ± 1,9	3,12 ± 0,003

Табл. 3. Молочная продуктивность коров по 3-й лактации в зависимости от возраста первого осеменения

Table 3. Milk productivity of cows in the 3d lactation depending on the age of first insemination

Age of the first insemination, months	Cows, heads	Milk productivity			
		Milk yield, kg	Fat, %	Fat, kg	Protein, %
13	9	5418 ± 72	3,89 ± 0,004	210,6 ± 2,8	3,11 ± 0,002
14	149	5817 ± 48	3,90 ± 0,004	199,4 ± 1,9	3,12 ± 0,004
15	160	5510 ± 72	3,89 ± 0,003	214,4 ± 2,8	3,11 ± 0,002
16	168	5308 ± 55	3,89 ± 0,003	206,6 ± 2,1	3,12 ± 0,002
17	151	5325 ± 66	3,88 ± 0,008	206,3 ± 2,5	3,13 ± 0,003
18	161	5283 ± 55	3,89 ± 0,004	205,4 ± 2,1	3,12 ± 0,002
19	70	5256 ± 372	3,88 ± 0,02	243,2 ± 15,1	3,11 ± 0,008
20 and older	102	5203 ± 41	3,89 ± 0,004	202,4 ± 1,6	3,12 ± 0,002

Табл. 4. Влияние живой массы при первом отеле на молочную продуктивность коров по 1-й лактации

Table 4. Effect of live weight at first calving on milk productivity of cows in the 1st lactation

Live weight at first calving, kg	Cows, heads	Milk productivity			
		Milk yield, kg	Fat, %	Fat, kg	Protein, %
До 480	21	4567 ± 444	3,82 ± 0,05	175,4 ± 19,3	3,14 ± 0,02
481–500	34	5122 ± 40	3,73 ± 0,006	191,2 ± 1,5	3,12 ± 0,002
501–520	178	5229 ± 35	3,73 ± 0,003	195,1 ± 1,3	3,11 ± 0,002
521–530	350	5197 ± 76	3,70 ± 0,004	192,5 ± 2,8	3,11 ± 0,004
531–540	127	5164 ± 26	3,73 ± 0,003	192,7 ± 1,0	3,11 ± 0,001
541–550	109	5264 ± 53	3,76 ± 0,01	198,1 ± 1,9	3,12 ± 0,003
551 and more	130	5526 ± 339	3,75 ± 0,02	207,2 ± 13,0	3,13 ± 0,02

Табл. 5. Влияние живой массы при первом отеле на молочную продуктивность коров по 3-й лактации

Table 5. Effect of live weight at first calving on milk productivity of cows in the 3d lactation

Live weight at first calving, kg	Cows, heads	Milk productivity			
		Milk yield, kg	Fat, %	Fat, kg	Protein, %
Up to 480	21	4943 ± 350	3,92 ± 0,06	192,8 ± 12,2	3,13 ± 0,05
481–500	34	5009 ± 249	3,85 ± 0,06	193,3 ± 12,2	3,15 ± 0,02
501–520	178	5282 ± 50	3,89 ± 0,004	205,2 ± 1,9	3,12 ± 0,002
521–530	350	5249 ± 124	3,88 ± 0,007	203,6 ± 4,7	3,10 ± 0,003
531–540	127	5200 ± 60	3,89 ± 0,004	202,3 ± 2,3	3,11 ± 0,002
541–550	109	5436 ± 84	3,89 ± 0,004	211,2 ± 3,2	3,11 ± 0,002
551 and more	130	5545 ± 66	3,89 ± 0,004	215,5 ± 2,5	3,13 ± 0,002

CONCLUSION

According to the research data, the most optimal age of the first insemination and live weight of cows that allow to get the highest milk yield under farm conditions at the first calving were determined. The highest milk productivity in 305 days of the first lactation (5309-5476 kg of milk with fat content 3,74%) was registered in cows of 13-14 months of age of the first insemination with an average live weight of 370-374 kg at the first fruitful insemination. The highest milk productivity in the 1st and 3rd lactations in the Okinsky SEC of the Irkutsk region was obtained from cows with a live weight of more than 541 kg at the first calving.

СПИСОК ЛИТЕРАТУРЫ

1. *Вильвер Д.С.* Влияние живой массы и возраста первого осеменения телок на молочную продуктивность // Ветеринарный врач. 2007. № 3. С. 63–65.
2. *Вильвер Д.С.* Влияние возраста первого осеменения телок на молочную продуктивность // Вестник Челябинского государственного университета. 2008. № 4. С. 159–160.
3. *Косилов В.И., Комарова Н.К., Востриков Н.И.* Молочная продуктивность коров разных типов телосложения после лазерного облучения БАТ вымени // Известия Оренбургского государственного аграрного университета. 2014. № 3. (47). С. 107–110.

4. *Хабарова Г.В., Болтушкина Т.Н., Литонина А.С.* Выращивания ремонтных телок в племзаводах Вологодской области // Молочнохозяйственный вестник. 2011. № 3. С. 23–27.
5. *Стрекозов Н.И., Конопелько Е.И.* Оптимальная структура высокопродуктивного стада молочного скота и интенсивность выращивания телок // Достижения науки и техники АПК. 2013. № 3. С. 5–7.
6. *Исупова М.* Как получить качественный ремонтный молодняк? // Молоко и корма: Менеджмент. 2007. № 2. С. 16–19
7. *Лукичев Д.Л., Лукичев В.Л.* Эффективное выращивание ремонтных телок от высокопродуктивных коров с 4,2– до 15,7–месячного возраста // Вестник Бурятской государственной сельскохозяйственной академии им. В.Р. Филиппова. 2018. Вып. 3 (52). С. 72–79.
8. *Абылкасымов Д., Сударев Н.П., Чаргеишвили С.В., Сизова К.Ю., Востряков К.В.* Селекционная оптимизация ремонта высокопродуктивного молочного стада // Зоотехния. 2021. № 3. С. 2–5.
9. *Стрекозов Н.И., Сивкин Н.В., Рябов Д.С.* Связь интенсивности роста с молочной продуктивностью коров голштинской и айрширской пород // Достижение науки и техники АПК. 2009. № 8. С. 35–38.
10. *Романенко Л.В., Павлий В.А.* Интенсивная система выращивания племенных телок айрширской породы // Зоотехния. 2008. № 3. С. 7–10.
11. *Пеллинен А.В., Голубков А.И., Голубков А.А., Лефлер К.В., Сиротинин Е.Г., Мирвалиев Ф.С.* Эффективность разведения крупного рогатого скота енисейского типа красно-пестрой породы в ПЗ АО «Солгон» // Вестник КрасГАУ. 2019. № 6. С. 114–122.
12. *Жебровский Л.С., Васильева В.И., Волгин О.Р.* Влияние роста молодняка на реализацию молочной продуктивности // Известия Санкт-Петербургского государственного аграрного университета. 2011. № 22. С. 121–126.
13. *Чомаев А., Текеев М., Камбиев И.* Влияние живой массы и возраста телок при первом осеменении на их последующую молочную продуктивность // Молочное и мясное скотоводство. 2010. № 3. С. 11–13.
14. *Прахт В.* Влияние интенсивности роста голштинизированных телок холмогорской породы на последующую молочную продуктивность // Молочное и мясное скотоводство. 2013. № 5. С. 31–32.
15. *Сергеев И.И.* Целесообразность раннего оплодотворения телок // Зоотехния. 2005. № 4. С. 25–27.

REFERENCES

1. Vilver D.S. Influence of live weight and the age of heifers first insemination on the milk productivity. *Veterinarnyi vrach = The Veterinarny Vrach journal*, 2007, no. 3, pp. 63–65. (In Russian).
2. Vilver D.S. Influence of the age of heifers first insemination on the milk productivity. *Vestnik Chelyabinskogo gosudarstvennogo universiteta = Bulletin of the Chelyabinsk State University*, 2008, no. 4, pp. 159–160. (In Russian).
3. Kosilov V.I., Komarova N.K., Vostrikov N.I. Milk yields of cows with different types of body-built after laser irradiation of udders. *Izvestiya Orenburgskogo gosudarstvennogo agrarnogo universiteta = Izvestiya Orenburg State Agrarian University*, 2014, no. 3 (47), pp. 107–110. (In Russian).
4. Khabarova G.V., Boltushkina T.N., Litonina A.S. The breeding of the remount heifers on cattle breeding farms of Vologda region. *Molochnokhozyaistvennyi vestnik = Molochnokhozayistvenny vestnik*. 2011, no. 3, pp. 23–27. (In Russian).
5. Strekozov N.I., Konopelko E.I. Optimal structure of high producing dairy herd and intensity of heifer rearing. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC,* 2013, no. 3, pp. 5–7. (In Russian).
6. Isupova M. How to get high-quality replacement young cattle? *Moloko i korma: Menedzhment = Milk, forages, management,* 2007, no. 2, pp. 16–19. (In Russian).
7. Lukichev D.L., Lukichev V.L. Effective breeding of 4.2-15.7 months old replacement heifers received from highly productive cows. *Vestnik Buryatskoi gosudarstvennoi sel'skokhozyaistvennoi akademii im. V.R. Filippova = Bulletin of Buryat State Academy of Agriculture,* 2018. vol. 3 (52), pp. 72–79. (In Russian).
8. Abylkasymov D., Sudarev N.P., Chargeishvili S.V., Sizova K.Y., Vostryakov K.V. Breeding optimization of repairs of high productive dairy herd. *Zootechniya*, 2021, no. 3, pp. 2–5. (In Russian).

9. Strekozov N.I., Sivkin N.V., Ryabov D.S. Dependence of growth intensity with milk productivity of holstein and ayrshire cows. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC,* 2009, no. 8, pp. 35–38. (In Russian).
10. Romanenko L.V., Pavliy V.A. Intensive system of growing a herd heifers of Ayrshire breed. *Zootechniya*, 2008, no. 3, pp. 7–10. (In Russian).
11. Pellinen A.V., Golubkov A.I., Golubkov A.A., Lefler V.K., Sirotinin E.G., Mirvaliev F.S. The efficiency of breeding of cattle of the Yenisei type of red and motley breed in BF JSC "Solgon". *Vestnik KrasGAU = The Bulletin of KrasGAU*, 2019, no. 6, pp. 114–122. (In Russian).
12. Gebrovsky L.S., Vasileva V.I., Volgin O.R. The effect of young animals' growth on the milk performance. *Izvestiya Sankt-Peterburgskogo gosudarstvennogo agrarnogo universiteta = Izvestiya Saint-Petersburg State Agrarian University*, 2011, no. 22, pp. 121–126. (In Russian).
13. Chomaev A., Tekeev M., Kambiev I. Effect of live weight and age of heifers at first insemination on their subsequent milk production. *Molochnoe i myasnoe skotovodstvo = Dairy and Beef Cattle Farming*, 2010, no. 3, pp. 11–13. (In Russian).
14. Pracht V. Effect of growth rate of Holsteinized heifers of Kholmogorskaya breed on subsequent milk performance. *Molochnoe i myasnoe skotovodstvo = Dairy and Beef Cattle Farming*, 2013, no. 5, pp. 31–32. (In Russian).
15. Sergeev I.I. Expediency of heifer early conception. *Zootechniya*, 2005, no. 4, pp. 25–27. (In Russian).

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АГРОЭКОЛОГИЧЕСКАЯ ТИПИЗАЦИЯ ЗЕМЕЛЬ

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Описаны минимально необходимая информация и последовательность выделения агроэкологических типов земель на территории землепользования опытной станции (ОС), расположенной в лесостепи Приобья Новосибирской области. Выделены агроэкологические типы земель: первый тип (плакорные земли) представлен черноземом выщелоченным в сочетании с обыкновенным, оподзоленным и темно-серой лесной почвой, второй тип (слабоэрозионные земли) – черноземом выщелоченным в сочетании с темно-серой лесной почвой. Почвенный покров ОС в обоих типах земель представлен черноземом выщелоченным (Чв-2-2с), доля которого для первого типа составляет 75,26%, для второго – 76,26% от общей площади типов. Для первого агроэкологического типа земель характерно варьирование высот от 134 до 165 м. Рабочие участки относительно угла наклона рельефа расположены на склонах от 0 до 3 град. Вертикальное расчленение рельефа в среднем составляет 1,3 м, горизонтальное расчленение эрозионными формами – 0,8 км/км^2. Второй тип земель характеризуется высотой над уровнем моря от 113 до 137 м, углом наклона рельефа – от 1 до 4 град. Вертикальное расчленение рельефа в среднем составляет 1,7 м, горизонтальное расчленение эрозионными формами – 0,9 км/км^2. Типизация осуществлена с помощью сформированной цифровой модели землепользования (ЦМЗ) ОС на основе анализа географической информации, материалов дистанционного зондирования Земли (ДЗЗ) и кадастровой карты. ЦМЗ состоит их следующих геоинформационных слоев: топография, почвенный покров, цифровая модель рельефа (ЦМР), рабочие участки. ЦМР включает информацию о крутизне и экспозиции склонов, вертикальном и горизонтальном расчленении.

Ключевые слова: агроэкологические типы земель, геоинформационная модель, ДЗЗ, ГИС, базы данных

AGROECOLOGICAL LAND TYPIFICATION

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The minimum required information and the sequence of agroecological land type allocation on the land management territory of the experimental station (ES) located in the forest-steppe of the Priob'ye region of Novosibirsk is described. Two agroecological land types are distinguished: the first type (upland lands) is represented by leached chernozem in combination with common, podzolized and dark-grey forest soils; the second type (slightly erosive lands) is represented by leached chernozem in combination with dark-grey forest soils. Soil cover of ES in both types of lands is represented by leached chernozem (Lch-2-2s), the share of which for the first type is 75.26%, for the

second - 76.26% of the total area of the types. The first agroecological land type is characterized by a range of heights from 134 to 165 m. The working areas are located on the slopes between 0 and 3 degrees in relation to the terrain angle. Vertical dissection of the relief averages 1.3 m, horizontal dissection by erosion forms is 0.8 km/km^2. The second type of land is characterized by an elevation of 113 to 137 meters above sea level and a slope of 1 to 4 degrees. Vertical dissection of the terrain averages 1.7 m, horizontal dissection by erosion forms 0.9 km/km^2. Typification was carried out with the help of a generated Digital Land Use Model (DLM) of the ES based on the analysis of geographical information, remote sensing materials (ERS) and cadastral map. The DLM consists of the following geo-information layers: topography, land cover, digital elevation model (DEM), working areas. The DEM includes information on slope steepness and exposure, vertical and horizontal dissection.

Keywords: agroecological types of lands, geoinformation model, remote sensing, GIS, databases

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The work was carried out under the supervision of V.K. Kalichkin, Doctor of Agricultural Sciences, Professor, Chief Researcher of the Siberian Federal Scientific Center of AgroBioTechnologies of the Russian Academy of Sciences.

INTRODUCTION

The design of adaptive-landscape farming systems is impossible without a comprehensive agro-ecological assessment of lands. Agroecological assessment of lands takes into account the characteristics of the soil cover, geomorphological and agroclimatic features of the land use area, which determines the productivity of agricultural crops [1]. The capabilities of geographic information systems (GIS), which allow you to systematize spatial information and analyze it in accordance with the objectives are used to carry out analytical work [2-4]. Geoinformation solution of such tasks consists in the system of accumulation, storage and processing of the information obtained [5]. There are a number of functions in GIS with the help of which it is possible to carry out the analysis connected with changes of land resources (calculation of the areas, lengths and other parameters), to receive geomorphometric characteristics of the surface of a territory (slope angle, exposition of a slope, vertical and horizontal dissection of a relief), that allows to give an estimation of the land use.

The basis for GIS is geodata. They are information about a real object obtained through observation or measurement, with the data unit having two components: information about the location of the object in space and information about the properties of the object describing its essence, and respectively spatial and attribute characteristics [6]. With the integration of GIS and Earth's remote sensing (ERS) it is possible to obtain information about land resources for their analysis on-line.

The purpose of the study is to carry out agro-ecological typification of land using the created digital model of land use.

MATERIAL AND METHODS

The research was conducted on the territory of the ES "Elitnaya" (54°54'57 "N, 82°57'6 "E) of the Novosibirsk district of the Novosibirsk region, located on the third terrace of the Priob

plateau, which has a slight slope towards the Ob river. According to the scheme of agrolandscape zoning of the Novosibirsk region compiled by the Siberian Research Institute of Soil Management and Chemicalization of Agriculture (SibNIIZiH) of SFSCA RAS, the farm territory belongs to the forest-steppe Priobsky agrolandscape district of the North-Pre-Altai forest-steppe province [7]. The soil cover is mainly represented by different subtypes of chernozem and dark gray forest soil.

Public cadastral and topographic maps were used to clarify information on the boundaries of the objects. The geospatial database (GDB) reflects information about geometry, spatial location of objects and characteristics of the territory. The GDB is developed in SpatiaLite DBMS. GIS geo-information layers were formed with the use of land use project data of M 1: 21 000, topographic map of M 1: 100 000, Landsat-8 satellite images with the resolution of 30õ30 m in one pixel. The satellite images were downloaded from the site of the US Geological Survey (https://earthexplorer.usgs.gov). All electronic layers were created in the unified 3857 WGS-84/Pseudo-Mercator coordinate system using Quantum GIS (QGIS) software with open modular architecture (https://qgis.org/ru/site/) [8]. When preparing the geoinformation layer soil cover, the map of the experimental-production farm "Elitnoe" (1999 M 1: 10 000) was taken as the basis.

The GDB terrain model includes slope angles, horizontal and vertical dissection, and slope exposure. Digital elevation model (DEM) is formed on the basis of topographic map with digitized elevations and isolines, as well as SRTM data (https://earthexplorer.usgs.gov).

To assess the dissection of the relief, the area was divided into squares of 1 × 1 km. Within the resulting squares, the main indicators were calculated using GRASS GIS in the QGIS interface. Horizontal landform dissection was calculated using the algorithm "Fill sinks" → "catchment area" → "channel network" and linked attribute information about the area and the degree of erosion development. The vertical dissection of the relief was calculated based on a map of elementary catchments using the algorithm → "r.watershed". Then, using the tool "Vector <-> raster" - "Raster statistic for polygons", the maxima and minima of heights in each watershed were calculated. Using the field calculator in the attribute information, the value of height difference and the area occupied by a certain height on the terrain were calculated.

RESULTS AND DISCUSSION

The data obtained during the formation of a digital land-use model (DLUM) were formed into geoinformation layers with a GDB. Geoinformation layer topographic map carries information about actual boundaries of land use, working areas, reference points of the geodetic network, settlements, road network, power lines, gas pipelines, heights, horizontals, etc. With the help of the public cadastral map the boundaries of the working areas of land use were specified. When digitizing and clarifying the areas of the working areas with the help of the territorial land management project, remote sensing, raster map substrate (Google Satellite Hybrid) and the data provided from the ES, it turned out that the accounting area is different everywhere. Therefore, it is necessary to specify the acreage of the working sites with the help of contour interpretation of aerial photos.

The formed GDB by working plots includes attributive information: plot number, area, ridge length, configuration of the working sites, distance from the central farmstead, thickness of the humus horizon, crops cultivated over the last 5 years, and their yields (see Fig. 1).

The basis of land management is crop rotations, the placement of which depends on soil and climatic conditions. The geoinformation layer of the crop rotation scheme in the ES "Elitnaya" is shown in Fig. 2. Field and forage crop rotations prevail equally on the territory of the ES "Elitnaya", since the specialization of the agricultural organization is cattle-breeding and plant-growing.

As one of the thematic layers of GIS, a geoinformation layer soil cover was created, which contains the characteristics of the soil cover of the territory, and serves as the basis for agro-ecological land typing [9].

The soil cover of the "Elitnaya" ES territory is represented by different subtypes, the share of which from the total area is the following values: leached chernozem - 83.35%, common - 6.11, podzolized - 3, dark gray forest - 7.54% (see Fig. 3). Soil GDB contains information on soil index, soil name, content of humus and physical clay, pH, mobile phosphorus, and exchangeable potassium. The granulometric composition of soils varies from medium to heavy loamy. The humus content in the soils varies from 2 to 5%, pH from 4.51 to 5.01.

The relief of the earth's surface influences the physical and geographical elements of the landscape, being the main factor of its formation. Microclimatic and geochemical conditions of the territory under study - water flow and soil erosion, which are its main characteristics, depend on the steepness, shape, exposition of the slope and dissection of the territory. The temperature of soil warming, the intensity of erosion and the thickness of the soil profile depend on the steepness and shape of the slopes. Therefore, the obtained spatial data on the morphometric characteristics help to estimate the erosion potential of the territory [10]. For these purposes a DEM was created. A GDB with point and linear geometry was formed for the DEM. The linear layer contains information about heights, which are built with a cross section in 10 m (see Fig. 4).

The calculation and analysis of maps of horizontal and vertical dissection, exposure and steepness of slopes, and conclusions about the exposure of the territory to geomorphological risks depending on the values of morphometric parameters of the relief were made [11].

One of the main characteristics of the relief is the steepness of the slope and its shape, which determine the rate of surface water runoff. Proceeding from the fact that it is the steepness of the slope that affects the manifestation of erosion processes, we calculated the slope indicators of the territory of ES "Elitnaya" on the basis of SRTM.

The territory of the ES "Elitnaya" has land plots of different steepness, the classification

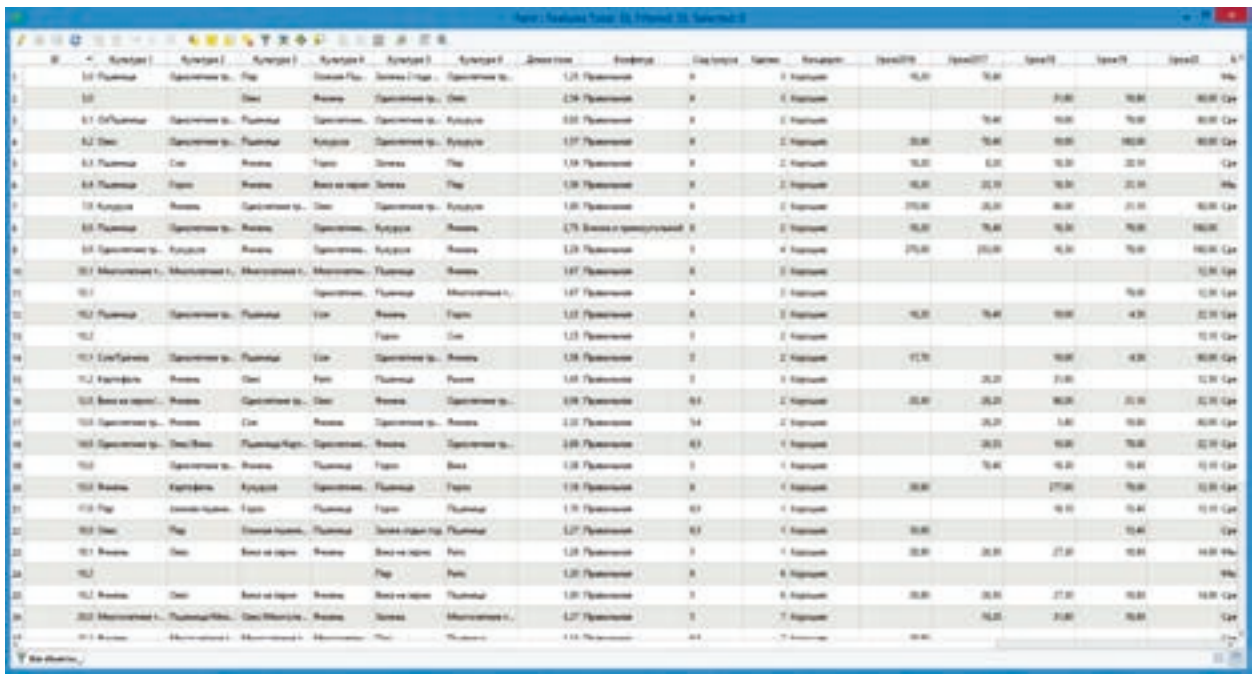

Рис. 1. Фрагмент базы геопространственных данных рабочих участков
Fig. 1. Fragment of the geospatial database of work sites

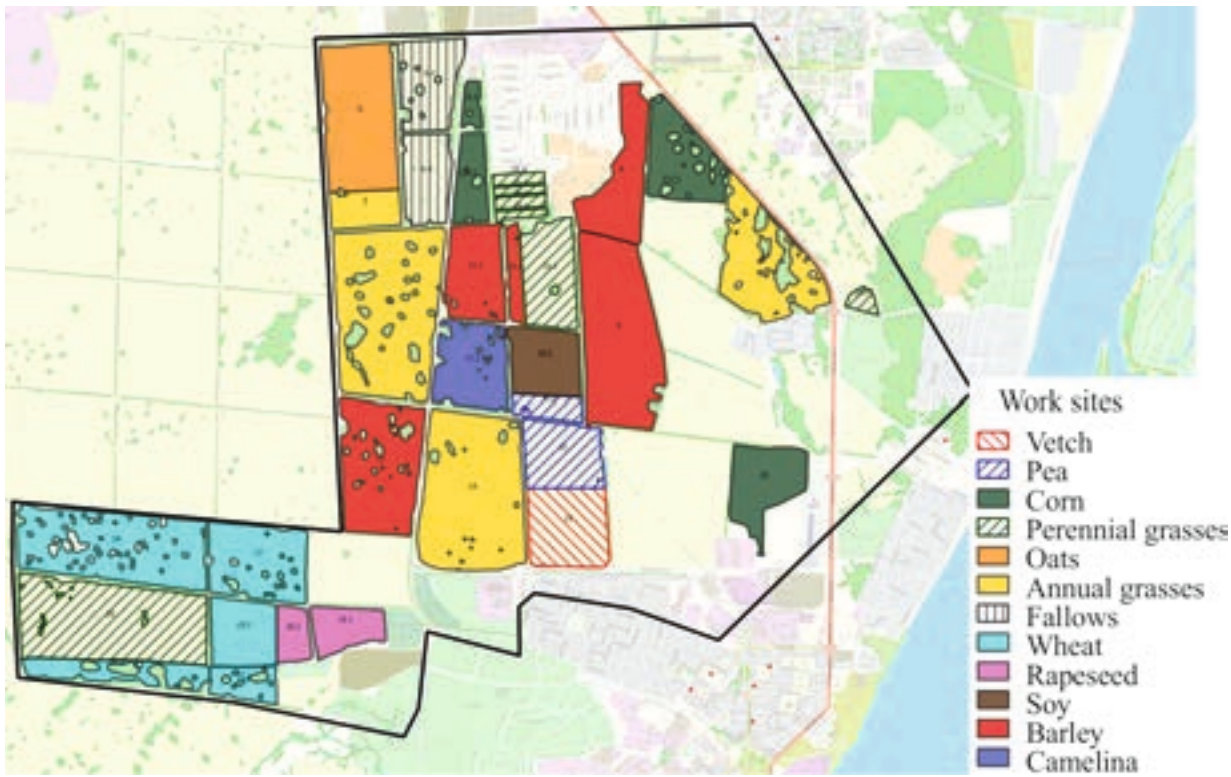

Рис. 2. Геоинформационный слой рабочих участков посевов сельскохозяйственных культур ОС «Элитная» в 2021 г.

Fig. 2. Geographic information layer of working areas of crops of the ES «Elitnaya» in 2021

of which was carried out by the method of M.N. Zaslavsky (see Fig. 5) [12].

The largest part of the ES "Elitnaya" is occupied by 0-1-degree slopes. They cover 57.17% of the area, slopes 1-3 deg. occupy 41.03%, 3-5 deg. - 1.77, 5-7 deg. - 0,03%. This shows that the relief of the slopes varies from very gentle to slightly sloping [1]. Working sites are mostly located on slopes 0-3 degrees, they are less washed away than the location on steeper slopes.

The intensity of sunlight distribution, vegetation and soil cover, microclimate, and snow distribution in winter depend on the exposure of slopes. The most favorable slopes for placing agricultural crops in the forest-steppe are considered the southern ones, they warm up faster, the duration of vegetation period of plants on them is higher, and the most unfavorable - the northern, colder and often overmoistened. On the eastern slopes, the maximum temperature is reached in the morning and in the evening on the western slopes [13]. When forming the electronic layer of slope exposures, a breakdown into eight ranges was adopted: north, northeast, east, southeast, south, southwest, west, and northwest (see Fig. 6).

The analysis showed that the slopes of the northern exposure account for 14.79%, northeastern - 15.86%, eastern - 14.22%, southeastern - 10.57%, southern - 14.42% of the total area on the territory of "Elitnaya" ES. The southwestern exposure slopes are represented by the smallest proportion and account for 8.96%, the western exposure 11.20, and the northwestern exposure 9.99%. The southern exposure of slopes is most significantly expressed in the working sites located in the southwestern part of the ES "Elitnaya", the other sites have equally complex distribution of slope exposures.

The degree of horizontal dissection of the territory under study depends on the development of the erosion network, the classifica-

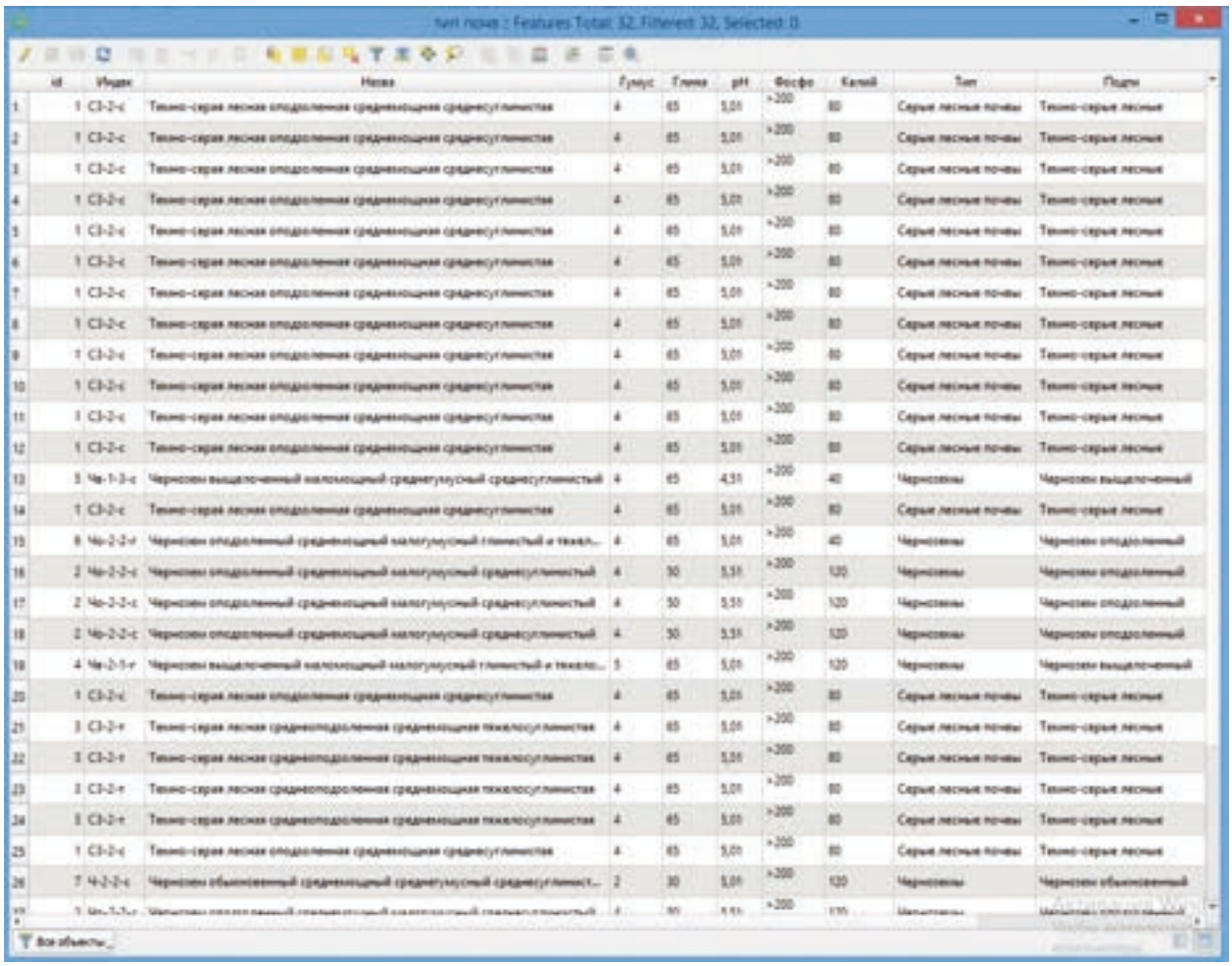

Рис. 3. Фрагмент базы геопространственных данных электронного слоя почвенный покров
Fig. 3. Fragment of the geospatial database of the electronic layer soil cover

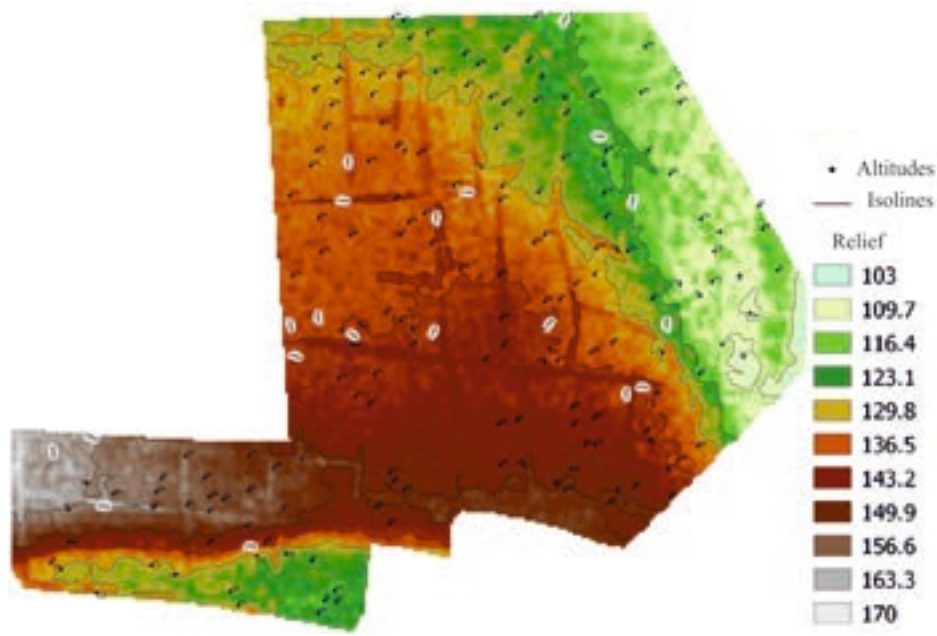

Рис. 4. Цифровая модель рельефа ОС «Элитная», м
Fig. 4. Digital relief model of the ES «Elite», m

Рис. 5. Геоинформационный слой распределения значений крутизны склонов, град.
Fig. 5. Geographic information layer for the distribution of slope steepness values, degrees

tion of which is generally accepted [12]. The formed layer of horizontal dissection of the relief is characterized by the indicator of the territory division into sections on the basis of a regular grid with the area of 1 km^2, with subsequent calculation of the length of the erosion network in each cell. The attributive GDB data contain information about the area, length of permanent and temporary watercourses.

According to the calculations of horizontal dissection of the relief, 64.98% of the territory of ES "Elitnaya" is attributed to slightly dissected plain with little manifestation of erosion processes. Dissection by erosion forms is less than 0.2 km/km^2. Average dissection of the territory is 12.77% of the total area, strong - 12.77% and very strong - 9.57%.

The dissection of the relief by erosive landforms from north to north-east increases from 0.1 to 0.9 km/km^2. In the eastern part, the horizontal dissection coefficient varies from 0.1 to 0.5 km/km^2, in the south-west - from 0.2 to 0.5, in the western part - from 0.1 to 0.3, in the north-west - from 05 to 0.8 km/km^2.

Attributive information of geoinformation layer of vertical dissection of relief contains information about heights, the difference between maximum and minimum heights, the areas occupied by heights on the terrain. The difference between heights varies from 11 to 73 m. In general, the territory of land use of ES "Elitnaya" is characterized by conditionally undivided plain, the share of which from the total area is 96.83%. Shallowly partitioned plain is 0.52% of the total area, moderately partitioned - 0.51, deeply partitioned - 0.63 and heavily partitioned - 3.06%.

Agroecological types of lands are identified by mutual superimposition of map layers [14]. On the basis of the analysis an electronic layer of agroecological types of land was formed. The basis of agroecological land typification is the definition of agroecologically homogeneous territory according to the conditions of crops cultivation.

Agro-ecological land typification was carried out according to the methodology of V.I. Kiryushin [15]. Two types of lands were singled out on the land use territory of ES "Elit-

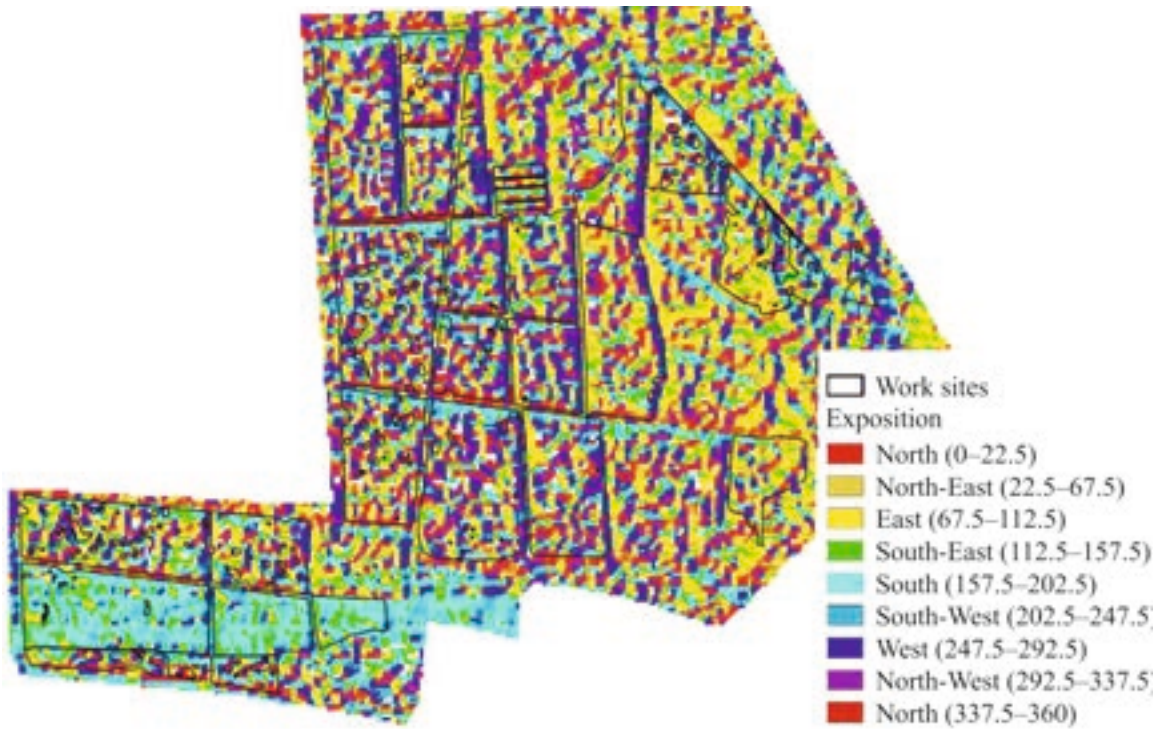

Рис. 6. Геоинформационный слой распределения значений экспозиции склонов, град.
Fig. 6. Geographic information layer of slope exposure values distribution, degrees

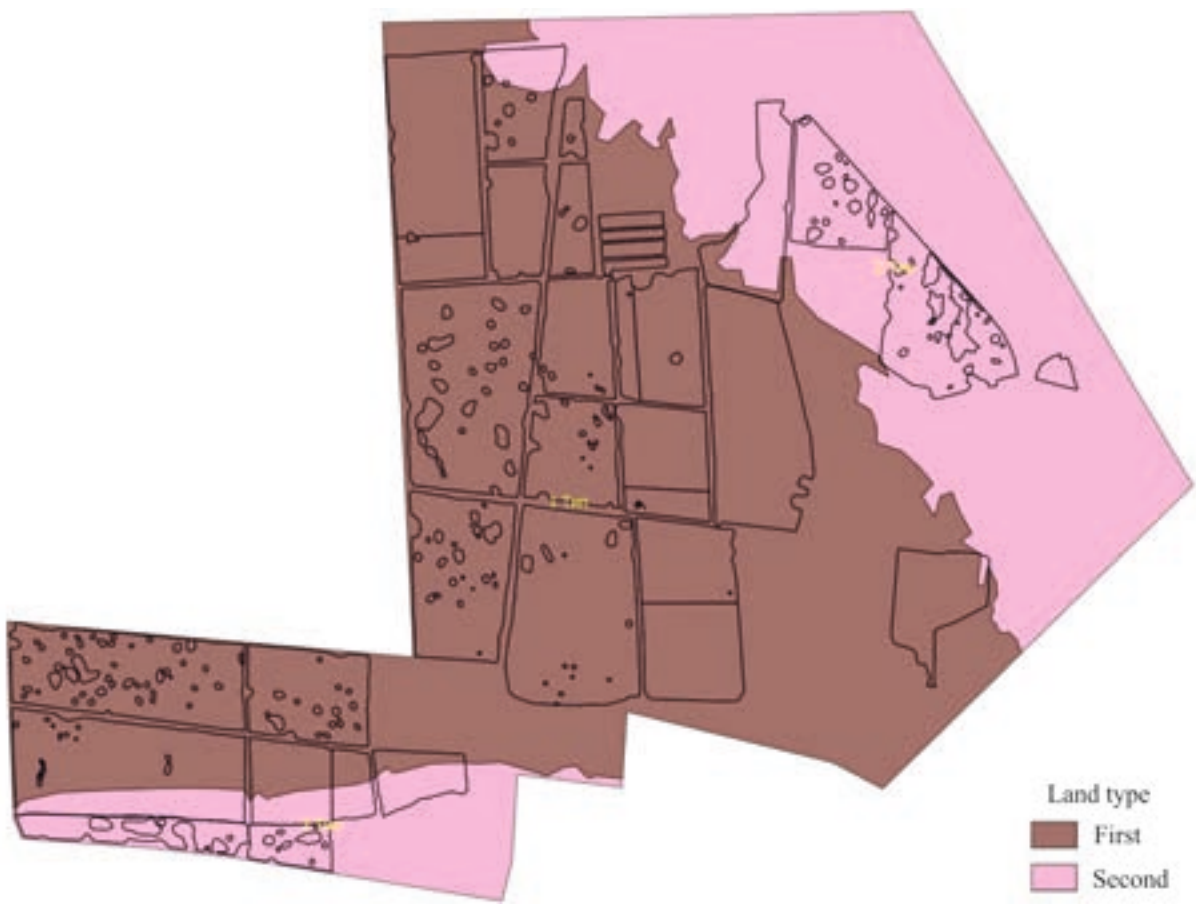

Рис. 7. Геоинформационный слой агроэкологических типов земель
Fig. 7. Geoinformation layer of agroecological land types

naya" (see Fig.7). The first agro-ecological type of lands (upland lands) is represented by leached chernozem in combination with common, podzolized and dark gray forest soils. Elevations above sea level vary from 134 to 165 m. Relief slope angle varies from 0 to 3 degrees. Vertical dissection of the relief averages 1.3 m, horizontal dissection by erosion forms - 0.8 km/km^2. The largest area is occupied by medium-humus medium-loamy leached chernozem (Chv-2-2s), the share of which is 75.26% of the total area of the type.

The second agro-ecological land type is located on slightly erosive lands and includes chernozem, leached in combination with dark gray forest soil. The elevation varies from 113 to 137 m above sea level. Relief slope angle varies from 1 to 4 degrees. Vertical relief dissection averages 1.7 m, horizontal dissection by erosion forms - 0.9 km/km^2. The largest area is occupied by medium-humus medium-loamy leached chernozem (Chv-2-2s), the share of which is 76.26% of the total area of the type.

CONCLUSION

The land use area of ES "Elitnaya" has an upland and a slightly sloping type of terrain, rugged with linear erosion forms. The working sites are mainly located on the predominant slopes of 0-3 degrees. (98,2%). In the soil cover, leached chernozem is predominantly expressed, which accounts for 83.35% of the total ES area. Slopes of the north-eastern exposition prevail; they account for 15.86% of the total area. The ES territory is attributed to the poorly broken relief plain, where the dissection by erosion forms is less than 0.2 km/km^2, and the vertical relief dissection varies from 11 to 73 m.

Agroecological land typing using DEM consists of the following algorithm sequence: coordinate referencing, geoinformation layers formation using RS data processing, DEM formation (horizontal and vertical relief partitioning, slope angle, slope exposition), GDB creation. To form a higher-quality DEM, it is necessary to specify the boundaries of the working sites and the spatial location of geographical objects, as well as to create a soil map (the paper version of the map is lost) with the help of RS data and field soil survey.

СПИСОК ЛИТЕРАТУРЫ

1. Агроэкологическая оценка земель, проектирование адаптивно-ландшафтных систем земледелия и агротехнологий: монография. М.: ФГНУ «Росинформагротех», 2005. 784 с.
2. *Каличкин В.К., Павлова А.И.* Агрономические геоинформационные системы: монография. Новосибирск: СФНЦА РАН, 2018. 347 с.
3. *Павлова А.И., Каличкин В.К.* Использование геоморфометрического анализа рельефа при создании базы данных сельскохозяйственных земель // Сибирский вестник сельскохозяйственной науки. 2016. № 5. С. 5–13.
4. *Смирнова Л.Г., Нарожняя А.Г., Кривоконь Ю.Л., Петрякова А.А.* Применение геоинформационных систем для агроэкологической оценки земель при проектировании адаптивно-ландшафтных систем земледелия // Достижения науки и техники АПК. 2011. № 11. С. 11–14.
5. *Каличкин В.К.* Геоинформационное моделирование в изучении трансформации и использования земель сельскохозяйственного назначения // Достижения науки и техники АПК. 2016. Т. 30. № 4. С. 70–72.
6. *Майорова О.В., Малева М.Л., Майоров А.Н.* Земельный мониторинг РФ на основе применения ГИС технологий // International Agricultural Journal. 2020. Т. 63. № 6. С. 38.
7. *Кирюшин В.И., Власенко А.Н., Каличкин В.К., Власенко Н.Г., Филимонов Ю.П., Иодко Л.Н., Шарков И.Н., Тарасов А.С., Понько В.А., Южаков А.И., Хмелев В.А., Семендяева Н.В., Киншт А.В., Синещеков В.Е., Новиков В.М., Шоба В.Н., Кожевников А.И., Усолкин В.Т., Добротворская Н.И., Ким С.А., Солосич Н.А., Филимонова Л.Н., Коняева Н.М., Полухин Н.И.* Адаптивно-ландшафтные системы земледелия Новосибирской области: монография. Новосибирск: СО РАСХН, 2002. 387 с.
8. *Каличкин В.К., Логачева О.М., Сигитов А.А., Гарафутдинова Л.В.* Интеграция геоинформационной системы и методов многокритериального анализа решений для оценки пригодности земель сельскохозяйственного

использования // Сибирский вестник сельскохозяйственной науки. 2020. Т. 50. № 6. С. 93–105. DOI: 10.26898/0370-8799-2020-6-11.
9. *Каличкин В.К., Павлова А.И., Шоба В.Н., Каличкин А.В.* Интеграция оценки агроэкологических и технологических свойств земель // Достижения науки и техники АПК. 2019. Т. 33. № 3. С. 11–14.
10. *Павлова А.И., Каличкин В.К.* Использование геоморфометрического анализа рельефа при создании базы данных сельскохозяйственных земель // Сибирский вестник сельскохозяйственной науки. 2016. № 5. С. 5–13.
11. *Савельева Д.А., Каличкин В.К.* Применение цифровых технологий при изучении водной эрозии почв Западной Сибири // Сибирский вестник сельскохозяйственной науки. 2019. Т. 49. № 4. С. 86–100. DOI 10.26898/0370-8799-2019-4-10.
12. *Заславский М.Н.* Эрозиоведение. Основы противоэрозионного земледелия: монография. М.: Высшая школа, 1987. 375 с.
13. *Соколова Г.Г.* Влияние высоты местности, экспозиции и крутизны склона на особенности пространственного распределения растений // Acta Biologica Sibirica. 2016. Т. 2. № 3. С. 34–45.
14. *Иванов А.Л., Козубенко И.С., Савин И.Ю., Кирюшин В.И.* Цифровое земледелие // Вестник российской сельскохозяйственной науки. 2018. № 5. С. 4–9.
15. *Кирюшин В.И.* Экологизация земледелия и технологическая политика: монография. М.: МСХА, 2000. 473 с.

REFERENCES

1. *Agroecological assessment of land, design of adaptive landscape systems of farming and agricultural technologies.* Moscow, FGNU "Rosinformagrotech", 2005. 784 p. (In Russian).
2. Kalichkin V.K., Pavlova A.I. *Agronomic geoinformation systems.* Novosibirsk, SFSCA RAS, 2018, 347 p. (In Russian).
3. Pavlova A.I., Kalichkin V.K. The use of geomorphometric analysis of the relief when creating a database of agricultural lands. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2016, no. 5, pp. 5–13. (In Russian).
4. Smirnova L.G., Narozhnyaya A.G., Krivokon Yu.L., Petryakova A.A. Application of geographic information systems for agroecological land assessment in the design of adaptive landscape farming systems. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC,* 2011, no. 11, pp. 11–14. (In Russian).
5. Kalichkin V.K. Geoinformation modeling in the study of transformation and use of agricultural lands. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC,* 2016, Vol. 30, no. 4, pp. 70–72. (In Russian).
6. Mayorova O.V., Maleva M.L., Mayorov A.N. Land monitoring of the Russian Federation based on the use of GIS technologies. International Agricultural Journal, 2020.Vol. 63.№. 6, pp. 38. (In Russian).
7. Kiryushin V.I., Vlasenko A.N., Kalichkin V.K., Vlasenko N.G., Filimonov Y.P., Iodko L.N., Sharkov I.N., Tarasov A.S., Ponko V.A., Yuzhakov A.I., Khmelev V.A., Semendyaeva N.V., Kinsht A.V., Sineschekov V.E., Novikov V.M., Shoba V.N., Kozhevnikov A.I., Usolkin V.T., Dobrotvorskaya N.I., Kim S.A., Solosich N.A., Filimonova L.N., Konyaeva N.M., Polukhin N.I. *Adaptive-landscape farming systems of the Novosibirsk region.* Novosibirsk, SB RAAS Publ., 2002, 387 p. (In Russian).
8. Kalichkin V.K., Logacheva O.M., Sigitov A.A., Garafutdinova L.V. Integration of geoinformation system and methods of multicriteria analysis of solutions for assessing the suitability of agricultural land. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2020, vol. 50, no. 6, pp. 93–105. (In Russian). DOI: 10.26898 / 0370-8799-2020-6-11.
9. Kalichkin V.K., Pavlova A.I., Shoba V.N., Kalichkin A.V. Integration of assessment of agroecological and technological properties of lands. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC,* 2019, vol. 33, no. 3, pp. 11–14. (In Russian).
10. Pavlova A.I., Kalichkin V.K. The use of geomorphometric analysis of the relief when creating a database of agricultural lands. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2016, no. 5, pp. 5–13. (In Russian).
11. Savelieva D.A., Kalichkin V.K. Application of digital technologies in the study of water erosion of soils in Western Siberia. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Sibe-*

rian Herald of Agricultural Science, 2019, vol. 49, no. 4, pp. 86–100. (In Russian). DOI: 10.26898 / 0370-8799-2019-4-10.
12. Zaslavsky M.N. Erosiology. *Fundamentals of anti-erosion agriculture.* Moscow, Vysshaya Shkola Publ., 1987, 375 p. (In Russian).
13. Sokolova G.G. The influence of the height of the area, exposure and steepness of the slope on the features of the spatial distribution of plants. Acta Biologica Sibirica, 2016, vol. 2, no. 3, pp. 34–45. (In Russian).
14. Ivanov A.L., Kozubenko I.S., Savin I. Yu., Kiryushin V.I. Digital agriculture. *Vestnik rossiiskoi sel'skokhozyaistvennoi nauki = Vestnik of the Russian agricultural science,* 2018, no. 5, pp. 4–9. (In Russian).
15. Kiryushin V.I. *Ecologization of agriculture* and technological policy. Moscow, Moscow Agricultural Academy, 2000. 473 p. (In Russian).

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ОБНОВЛЕНИЕ ТЕХНИЧЕСКИХ СРЕДСТВ ЗЕРНОУБОРОЧНОГО КОМПЛЕКСА

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В настоящее время разработано много вариантов реализации алгоритма по обновлению парка зерноуборочных средств. В соответствии с урожайностью и учетом других показателей предложены рекомендации по формированию и обновлению парка зерноуборочной техники дискретно в виде таблиц или диаграмм. Данная форма информации не всегда соответствует требованиям оперативного корректирования и не позволяет оценить технологические возможности уборочных агрегатов в зависимости от условий уборки. Предложен способ совершенствования формирования исходной информации для оперативного принятия решения по эффективному обновлению технических средств зерноуборочного комплекса с учетом зональных особенностей конкретного агропредприятия. Разработан графоаналитический метод определения основных параметров базовых уборочных средств в зависимости от прогнозируемого уровня урожайности и дана оценка влияния факторов, определяющих состав парка зерноуборочного комплекса. Данный метод позволяет выявить наиболее рациональные основные параметры альтернативных базовых уборочных средств конкретного агропредприятия. На первом этапе определяют основные параметры базовых технических средств, затем производят выбор соответствующих типоразмерных рядов самоходных молотилок комбайнов и жаток. Далее формируют альтернативные варианты различных моделей зерноуборочных агрегатов и комплексов. Для последующего выбора рациональных типажей уборочных средств и их критериальной оценки привлекают технико-технологические, экологические и другие показатели. Экспертно-логический анализ информационных ресурсов дает возможность выявить и дать оценку факторам, определяющим количественный состав технических средств зерноуборочного комплекса. Итоговым этапом формирования исходной информации для принятия решения по обновлению технических средств зерноуборочного комплекса должна стать их экономическая оценка, позволяющая прогнозировать конкурентоспособность намолачиваемого зерна.

Ключевые слова: уборка урожая, урожайность, зерноуборочный комплекс, обновление технических средств, агропредприятие

UPDATE OF TECHNICAL EQUIPMENT OF THE GRAIN HARVESTING COMPLEX

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Many options have been developed for the implementation of the algorithm for updating the fleet of grain harvesters to date. In accordance with the yield and other indicators, recommendations for the formation and renewal of the harvester fleet are proposed discretely in the form of tables or charts. This form of information does not always meet the requirements of operational correction and does not allow assessing the technological capabilities of the harvesting units, depending on the harvesting conditions. The method to improve the formation of the initial information for operational decision-making on the effective upgrading of technical means of grain harvesting complex taking into account the zonal features of a particular agricultural enterprise is proposed. A graph-analytical method for determining the main parameters of the basic harvesting tools depending on the predicted yield level is developed and the influence of the factors determining the composition of the grain harvesting fleet

is assessed. This method makes it possible to identify the most rational basic parameters of alternative basic harvesting tools for a specific agricultural enterprise. The first step is to determine the basic parameters of the basic equipment, then select the appropriate size series of self-propelled threshers for combine harvesters and reapers. Further, alternative versions of various models of grain harvesting units and complexes are formed. For the subsequent selection of rational types of cleaning agents and their criterion assessment, technical and technological, environmental and other indicators are used. The expert-logical analysis of information resources makes it possible to identify and assess the factors that determine the quantitative composition of the technical means of the grain harvesting complex. The final stage in the formation of the initial information for making a decision on updating the technical means of the grain harvesting complex should be their economic assessment, which makes it possible to predict the competitiveness of the threshed grain.

Keywords: harvest, crop yield, grain harvest complex, updating of technical means, agricultural enterprise

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INTRODUCTION

Timely effective renewal of technical means of grain harvesting complex of agricultural enterprise allows to obtain quality grain of different purposes in appropriate agrotechnical terms with minimal losses. At present, many variants of the formation of technical strategy for the renewal of grain harvesting facilities have been developed [1-5]. All variants take into account zonal conditions of harvesting, financial condition and other production and technological features of grain grower.

Grain yield is the most informative indicator that reflects the conditions of harvesting, since its level determines the value of technological loading of harvesting machine [2, 3, 5-7]. In this regard, in accordance with the level of this indicator recommendations for the formation and renewal of the fleet of grain harvesting equipment are given. The materials of the recommendations are presented mainly discretely in the form of tables or charts [2, 3, 5, 6]. This form of presentation of the original information does not always meet the requirements of its operational correction and does not allow to assess the trends in the technological capabilities of harvesting units.

At present, grain growers are presented with a very diverse market of technical means of harvesting complex with comparable technical and technological capabilities. In this regard, the decision to update the fleet of grain harvesting equipment is always associated with a comparative assessment of alternative technical means analogues. For its implementation it is necessary to choose certain criteria. Economic, technical and technological and other indicators may be involved in the criterial evaluation [1, 4, 7]. Multicriteria not only reflect the distinctive production features of a particular agricultural enterprise, but also indicate the lack of a single generally accepted approach to the selection of effective technical means and the multistage nature of its implementation [1, 7-9].

The dominant input data for the classical calculation of the need for grain harvesting equipment are the volume of work, productivity of technical means and agrotechnical terms of harvesting. These analytically interrelated

dominants, in turn, depend on different levels of production situational factors that significantly affect the final results of the calculation. It is necessary to identify and evaluate the factors determining the quantitative composition of the grain harvesting machinery fleet for the production of competitive basic crop production.

The purpose of the study is to improve the way of forming the initial information for operational decision-making on the effective renewal of technical means of grain harvesting complex, taking into account the zonal features of a particular agricultural enterprise.

Research objectives:

– using the graph-analytical method to determine the main parameters of basic harvesting tools depending on the projected yield level;

– identify and assess the factors determining the need for technical means of grain harvesting complex.

MATERIAL AND METHODS

Graphoanalytical method as the initial stage of forming the initial information for making decisions on updating the basic technical means of grain harvesting complex is implemented due to the fact that the main parameters of the latter have a formalized relationship with the yield as the main information indicator, reflecting the zonal harvesting conditions. The generally accepted analytical dependence, which is used to estimate both the required level of grain crop yield and its "boundary" value [3, 7], is as follows

$$Y = 360P^0 / (BV_{gr} (1 + \varphi)), \text{ c/ha}, \quad (1)$$

where P^0 is the nominal (nameplate) carrying capacity of threshing and separating working bodies of the combine harvester, kg/s; B – the width of the cutterbar, m; V gr – the maximum speed of combine harvester in specific conditions, km/h; φ - specific indicator of strawiness of threshed bread mass; 360 – the coefficient of agreement of measurement units.

Analytical dependence (1) after substitution of numerical values of its constituent values (Vgr = 7.2 km/h and φ = 1.5) is transformed into the following final equation:

$$Y = 20P^0 /B. \quad (2)$$

Graphical representation of this equation (2) and its inverse solution will allow us to estimate the main parameters of basic harvesting tools depending on the predicted level of yield of a particular agricultural enterprise.

The main method of identifying and evaluating the factors determining the quantitative composition of the grain harvesting machinery fleet is an expert-logical analysis of information resources concerning the machine use of technical means that implement resource-saving technologies of harvesting grain crops.

RESULTS AND DISCUSSION

Efficiency of the renewal of the grain harvesting complex fleet is determined by the rationality of the choice of the basic parameters of its basic technical means: self-propelled thresher combine and harvesters, designed to implement direct or separate harvesting. The main parameters of the basic technical means, which determine the productivity of the combine harvester are throughput and working width. Graphical representation of the resulting equation (2) in linear form, in contrast to the previously obtained result[1] allows us to predict the completeness of grain harvesting units with less error (see figure).

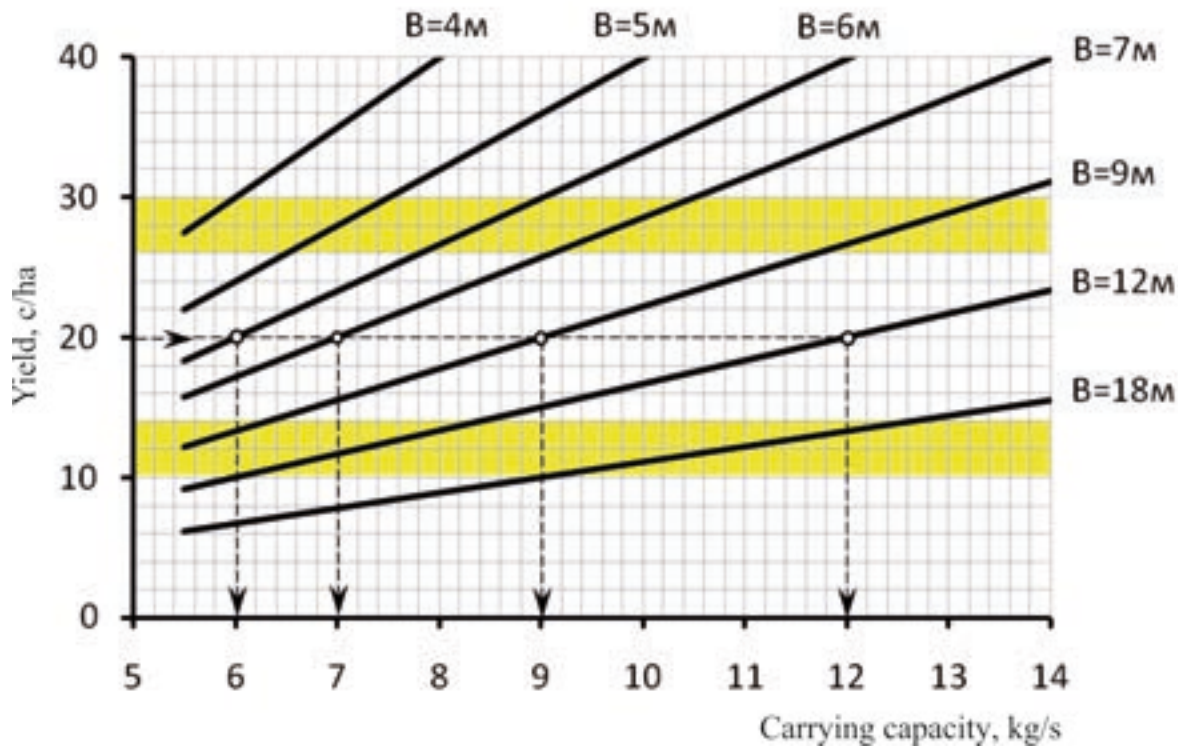
The figure shows that the inverse solution of the final equation makes it possible to determine the basic parameters of the basic harvesting tools needed for a particular agricultural enterprise with a given, predicted or established level of yield. Thus, for an agricultural enterprise with the yield of 20 c/ha the following dimension range of self-propelled threshers is the most effective: Grade 3 - 5-6 kg/s,

[1]Chemodanov S.I. Update of the grain harvesting equipment complex. Agrarian science to agriculture: materials: 15th International Scientific-Practical Conference in 2 parts. pp. 88-90.

Grade 4 - 7-8, Grade 5 - 9-10, Grade 6 - 11-12 kg/s. At the same time the nominal size range of cutterbars should be respectively 6, 7, 9 and 12 m regardless of the phase of harvesting. The design parameters of the working width shown in the figure apply to headers, universal cutterbars, as well as to windrower cutterbars, including those with the ability to form twin windrows.

At the first stage the basic parameters of the basic technical means are determined, then the choice of the appropriate size series of self-propelled threshers of combines and harvesters is made. Further, alternative variants of different models of grain harvester units and complexes are formed. For the subsequent selection of rational types of harvesters and their criterial evaluation technical, technological, environmental and other indicators are involved. These intermediate indicators, which take into account the production peculiarities of a particular grain producer, should be aimed at the rational use of the resource provision of the agricultural enterprise. Thus, the step-by-step identification of the most priority basic technical means makes it possible to choose the optimal variants of grain harvesting units and complexes.

The figure on the abscissa shows the capacity of the self-propelled threshing machine, which defines the passport (theoretical) capacity as an assessment of the potential capabilities of the grain harvester under normalized operating conditions. Real operating conditions reduce the realization of the potential capabilities of the grain harvester. Therefore, the required number of harvesting units is determined based on the real (operational) capacity, as well as taking into account the harvesting area in the peak period and the permissible agricultural terms of harvesting. The quantitative composition of the harvesting park depends on the technical level and efficiency of the use of technological



Графическая интерпретация взаимосвязи уровня урожайности и пропускной способности самоходных молотилок комбайна при различной ширине захвата жаток (B)

Graphical interpretation of the relationship between the yield level and the throughput of self-propelled combine threshers at different reaper capture widths (B)

machines, the structure and size of the sown areas, the harvesting technologies adopted, the technical equipment of post-harvest grain processing stations, the professional level of machine operators and specialists.

Operational performance of the grain harvesting complex is determined by the level of availability of technical means. It largely depends on the scheduled preventive maintenance and appropriate repair (preferably aggregate) in the inter-harvest period. Qualitative implementation of these measures allows maintaining the availability factor at a sufficiently high level throughout the life of the harvesting equipment, but at the same time direct operating costs will be increased.

From the economic point of view, for effective harvesting, it is necessary to maximize the potential of all technical means of the harvesting and transport complex. The priority object is a combine harvester as the most expensive basic technical means in technological process. Experimental studies have revealed that the maximum possible level of technological loading of the combine harvester also allows us to obtain the minimum indicators of grain injury and meet the environmental requirements for the content of harmful engine exhaust gases.

The implementation of different harvesting technologies must be interconnected with the previous and subsequent modules of grain production. This initial agrotechnical requirement assumes the presence of grain dryers and tedders of appropriate capacity in agricultural enterprises, as well as "engineering" crop rotations. Formation of "engineered" crop rotations as planning of sowing areas for crops with different periods of vegetation and terms of sowing is desirable to be carried out taking into account the routing of technical means. The implementation of the modular relationship of grain production will provide an opportunity to expand the calendar agricultural terms of harvesting, i.e. reduce the peak load on the harvesting equipment and, consequently, its need.

Increasing the harvesting period to the beginning of intensive shattering of grain in the phase of hard ripeness also contributes to the implementation of separate harvesting in the classical version (with drying of the bread mass in windrows). Extension of the boundaries of effective functioning of harvesting units is possible with the use of combing harvester in grain harvesting complex and introduction of technology of harvesting high-moisture grain (including threshing-free) for fodder purposes with subsequent conditioning and preservation [10]. It should be taken into account that the limitation in the use of combing working tools is the condition of the productive part of the crop, prone to self-drainage during the phase of firm ripeness.

The expediency of the quantitative composition of technical means of grain-harvesting complex is determined by the method of classical calculation of the need for grain-harvesting equipment, taking into account the actual and estimated dominant source data. The final stage of formation of the initial information for making decisions on the renewal of the structural and quantitative composition of the grain harvesting complex is their economic evaluation. The efficiency of renewal is estimated by "minimum direct operating costs" (GOST 34393-2018), because this indicator allows predicting the competitiveness of threshed grain.

CONCLUSIONS

1. The grapho-analytical method of determining the basic parameters of the basic harvesting tools for any agricultural enterprise with a given, predicted or established interval of grain yield. This makes it possible to obtain illustrative initial information at the initial stage for operative decision-making on the renewal of technical means of grain-harvesting complex.

2. Expert-logical analysis of information resources allows you to identify and evaluate the factors that determine the need for technical means of grain harvesting complex.

СПИСОК ЛИТЕРАТУРЫ

1. *Жалнин Э.В.* Системно-аналитический метод формирования технической политики в АПК РФ // Тракторы и сельхозмашины. 2012. № 6. С. 3–8.
2. *Чепурин Г.Е.* Методика выбора типажа техники для уборки зерновых с учетом зональных особенностей // Вестник Государственного аграрного университета Северного Зауралья. 2008. № 2 (29). С. 68–75.
3. *Пронин В.М., Прокопенко В.А., Добрынин Ю.М.* Критерии выбора зерноуборочных комбайнов // АгроСнабФорум. 2016. № 5 (144). С. 20–22.
4. *Докин Б.Д., Ёлкин О.В., Лапченко Е.А., Исакова С.П.* Технологическая и техническая политика модернизации растениеводства Сибири // Сельскохозяйственные машины и технологии. 2014. № 4. С. 38–42.
5. *Клочков А.В.* Обоснование состава парка зерноуборочных комбайнов в Республике // Весці нацыянальной акадэміі навук Беларусі. 2010. № 4. С. 114–119.
6. *Астафьев В.Л., Голиков В.А.* Обоснование типажа зерноуборочных комбайнов и жаток, применяемых в регионах Казахстана // Сельскохозяйственные машины и технологии. 2018. Т. 12. № 4. С. 10–15. DOI:10.22314/2073-7599-2018-12-4-10-15.
7. *Машков С.В., Прокопенко В.А.* Методика расчета оптимального комбайнового парка предприятия // Никоновские чтения. 2016. № 21. С. 179–182.
8. *Чижов В.Н., Шеремет А.Н.* Пути решения проблемы комплектования и выбора сельскохозяйственной техники // Вестник Алтайского государственного аграрного университета. 2009. № 12 (62). С. 77–80.
9. *Ерохин Г.Н., Коновский В.В.* Влияние ширины захвата жатки на производительность зерноуборочного комбайна // Наука в Центральной России. 2020. № 2 (44). С. 35–42. DOI: 10.35887/2305-2538-2020-2-35-42.
10. *Чемоданов С.И., Патрин П.А., Патрин В.А., Сабашкин В.А.* Результаты очеса высоковлажной растительной массы пшеницы // Сибирский вестник сельскохозяйственной науки. 2019. Т. 49. № 6. С. 96–103. DOI: 10.26898/0370-8799-2019-6-11.

REFERENCES

1. Zhalnin E.V. System-analytical method of technical policy formation in the agro-industrial complex of the Russian Federation. *Traktory i sel'hozmashiny = Tractors and Agricultural Machinery,* 2012, no. 6, pp. 3–8. (In Russian).
2. Chepurin G.E. Methodology for selecting the type of machinery for grain harvesting, taking into account zonal features. *Vestnik Gosudarstvennogo agrarnogo universiteta Severnogo Zaural'ya = Bulletin of the Northern Trans-Ural State Agricultural University,* 2008, no. 2 (29), pp. 68–75. (In Russian).
3. Pronin V.M., Prokopenko V.A., Dobrynin Yu.M. Selection criteria for combine harvesters. *AgroSnabForum = AgroSnabForum,* 2016, no. 5 (144), pp. 20–22. (In Russian).
4. Dokin B.D., YOlkin O.V., Lapchenko E.A., Isakova S.P. Technological and technical policies to modernize crop production in Siberia. *Sel'skohozyajstvennye mashiny i tekhnologii = Agricultural machinery and technology,* 2014, no. 4, pp. 38–42. (In Russian).
5. Klochkov A.V. Justification of the composition of the grain harvester fleet in the Republic. *Vesci nacyyanal'noj akademii navuk Belarusi = Proceedings of the National Academy of Sciences of Belarus*, 2010, no. 4, pp. 114–119. (In Belarus).
6. Astaf'ev V.L., Golikov V.A. Justification of the type of combine harvesters and reapers used in the regions of Kazakhstan. *Sel'skohozyajstvennye mashiny i tekhnologii = Agricultural machinery and technology*, 2018, vol. 12, no. 4, pp. 10–15. (In Russian). DOI: 10.22314/2073-7599-2018-12-4-10-15.
7. Mashkov S.V., Prokopenko V.A. Methodology for calculating the optimum combine harvester fleet. *Nikonovskie chteniya = Nikon Readings*, 2016, no. 21, pp. 179–182. (In Russian).
8. Chizhov V.N., Sheremet A.N. Ways of solving the problem of agricultural machinery procurement and selection. *Vestnik Altajskogo gosudarstvennogo agrarnogo universiteta = Bulletin of Altai State Agricultural University*, 2009, no. 12 (62), pp. 77–80. (In Russian).

9. Erokhin G.N., Konovsky V.V. Impact of the width of the header on the productivity of the combine harvester. *Nauka v tsentralnoi Rossii = Science in the Central Russia,* 2020, no. 2 (44). pp. 35–42. (In Russian). DOI: 10.35887/2305-2538-2020-2-35-42.

10. Chemodanov S.I., Patrin P.A., Patrin V.A., Sabashkin V.A The results of stripping high-moisture wheat plant mass. *Sibirskij vestnik sel'skohozyajstvennoj nauki = Siberian Herald of Agricultural Science*, 2019, vol. 49, no. 6. pp. 96–103. (In Russian). DOI: 10.26898/0370-8799-2019-6-11.

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