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SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

УЧРЕДИТЕЛИ: СИБИРСКИЙ ФЕДЕРАЛЬНЫЙ НАУЧНЫЙ ЦЕНТР АГРОБИОТЕХНОЛОГИЙ РОССИЙСКОЙ АКАДЕМИИ НАУК
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ЭФФЕКТИВНОСТЬ ПРИМЕНЕНИЯ БИОПРЕПАРАТОВ И ФУНГИЦИДОВ ПРИ ВЫРАЩИВАНИИ ЯРОВОЙ ПШЕНИЦЫ В ЛЕСОСТЕПИ ПРИОБЬЯ

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Представлены данные по эффективности использования химических, грибных и бактериальных фунгицидов для обработки семян и посевов яровой мягкой пшеницы с целью ограничения вредоносности основных болезней. Исследования проведены в 2020–2022 гг. на черноземе выщелоченном лесостепи Приобья Новосибирской области. В борьбе с корневыми гнилями наиболее эффективным оказался химический протравитель Скарлет и его смесь с Витапланом. Показано, что биопрепараты хотя и уступают по эффективности химическим, но они действуют более длительно и дольше защищают растение от болезни. Протравливание семян химическим препаратом снизило развитие листовых болезней на 53–58%, биопрепаратами – на 34–41%. Из обработок по вегетации наиболее эффективным оказался Титул 390 – 60–98%. Эффективность биопрепаратов составила 42–64% в годы умеренного развития болезней. В годы сильного развития септориоза или мучнистой росы эффективность биопрепаратов не превышала 22–30%. Биопрепараты оказывали ростостимулирующее действие на растения: увеличивали площадь флагового листа на 22–39%. При обработке семян наблюдали тенденцию роста числа колосков, зерен в колосе и массы зерна с колоса. Применение препаратов по вегетации повышало достоверно длину колоса на 16–28%, число колосков – на 15–20, зерен – на 24–31, массу зерна с колоса – на 33–51%. При протравливании семян наибольшую прибавку урожайности (0,15 т/га) обеспечивал Скарлет, при использовании смеси биологического и химического препаратов она составила 0,11 т/га. При обработке по вегетации химический фунгицид повышал урожайность на 0,33 т/га, биопрепараты – на 0,11–0,14 т/га. Комплексное использование химических препаратов (Скарлет + Титул 390) обеспечило максимальную прибавку урожайности – 0,62 т/га, от совместного использования химического и биологического препарата урожайность повышалась на 0,15–0,33 т/га. Биологические препараты увеличивали этот показатель на 0,13–0,23 т/га. Сделан вывод о возможности подбора сочетаний химических и биологических препаратов, способных контролировать фитосанитарную ситуацию и обеспечивать приемлемую урожайность.

Ключевые слова: яровая пшеница, болезни, фунгициды, биопрепараты, эффективность, урожайность

EFFECTIVENESS OF THE USE OF BIOPREPARATIONS AND FUNGICIDES IN THE CULTIVATION OF SPRING WHEAT IN THE FOREST-STEPPE OF THE PRIOBYE

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The data on the effectiveness of using chemical, fungal and bacterial fungicides to treat seeds and crops of spring soft wheat in order to limit harmfulness of major diseases are presented. The research

was conducted in 2020–2022 on chernozem leached forest-steppe of the Novosibirsk region Priobye. Chemical seed protectant Scarlet and its mixture with Vitaplan were the most effective dressers in the fight against root rots. It has been demonstrated that although biopreparations are inferior in efficiency to chemical ones, they act for a longer period of time and protect the plant from the disease for a longer period of time. Seed dressing with chemical preparation reduced the development of leaf diseases by 53–58%, and with biopreparations – by 34–41%. Titul 390 was the most effective of the vegetation treatments – 60–98%. The efficiency of the biopreparations was 42–64% in the years of moderate disease development. In the years of strong development of septoriosis or powdery mildew, the efficiency of biopreparations did not exceed 22–30%. The biological preparations had a growth-stimulating effect on the plants: they increased the flag leaf area by 22–39%. The seed treatment showed an increasing trend in the number of spikelets, grains per ear and grain weight per ear. Application of the preparations during the vegetation period increased reliably the ear length by 16–28%, the number of spikelets – by 15–20, grains – by 24–31, grain weight per ear – by 33–51%. At seed dressing the greatest increase in the yield (0.15 t/ha) was provided by Scarlet, when using a mixture of biological and chemical preparations it amounted to 0.11 t/ha. When treated during the growing season, chemical fungicide increased the yield by 0.33 t/ha, while biopreparations increased the yield by 0.11–0.14 t/ha. Complex use of chemical preparations (Scarlet + Titul 390) provided the maximum yield increase – 0.62 t/ha, from the joint use of chemical and biological preparation the yield increased by 0.15–0.33 t/ha. The biological preparations increased this indicator by 0.13–0.23 t/ha. It has been concluded that it is possible to select combinations of chemical and biological preparations that can control phytosanitary situation and provide acceptable yield.

Keywords: spring wheat, diseases, fungicides, biopreparations, efficacy, yield

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INTRODUCTION

The development of ecologically oriented technologies of agricultural production requires a wide range of effective biopreparations. Unlike chemical ones, biopreparations allow to stabilize phytosanitary condition, reduce environmental pollution by pesticide residues, increase environmental sustainability of agrocenosis and soil fertility. The demand for biofungicides is indicated by a 3-fold increase in the number of registered formulations in Russia from 2005 to 2020 [1, 2].

Bacillus and *Pseudomonas* bacteria and *Trichoderma* fungi are commonly used as active agents in biofungicides. Protection of plants against diseases using bacterial-based biopreparations is a promising strategy that can become an alternative to some methods based on commonly used synthetic fungicides, therefore, it is the subject of intensive research [3, 4]. Bacterial antagonism to pathogens is based on three main types of interactions or their combinations: antibioticosis, competition for nutrients and space, and parasitism[1, 2] [5, 6]. Some bacteria can also enhance natural resistance and stimulate plant defense responses, including the production of reactive oxygen species, phytoalexins, phenolic compounds, pathogenesis-related proteins (PR

[1]*Raaijmakers J.M., Vlami M., De Souza J.T.* Antibiotic production by bacterial biocontrol agents // Antonie van leeuwenhoek. 2002, vol. 81 (1), pp. 537–547. DOI: 10.1023/A:1020501420831.

[2]*Compant S., Duffy B., Nowak J., Clément C., Barka E.A.* Use of plant growth-promoting bacteria for biocontrol of plant diseases: principles, mechanisms of action, and future prospects // Applied and Environmental Microbiology, 2005, vol. 71 (9), pp. 4951–4959. DOI: 10.1128/AEM.71.9.4951-4959.2005.

proteins), or the formation of physical barriers, e.g. in the epidermis[3].

Fungi of the genus *Trichoderma* are an important alternative in biocontrol of phytopathogens because they have similar mechanisms of action as bacteria: competition (water, air, light and nutrients); host-parasite association, which can be physical or metabolic with digestion by hydrolytic enzymes including chitinases, proteases, glucanases and lipases; antibioticosis[4, 5].

Trichoderma synthesizes rich hydrolase complexes and has high hyperparasitic and antagonistic activity against soil-borne phytopathogenic micro-mycetes and produces antibiotics gliotoxin, viridin, trichodermin, satsukcalin and other, which limit the viability of phytopathogens by disrupting protein and chitin biosynthesis. In the rhizosphere, trichoderma produces enzymes invertase, catalase, amylase, urease and other enzymes that activate photosynthesis and nutrient uptake by the plant. It also improves nitrogen utilization by stimulating bacteria of the genus Azotobacter and nodule bacteria. In addition, trichoderma is an active stubble degrader due to its powerful enzyme complex. Straw-degrading ability of trichoderma is very relevant, because the problem of utilization of the non-grain part of the crop has become more acute in recent years due to the introduction of minimum tillage and direct seeding technology. Accumulation of undecomposed straw increases the activity of phytopathogenic micromycetes, and the application of trichoderma makes it possible to solve this problem [3, 7].

The disadvantages of biopreparations include the dependence of efficiency on the level of disease development. Long-term studies have shown that while chemical fungicides always demonstrate high (82– 98%) efficacy against leaf infections, the efficacy of Bacillus subtilis-based preparations decreases from 88 to 38% when the level of disease development increases from 8 to 49%. At the same time, the yield increase in epiphytotic years from the use of chemical fungicides is 24%, biological fungicides – only 8% [8].

Analyzing the current state of application of biopreparations for optimization of phytosanitary situation and formation of environmentally safe plant protection systems, it should be noted that there is a certain reserve of positive results, but it is necessary to determine the conditions for their successful use. This emphasizes the relevance of testing biopreparations in specific soil and climatic conditions on the crops grown in the region.

The purpose of the research is to evaluate the possibility of using different methods of biopreparations application in wheat cultivation in the forest-steppe of Western Siberia.

The objectives of the research were to study the influence of seed treatment and application of Sternifag, as well as treatments during vegetation with chemical and biological preparations on phytosanitary condition and productivity of spring wheat crop.

MATERIAL AND METHODS

The research was conducted in 2020-2022 in a multifactorial field experiment on the fields of the SFSCA RAS station, located in the forest-steppe of the Priobie region, on leached chernozem of medium loamy composition. Novosibirskaya 31 wheat was sown in the experiment, which was placed as the second crop after fallow on grain forecrop. The main autumn no-tillage cultivation was carried out to a depth of 20 –22 cm. 90 kg a.i. nitrogen/ha and 30 kg a.i. phosphorus/ha were applied under pre-sowing cultivation. Further, pre-sowing cultivation was carried out with a cultivator "Stepnyak" to the depth of seed embedment. Sowing was carried out in the beginning of the III ten-day period of May by the seeder SZS 2.1 with anchor coulters with a seeding rate of 6 million germinating grains/ha.

[3] *Wiesel L., Newton A.C., Elliott I., Booty D., Gilroy E.M., Birch P.R.J., Hein I.* Molecular effects of resistance elicitors from biological origin and their potential for crop protection // Frontiers in Plant Science, 2014, vol. 5, p. 655. DOI: 10.3389/fpls.2014.00655.

[4] *Machado D.F.M., Parzianello F.R., Silva A.C.F., Antoniolli Z.I.* Trichoderma in Brazil: the fungus and the bioagent // Journal of Agricultural Sciences, 2012, vol. 35 (1), pp. 274–288.

[5] *Woo S.L., Ruocco M., Vinale F., Nigro M., Marra R., Lombardi N., Pascale A., Lanzuise S., Manganiello G., Lorito M.* Trichoderma-based products and their widespread use in agriculture // The Open Mycology Journal, 2014, vol. 8, pp. 71–126. DOI: 10.2174/1874437001408010071.

The following factors were studied in the experiment:

1. Factor A - seed treatment:

– control (without treatment);

– Trichocin, WP (20 g/t) + Vitaplan, WP (20 g/t);

– Scarlet, ME (0.2 l/t) + Vitaplan, WP (20 g/t);

– Scarlet, ME (0,4 l/t).

2. Factor B - fungicide treatment during vegetation and regulation of crop residue decay. Variants of these factors were superimposed over variants A to obtain a combination of all the studied factors:

– control (without treatment);

– Titul 390, CSC (0,26 l/ha) in the phase flag leaf – beginning of earing;

– Alirin B, L at tillering (2.0 l/ha) + Vitaplan, WP – flag leaf – beginning of earing (40 g/ha);

– Alirin B, L at tillering (2.0 l/ha) + Trichocin, WP – flag leaf – beginning of earing (40 g/ha);

– Sternifag, WP pre-sowing stubble spraying (80 g/ha) + Alirin B, L at tillering (2.0 l/ha) + Vitaplan, WP – flag leaf – beginning of earing (40 g/ha);

– Sternifag, WP pre-sowing stubble spraying (80 g/ha) + Alirin B, L at tillering (2.0 l/ha) + Trichocin, WP – flag leaf – beginning of earing (40 g/ha).

Treatment was carried out with moistening of the seeds, consumption of the working solution - 10 l/t. The area of the experimental plot was 24 m^2, the area of the plot with each dressing agent was 432 m^2. Treatment of the plots with Sternifag, WP (80 g/ha) was carried out by hand sprayer, working solution consumption was 200 l/ha, treatment area - 576 m^2. The area of the fungicide treatment variant was 288 m^2. In tillering phase spring wheat was treated against weeds with tank mixture of herbicides Axial, EC (1.0 l/ha) + Primadonna, SE (0.4 l/ha) + Hextar, WDG (10 g/ha) by tractor sprayer with a working solution consumption of 270 l/ha.

The efficacy of the following preparations was studied: Scarlet, ME (imazalil (100 g/l) + tebuconazole (60 g/l)), Titul 390, CSC (propiconazole (390 g/l)), Alirin B, L (*B. subtilis*) strain B - 10 VIZR, titer not less than 1×10^9 CFU/ml, Vitaplan, WP (*B. subtilis*), strain VKM - B - 2604D titer 1×10^{10} CFU/g + (*B. subtilis*), strain VKM - B - 2605D titer 1×10^{10} CFU/ml, Vitaplan, WP (*B. subtilis*), strain VKM - B - 2604D titer 1×10^{10} CFU/g + (*B. subtilis*), strain VKM - B - 2605D titer 1×10^{10} CFU/g, Trichocin, WP (*T. harzianum*), strain G-30, titer 1×10^{10} CFU/g, Sternifag, WP (*T. harzianum*), strain VK - 4099D, titer 1×10^{10} CFU/g.

Records and observations in the experiments were carried out according to generally accepted methods. The effect of preparations on the flag leaf area [9], ear structure, grain size[6] was studied. The development of common root rot on plants was recorded in the phases of wheat tillering and milk-wax ripeness of grain differentiated by organs[7], the assessment of crop damage by leaf-stalk infections (brown rust, septoriosis, powdery mildew) - in the phase of grain filling[8]. Wheat yield was counted by direct harvesting, seed yield was brought to 100% purity and 14% moisture content. Mathematical processing of data was carried out using the Snedecor application program package[9].

Weather conditions during the study period differed significantly. In 2020, according to meteorological indicators, the growing season was characterized by increased heat supply and sufficient moisture content. The sum of precipitation for the growing season amounted to 245 mm. At the beginning of the vegetation period the distribution of precipitation was uneven. In May precipitation was 1.5 times more, in June it was 34 mm less than the norm. Later precipitation was evenly distributed and was similar to mean annual values. Mean daily air temperatures

[6] *Eshchenko V.E., Trifonova M.F., Kopytko P.G.* Fundamentals of experimental work in crop production. Moscow: KolosS, 2009, 268 p.

[7] *Chulkina V.A., Toropova E.Y., Stetsov G.Y., Marmuleva E.Y., Kirichenko A.A., Grishin V.M.* Phytosanitary diagnostics of agroecosystems: textbook. Novosibirsk, 2010, 127 p.

[8] *Sanin S.S., Sokolova E.A., Cherkashin V.I.* Diseases of grain crops (recommendations for phytosanitary monitoring). Moscow: Rosinformagroteh, 2010, 137 p.

[9] *Sorokin O.D.* Applied statistics on the computer; 2nd ed., Novosibirsk, 2012, 282 p.

were 15.5; 16.6; 19.6 and 18.6 °C, respectively. In 2021, the air temperature was close to mean annual values, in May, June, July and August it was 14.3; 16.2; 19.6 and 18.1 °C, respectively.

Precipitation during the vegetation period was 1.2 times less, and its distribution was extremely uneven. In May and July precipitation was 1.5 and 3.3 times less than the norm, in June and August it was close to the average annual values.

Meteodata of the growing season 2022 were characterized by lack of precipitation and increased temperature in May by 5.1 °C, further the temperature regime was satisfactory. However, in general, weather conditions were unfavorable for plant growth and development due to the deficit of precipitation: 2.5 mm fell in May, 59 mm in June, 29 mm in July, and 23 mm in August. During the vegetation period the atmospheric moisture inflow was 2 times lower than the norm.

RESULTS AND DISCUSSION

In all 3 years of research the level of root rot development was low, in the tillering phase it was only 4.0 –5.2%. The highest efficiency in all 3 years was possessed by chemical protectant Scarlet (58 –64%) and its mixture with Vitaplan (26 –57%). The mixture of biological preparations reduced the development of the disease more weakly (4-61%), the application of Sternifag only in 2021 reduced the disease by 52%, in the other 2 years had no effect on it. By the phase of milk-wax ripeness, the disease development index increased to 13-17%. In this phase, the most effective was the mixture Scarlet + Vitaplan (38 –71%), higher than Scarlet alone (31 –67%). The application of Sterniphag and the use of biopreparations alone reduced the level of the disease development by less than half (see Table 1). Thus, in the early phases of plant development, biopreparations are inferior in efficiency to the chemical ones, but they act longer and protect the plant from this disease for a longer period of time.

Phytosanitary situation with regard to leaf diseases was different. All major diseases – septoriosis, powdery mildew, rust – were detected in the crops, but their development differed by years. In 2020 and 2022, when septoriosis development was moderate (15.4 –17.8%), seed dressing reduced disease development: Scarlet by 53-58%, biopreparations by 34 – 41%. In 2021, when septoriosis developed more strongly (33.1%), the effectiveness of the preparations was significantly lower. A similar pattern was observed for powdery mildew: in 2022 (the year of the greatest development of the disease – 16.7%) the efficiency of preparations amounted to only 23-34%, in other years – 52 – 73% (see Table 2). Similar results of the decrease in the efficiency of biopreparations with the growth of infection load in seed dressing were also noted by other researchers [10]. This dependence of efficiency on the level of disease development narrows the possibilities of using biopreparations

Табл. 1. Влияние внесения Стернифага, СП в почву и протравливания семян на развитие корневой гнили в посеве яровой пшеницы (2020–2022 гг.), %

Table 1. Effect of application of Sternifag, WP in soil and seed dressing on root rot development in spring wheat crop (2020–2022), %

Option	Disease progression index					
	Wheat tillering			Milk-wax ripeness of grain		
	2020	2021	2022	2020	2021	2022
Control	5,1	5,2	4,02	15,8	13,4	17,0
Sternifag	5,3	2,5*	4,3	8,2*	9,2*	8,7*
Trichocin + Vitaplan	4,9	2,0*	3,3	7,1*	9,2*	9,5*
Scarlet + Vitaplan	2,4*	2,2*	3,0	7,6*	8,3*	4,9*
Scarlet	1,8*	1,9*	1,7*	7,9*	9,2*	5,5*

Note. Here and in Tables 2, 3: * - variants are significantly different from the control at the p_{05} level by the *U* - Mann-Whitney test.

(unlike chemical ones) and requires a differentiated approach to application taking into account the level of disease development.

The most effective chemical preparation Titul 390 was expected to be 60–84% against septoriosis, 80-93% against powdery mildew, 85–98% against rust. The efficiency of the application of biopreparations during vegetation and application of Sternifag against septoriosis was low in all the years of research and did not exceed 30% regardless of the level of the disease development. In the years of moderate development (2020-2021), Alirin B, L + Trichocin was most effective against powdery mildew – 42–54%. In the year of the greatest development of powdery mildew (2022), the efficiency of all preparations did not exceed 22%. Brown rust developed poorly in all 3 years of research. Alirin B, L + Trichocin (48–64%) was also most effective against it. Their application against Sternifag did not increase the efficiency of the biopreparations against rust (see Table 3).

In general, the growth-stimulating effect of the studied preparations on wheat plants can be noted (see Table 4).

Significant increase in flag leaf area was observed in 2020 and 2022, in 2021 it appeared as a trend. On average for 3 years, a large leaf area was formed when using a mixture of biopreparations Trichocin + Vitaplan, when applied during the growing season – Titul 390 and Alirin B, L + Trichocin on the background of Sternifag. It should be noted that on the background of Sternifag both treatments with biopreparations gave slightly better results. Only Scarlet + Vitaplan seed treatment significantly increased plant height, while Scarlet treatment only increased plant biomass, although the tendency to increase these indicators was observed in all the variants of the experiment.

The applied treatments also influenced the structural indicators of ear productivity. Seed

Табл. 2. Влияние обработки семян биопрепаратами и химическим протравителем на развитие болезней на флаг-листе (2020–2022 гг.), %

Table 2. Effect of seed treatment with biopreparations and chemical seed dressing on disease development on flag leaf (2020–2022), %

Option	Septoriose			Powdery mildew			Brown rust		
	2020	2021	2022	2020	2021	2022	2020	2021	2022
Control	17,8	33,1	15,4	6,9	4,6	16,7	6,1	3,3	0,9
Trichocin + Vitaplan	11,3*	30,9	7,7*	2,6*	2,2*	12,8*	1,6*	1,7	1,3
Scarlet + Vitaplan	11,7*	33,1	9,0*	2,1*	1,7*	10,9*	3,3	0,7*	0,5
Scarlet	8,2*	27,8	6,5*	2,8	1,2*	20,7	2,9*	1,9	1,7*

Табл. 3. Влияние обработок биопрепаратами по вегетации и внесения Стернифага, СП на развитие болезней (2020–2022 гг.), %

Table 3. Effect of treatments with biopreparations during vegetation and application of Sternifag, WP on disease development (2020–2022), %

Option	Septoriose			Powdery mildew			Brown rust		
	2020	2021	2022	2020	2021	2022	2020	2021	2022
Control	17,8	33,1	15,4	6,9	4,6	16,7	6,1	3,3	0,9
Titul 390	7,1*	5,2*	4,2*	1,3*	0,3*	3,2*	0,9*	0,2*	0,1
Alirin B, L + Vitaplan	12,9	32,1	15,8	9,4	2,6*	13,2	2,8*	2,0	0,5
Alirin B, L + Trichocin	18,4	26,2	12,1	4,0*	2,1*	13,0	2,2*	1,7	0,5
Sternifag + Alirin B, L + Vitaplan	19,6	29,9	10,9*	4,4*	2,7*	15,8	5,0	2,7	2,2
Sternifag + Alirin B, L + Trichocin	12,6	23,9*	12,4	6,0	2,7*	24,1	3,9	2,6	0,7

Табл. 4. Влияние протравливания и обработок по вегетации на биометрические показатели в период цветения пшеницы (среднее за 2020–2022 гг.)

Table 4. Effect of dressing and vegetation treatments on biometric parameters during wheat flowering (average for 2020–2022)

Option	Flag leaf area, cm^2	Plant height, cm	Air-dry weight of 25 plants, g
Control	12,0	79,8	33,7
Trichocin + Vitaplan	16,7	83,7	38,2
Scarlet + Vitaplan	15,2	85,0	41,7
Scarlet	15,9	83,3	44,1
Titul 390	15,1	81,8	42,7
Alirin B, L + Vitaplan	14,6	82,8	41,2
Alirin B, L + Trichocin	14,7	82,5	37,8
Sternifag + Alirin B, L + Vitaplan	14,8	82,0	36,0
Sternifag + Alirin B, L + Trichocin	15,4	82,3	39,8
LSD_{05}	1,8	7,9	9,3

dressing significantly increased ear length in the variants Scarlet + Vitaplan and Scarlet by 11.4%. When using a mixture of the biological dressing agent Vitaplan + Trichocin, an increase in this indicator by 7.8% was observed. In case of seed treatment, the number of grains in an ear increased on average for 3 years by 16.3-18.9%, the number of spikelets – by 8.9-10.1%, grain weight per ear – by 22.2-28.9%, but these differences are not reliable. Application of the preparations during the vegetation period increased almost all indicators reliably, spikelet length – by 16-28%, number of spikelets – by 15 –20%, grains – by 24-31%, grain weight per spikelet – by 33 –51% (see Table 5).

For 3 years, pre-sowing seed treatment significantly increased the yield of spring wheat on average by 0.08–0.23 t/ha (see Table 6). The greatest increase in the yield was noted at application of chemical mordant Scarlet (0.15 t/ha), at joint use of chemical preparation Scarlet with biological Vitaplan the increase was slightly lower (0.11 t/ha), at biological preparations it amounted to 0.1 t/ha. Chemical fungicide Titul 390 was the most effective among the treatments during vegetation (average factor): the yield increased by 0.33 t/ha. When applying biological preparations, this indicator was at the level of 0.11 –0.14 t/ha, on the background of Sternifag a slight decrease in the yield gain was observed. Complex use of chemical preparations (Scarlet + Titul) provided the maximum yield gain of 0.62 t/ha, from the combined use of chemical and biological preparations the yield increased by 0.17 –0.34 t/ha. Biological preparations increased this indicator by 0.13 –0.23 t/ha.

CONCLUSION

The study of the efficiency of biopreparations application revealed some peculiarities of their action. At the end of vegetation all seed treatment methods approximately equally reduced the development of root rot. At strong (33%) development of septoriosis neither chemical nor biological dressing agents reduced the development of this disease. Treatments during vegetation (except for fungicide Titul 390, CSC) also weakly reduced the disease incidence in plants. At the same time, it was confirmed that the higher the development of the disease, the lower the effectiveness of the biopreparations. Joint application of two chemical preparations provided yield growth by 0.62 t/ha, the best combinations of biopreparations - by 0.33 t/ha. Biopreparations demonstrate lower biological efficiency compared to the chemical ones, but such combinations of synthetic and microbiological fungicides can be selected, which will ensure phytosanitary condition of crops and yield at the

Табл. 5. Влияние обработок на структурные показатели продуктивности колоса
Table 5. Effect of treatments on structural indicators of ear productivity

Option	Spike length, cm	Number of spikelets	Number of grains	Grain weight per spike, g
Average for 2020–2022				
Control	8,5	14,6	30,1	0,90
Trichocin + Vitaplan	9,2	15,9	35,0	1,10
Scarlet + Vitaplan	9,5	16,0	35,2	1,11
Scarlet	9,5	16,1	35,8	1,16
LSD_{05}	0,94	1,88	7,5	0,29
Average for 2021–2022				
Control	8,1	13,6	29,6	0,90
Titul 390	9,7	16,4	38,7	1,31
Alirin B, L + Vitaplan	9,5	15,9	37,5	1,21
Alirin B, L + Trichocin	9,5	15,7	38,6	1,26
Sternifag + Alirin B, L + Vitaplan	10,4	16,3	39,7	1,36
Sternifag + Alirin B, L + Trichocin	9,4	15,9	36,8	1,21
LSD_{05}	1,44	1,98	7,0	0,27

Табл. 6. Влияние протравливания семян и обработок по вегетации на урожайность пшеницы (среднее за 2020–2022 гг.), т/га
Table 6. Effect of seed dressing and vegetation treatments on wheat yield (average for 2020–2022), t/ha

Seed treatment factor A	Vegetation treatment, factor B						
	Control	Titul 390	Alirin B, L + Vitaplan	Alirin B, L + Trichocin	Sternifag + Alirin B, L + Vitaplan	Sternifag + Alirin B, L + Trichocin	Average for factor A
Control	2,26	2,51	2,37	2,35	2,39	2,44	2,38
Trichocin + Vitaplan	2,36	2,70	2,39	2,45	2,40	2,49	2,46
Scarlet + Vitaplan	2,37	2,63	2,59	2,54	2,48	2,41	2,50
Scarlet	2,41	2,88	2,61	2,62	2,57	2,59	2,61
Average for factor B	2,35	2,68	2,49	2,49	2,46	2,48	
LSD_{05}	For factor A = 0,05, B = 0,06, partial averages = 0,14						

required level. Application of biopreparations should have a certain role in the system of improvement of phytosanitary condition of soft spring wheat crops.

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ВЛИЯНИЕ КУЛЬТУРАЛЬНЫХ ФИЛЬТРАТОВ ГРИБОВ РОДА *FUSARIUM* НА КАЛЛУСНЫЕ КУЛЬТУРЫ ОВСА

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Проведена оценка влияния трех концентраций (30, 40 и 50%) культурального фильтрата (КФ) грибов рода *Fusarium* (*F. sporotrichioides*, *F. poae*, *F. equiseti*, *F. oxysporum*) на параметры роста и развитие каллусной культуры овса. Использовали КФ на этапе пролиферации каллусов для отбора сомаклональных клеточных линий с признаками толерантности к микотоксинам. Индукцию каллусогенеза перед этим проводили на среде Мурасиге – Скуга (МС) с 3 мг/л 2,4-Д и 2 мг/л ИУК в культуре незрелых зародышей сортов Тюменский голозерный, Тубинский, Золотой початок и Талисман. Материал для эксперимента отобран из колосьев растений, выращенных в летний период 2016–2018 гг. на опытных полях в Красноярской лесостепи. При пересадке на среды пролиферации (МС + 1,5 мг/л 2,4-Д), контрольной и содержащей КФ, фиксировали размер каллусов. По истечении 30 дней культивирования отмечали прирост каллусов, признаки некроза и органогенеза. По окончании эксперимента подсчитывали число сформировавшихся регенерантов. Присутствие КФ в среде пролиферации уже в концентрации 40% обеспечивало снижение пролиферативной активности и увеличивало частоту некроза не менее, чем на 50%. Аналогичные результаты получены при уровне КФ 50%. На средах с КФ *F. poae* снижение жизнеспособности каллусов достигало 60–70%. Каллусы, сохранившие жизнеспособность в этих условиях, имели частоту формирования регенерантов и органогенеза в 2–3 раза выше, чем образцы, не подвергшиеся влиянию селективного фактора. Особенно это выражено при добавлении КФ *F. sporotrichioides*. Данный эффект не наблюдался при внесении КФ *F. oxysporum*. Это может быть связано с отличиями в составе комплекса микотоксинов данного вида грибов от остальных, использованных в исследовании. Для дальнейшей работы над технологией создания форм овса с устойчивостью к микотоксинам грибов рода *Fusarium* предполагается использовать уровень селективного давления не ниже 40%.

Ключевые слова: овес, клеточная селекция, *Fusarium,* культуральный фильтрат

EFFECT OF CULTURE FILTRATES OF *FUSARIUM* FUNGI ON OAT CALLUS CULTURES

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The effect of three concentrations (30, 40 and 50%) of the culture filtrate (CF) of the genus *Fusarium* fungi (*F. sporotrichioides*, *F. poae*, *F. equiseti*, *F. oxysporum*) on the growth and development parameters of oat callus culture was evaluated. CF at the callus proliferation stage was used to select somaclonal cell lines with mycotoxin tolerance traits. Prior to this, callusogenesis induction was car-

ried out on the Murashige-Skoog (MS) medium with 3 mg/l 2,4-D and 2 mg/l UIC in the culture of immature embryos of the Tyumensky Golozerny, Tubinsky, Zolotoy Pochatok and Talisman varieties. The material for the experiment was selected from the ears of the plants grown in the summer period of 2016–2018 on the experimental fields in the Krasnoyarsk forest-steppe. Callus size was recorded when transplanted onto the proliferation media (MS + 1.5 mg/l 2,4-D), control and CF-containing media. After 30 days of cultivation, callus growth, signs of necrosis and organogenesis were noted. At the end of the experiment, the number of the regenerants formed was counted. The presence of CF in the proliferation medium already at a concentration of 40% provided a decrease in the proliferative activity and increased the frequency of necrosis by at least 50%. Similar results were obtained at the CF level of 50%. On the media with *F. poae* CF, the reduction of callus viability reached 60–70%. The calluses that remained viable under these conditions had a frequency of regenerant formation and organogenesis 2–3 times higher than the samples that were not influenced by the selective factor. This is particularly pronounced when *F. sporotrichioides* CF is added. However, this effect was not observed when *F. oxysporum* CF was applied. This may be due to the differences in the composition of the mycotoxin complex of this mushroom species from the others used in the study. For further work on the technology of creating oat forms with resistance to mycotoxins of the *Fusarium* genus fungi, it is assumed to use a level of selective pressure not lower than 40%.

Keywords: oat, cell selection, *Fusarium*, culture filtrate

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INTRODUCTION

Mycotoxins synthesized by fungi of the genus Fusarium play an important role in the pathogenesis of fusariosis in cereal crops, in particular, they determine the virulence of the pathogen. This is confirmed by the low virulence of mutant strains with toxicity gene deficiency (*Tox minus*) [1]. Similarly, a correlation was shown between DON synthesis and virulence of *F. graminearum* [2] and *F. culmorum* [3]. Oats, due to the peculiarities of their anatomy, are quite resistant to colonization by phytopathogens (there is no spread of fungal hyphae through vascular tissues). As a consequence, the main source of infection is external inoculation, the main types of resistance are tolerance and ability to accumulate and/or degrade mycotoxins (types IV and V)[1]. It is believed that these types of resistance are based on cellular mechanisms [4].

In this regard, cell selection is a potentially successful method of selecting lines tolerant to mycotoxins. However, most research on fusariosis of cereal crops is conducted on wheat and barley. There is experience in increasing crop resistance to various phytopathogens through *in vitro* selection: wheat to *F. graminearum* and *F. culmorum* (culture filtrate (CF) and double-layer cultivation method); pineapple to *F. subglutinans* (CF); asparagus and chickpea to *F. oxysporum*, *F. proliferatum* (CF); barley to *Helminthosporium sativum* (medium with toxins); soybean to *F. solani* (CF)[2]. In combination with dihaploid cul-

[1] *Wang Y.Z., Miller J.D.* Effects of *Fusarium graminearum* metabolites on wheat tissue in relation to FHB resistance // Journal of Phytopathology, 1988, vol. 122, pp. 118–125.

[2] *Švábová L., Lebeda A.* In Vitro Selection for Improved Plant Resistance to Toxin-Producing Pathogens // Journal of Phytopathology, 2005, vol. 153, pp. 52–64. DOI: 10.1111/j.1439-0434.2004.00928.x.

ture, *in vitro* selection allowed to obtain several wheat and barley varieties tolerant to trichothecene producers in the early 2000s [5].

There are almost no similar works on oat breeding. This is due to the greater importance of wheat and barley in the food structure, as well as to the asymptomatic nature of fusariosis in oats, which resulted in its widespread cultivation without taking into account the sensitivity of varieties to fusariosis [6]. In the 2000s, a large number of data on high grain infestation forced researchers to pay attention to the need to improve the resistance of this crop to micromycetes of the genus Fusarium [7].

At present, interest in the creation of new forms of cereals through the mechanisms of somaclonal variability in tissue culture under selective exposure to CF or trichothecene compounds is again increasing. Wheat regenerants obtained in this way are undergoing field trials in the framework of governmental productivity improvement programs in Canada[3].

The first step in the development of technology for obtaining such forms of cereals is the selection of concentrations of selective agent (CF), providing a sufficient level of pressure to select cell lines tolerant to the toxins of the micromycete.

The purpose of the study was to determine the response of callus cultures of spring oat to different levels of CF regional isolates of fungi of the genus *Fusarium*.

MATERIAL AND METHODS

Spring oat varieties Tyumensky Holozerny, Tubinsky, Zolotoy Pochatok and Talisman were used as donor genotypes in this work.

Immature embryos for initiation of callus culture were selected at the Z-75 phase (milk-wax ripeness)[4] from the ears of plants grown in the summer of 2016-2018 in the experimental fields located in the central part of the Krasnoyarsk forest-steppe region.

Oat embryos were placed on agarized Murashige-Skoog medium (MS) containing 3 mg/l 2,4-D and 2 mg/l IAA (indole acetic acid). Calluses formed under these conditions were passaged on the proliferation media of the same composition, but with 2-fold reduced concentration of 2,4-D. In addition to the control medium, the media containing CFs of *Fusarium* fungi (*F. sporotrichioides, F. poae, F. equiseti, F. oxysporum*) at concentrations of 30, 40 and 50% (volume/volume) were used. 30-60 calluses were placed on each medium variant depending on the frequency of callus formation and culture contamination at the stage of callusogenesis induction. The experiments were performed in three biological repetitions (N = 90-180). After 30 days, calluses without signs of morphogenesis were passivated to regeneration medium (MS + 0.5 mg/l IAA + 1 mg/l kinetin). Specimens that formed stems were transferred to rooting medium (MS + 6 mg/l IAA + 0.1 mg/l kinetin) and acclimatized according to the method[5]. Callus cultures were cultured under artificial light (white light, 3500 lx), light regime of 14 h/10 h day/night and temperature of 22-25 °C. Fully formed regenerants were planted in the conditions of the light culture hall to obtain seed progeny.

During passivation of calluses to a new medium, their linear size was determined. At the end of the proliferation stage, callus sizes were recorded, the number of specimens without signs of necrosis (darkening of tissues, orange coloration of the medium around the callus) and the number of calluses with stem genesis were counted. The number of regenerants formed was recorded at each stage of cultivation and the total result was counted.

Statistical data processing was performed using the statistical package R 4.0.4 in the RStudio 1.4.1103 development environment (2009-2021 RStudio, PBC). Conformity of the data distribution on callus growth to normal was evaluated

[3]*Ryabova D., Randhawa H.S., Kathiria P., Jiang F., Spaner D., Hucl P., Graf R., Eudes F., Foroud N.A.* Development of new wheat varieties resistant to FHB through microspore *in vitro* selection technology // National Fusarium Head Blight Forum: proceedings. (St. Louis MO, United States, December 4–6 2016). St. Louis MO, 2016, p. 92.

[4]*Zadoks J.C., Chang T.T., Konzak C.F.* A decimal code for the growth stages of cereals // Weed Research, 1974, vol. 14, pp. 415–421. DOI: 10.1111/j.1365-3180.1974.tb01084.x.

[5]Patent No. 2754733, A01H 4/00 "Method of rooting and adaptation of shoots of bare-grained and filmy oats and wheat, obtained in *in vitro* culture, in aseptic conditions on slant agar" (Russian Federation) / S.Y. Lugovtsova, V.Y. Stupko, N.V. Zobova; filed. 24.08.2020; published 06.09.2021; Bulletin No. 25.

by the Shapiro-Wilk test. Reliability of the effect of the level of CF in the medium on callus growth was determined using the Kraskell-Wallis test. Data on the graphs represent median values (Me), bars represent the interquartile range of values [25%/75%]. Mann-Whitney test with Holm-Bonferroni correction was used as a posteriori analysis. To determine the statistical significance of the differences in the frequency of morphogenesis traits, as well as the proportion of viable callus between the media with different levels and types of CF, the Fisher's exact test for bipolar tables with the Holm-Bonferroni correction for multiple pairwise comparisons was calculated.

RESULTS AND DISCUSSION

At the proliferation stage, the presence of CF in the medium at any of the concentrations used in the experiment statistically significantly reduced the proportion of viable calluses relative to the results obtained on the control medium (see Fig. 1). At the same time, no differences in the frequency of callus necrosis were detected between the media with 40 and 50% CF regardless of the micromycete species used.

According to the data of callus volume growth on the media with different levels of CF, starting from 40%, proliferative activity was almost absent, and by the end of this stage, the overwhelming part of callus had the sizes not differing from those recorded at its beginning (see Fig. 2).

Against the background of decreased proliferative activity on the media with CF, an increase in the frequency of stem genesis in the callus mass was observed when it was cultured on all selective media, except for the variant with *F. oxysporum* (see Fig. 3, *а*).

When comparing the data obtained at the same concentration of CF, but using different species of micromycetes, the maximum decrease in callus viability was observed on the media with 30 and 40% CF of *F. poae* (see the Table). *F. poae* is the dominant species in the complex of pathogens causing oat fusariosis [7]. *F. sporotrichioides* infestation is also quite common. On the media with *F. sporotrichioides* CF, the max-

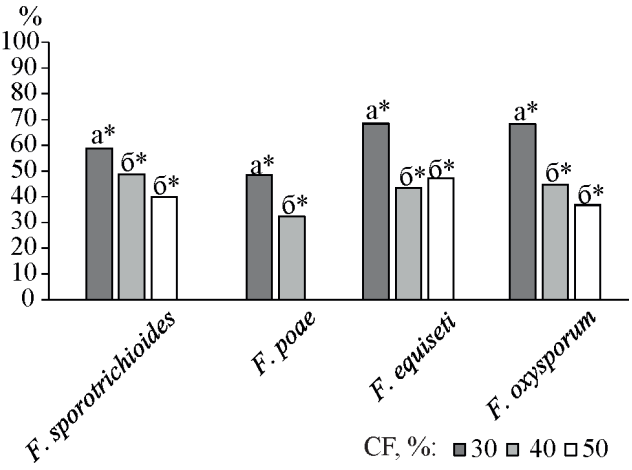

Рис. 1. Доля каллусов, сохранивших жизнеспособность при различном уровне КФ четырех видов грибов рода *Fusarium* в среде пролиферации (% относительно контроля)
Здесь и на рис. 2, 3 одинаковыми буквами отмечены значения, не различающиеся в пределах одного вида использованного микромицета при $p < 0,05$; * статистически значимое отличие от контрольных условий при $p < 0,05$

Fig. 1. The fraction of the calluses that remained viable at different levels of CF of four species of *Fusarium* fungi in the proliferation medium (% relative to the control)
Here and further on fig. 2, 3: the same letters indicate values that do not differ within one type of the micromycete used at $p < 0.05$; *statistically significant difference from control conditions at $p < 0.05$

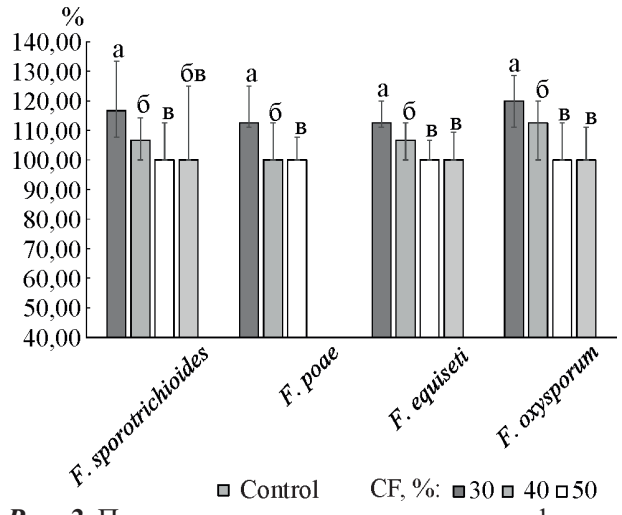

Рис. 2. Прирост каллусов на средах пролиферации, содержащих КФ грибов рода *Fusarium* в различной концентрации (% относительно размера при пассировании на среду пролиферации) (медиана ± [25/75])

Fig. 2. The volume gain of the calluses on the proliferation media containing CF of *Fusarium* fungi at various concentrations (% relative to the initial size) (median ± [25/75])

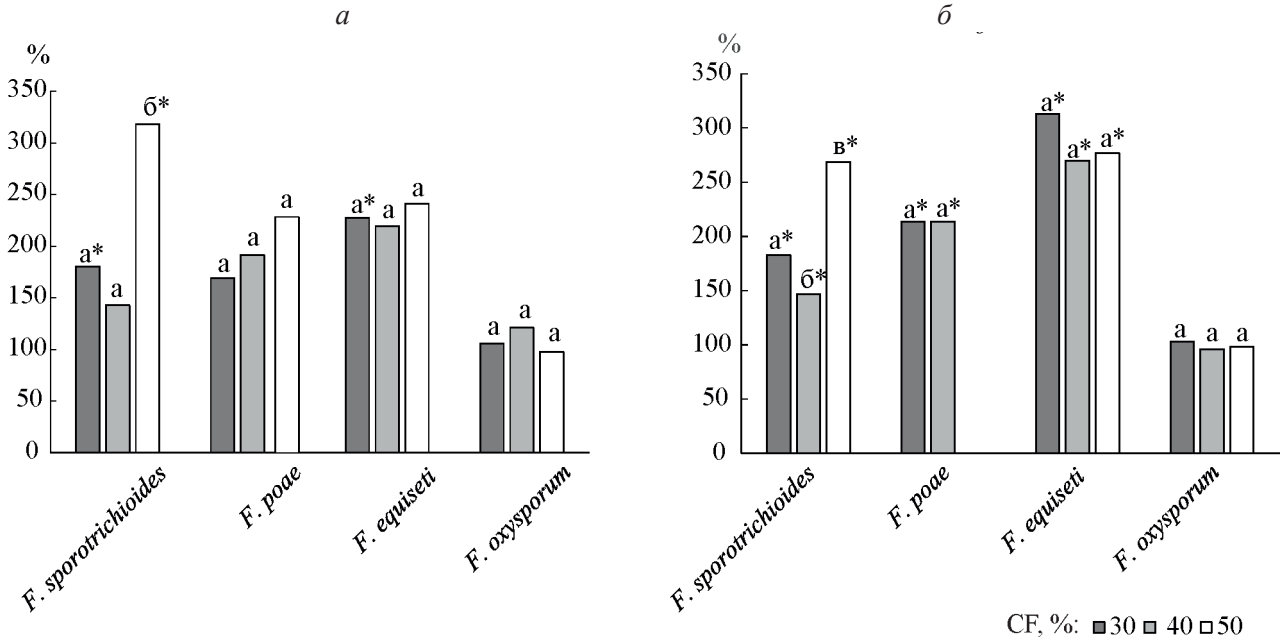

Рис. 3. Частота формирования стеблей (*а*) и регенерантов (*б*) в каллусной культуре овса на средах с КФ грибов рода *Fusarium* (% относительно значений, полученных на контрольной среде)

Fig. 3. The frequency of stem (*а*) and regenerant (*б*) formation in oat callus culture on the media with CF of *Fusarium* fungi (% relative to the values obtained on the control medium)

imum values of stem genesis frequency were observed at all the investigated stressor levels (see the Table). The least toxic for callus cells was the level of 30% CF *F. equiseti*. The isolate of this micromycete was isolated from the oat grain grown in the experimental fields of the Krasnoyarsk Research Institute of Agriculture. However, according to the data of O.P. Gavrilova et al [7], this species is quite rare when analyzing the infestation of grain of this crop in the Siberian Federal District.

Regeneration activity did not decrease below the values of the control medium in any of the medium variants with CF (see Fig. 3, a). There are several probable reasons for such a frequency of organogenesis, for example, the presence in CF synthesized by fungi of the genus *Fusarium* auxins and cytokinins that regulate tissue differentiation and growth of plant organs [8]. When using CF in work, these compounds, according to the researchers[6], may have a stimulating effect on regeneration in wheat callus culture. A similar effect is shown for fusaric acid, which played the role of a regeneration inducer in the work on in vitro selection of *Cucurbita pepo* ssp. *pepo* var. *styriaca* for resistance to fusariosis [9]. The authors attribute this effect to the influence of fusaric acid on ethylene synthesis, which can cause an increase in the DNA content and inhibition of cytokinins. As a result, a decrease in ethylene concentration leads to explosive cell division. The above works refer to "low concentrations" of selective agents. However, judging by the reduction of proliferative activity to almost zero (see Fig. 2) and the frequency of callus necrosis close to 50% (see Fig. 1), the level of 30% CF in the medium can be considered insufficient (low) in the current study.

The increase in the frequency of regeneration in the culture of isolated oat tissues *in vitro* under the action of stress factors is known and used to increase the yield of regenerants [10]. However, there is a possibility that calluses with low regeneration activity were more sensitive to the action of the stressor and underwent necrosis. In favor of the latter is evidenced by the fact that the samples that underwent such selection further demonstrated a high ability to form full-

[6]*Shayakhmetova I.F., Asfandiyarova P.P.* Phytotoxicity of the culture filtrate of *Fusarium oxysporum* Shlecht. to callus tissue of wheat // Mycology and Phytopathology, 1991, N 4 (25), pp. 343-347.

Влияние вида микромицетов рода *Fusarium* на жизнеспособность и регенерационную активность каллусов овса
Influence of the *Fusarium* genus micromycete species on viability and regeneration activity of oat calluses

CF concentration, %	*F. sporotrichioides*	*F. poae*	*F. equiseti*	*F. oxysporum*
		Percentage of calluses that remained viable		
30	0,47^{аб}	0,42^{а}	0,65^{в}	0,57^{бв}
40	0,39^{а}	0,28^{б}	0,41^{а}	0,37^{аб}
50	0,32^{аб}	–	0,44^{а}	0,31^{б}
		Incidence of stem genesis		
30	0,53^{а}	0,29^{бв}	0,28^{в}	0,34^{в}
40	0,42^{а}	0,32^{а}	0,27^{а}	0,38^{а}
50	0,94^{а}	–	0,30^{б}	0,31^{б}

Note. Identical letters indicate values that do not differ within the same CF concentration at $p < 0,05$.

grown regenerant plants (see Fig. 3, *б*). The indicators of these samples were higher than those that were not exposed to the stressor. Some callus disintegrated when passaged on the regeneration medium into large globules that were planted separately from each other. Often each of these globules formed a regenerant.

The proportion of the specimens that formed regenerants was calculated based on the data on the calluses that did not undergo necrosis. On media with *F. oxysporum* CF, neither a high proportion of calluses with stem genesis (see Fig. 3, *а*), nor a higher frequency of regenerant formation compared to control conditions (see Fig. 3, *б*) was observed. This may be due to the low representation of this species among oat pathogens in the conditions of the Krasnoyarsk forest-steppe, where the isolate used in this work was isolated. According to researchers' data, when analyzing the grain infestation, this species of micromycete is extremely rare in Eastern Siberia[7]. Probably, the tissue reaction to CF of the species not included in the dominant *Fusariums* is weaker. The difference in the reaction may also be due to the different complex of toxins secreted by the cultures of the species studied in this work. *F. sporotrichioides*, *F. poae* and *F. equiseti* produce diacetoxyscyrpenol, *F. sporotrichioides* and *F. equiseti* produce zearalenone, *F. sporotrichioides* and *F. poae* produce T-2 toxin. At the same time, *F. oxysporum* mainly synthesizes moniliformin. To clarify the validity of this hypothesis, experiments with pure preparations of toxins will be carried out in the future.

CONCLUSION

Culture filtrate introduced into the nutrient medium at the stage of callus proliferation provided a decrease in the proliferative activity and an increase in the frequency of tissue necrosis by more than 50% at a concentration of 40%. At the same time, the maximum decrease in callus viability was observed on the media with *F. poae* CF. The increase in the level of selective pressure did not lead to changes in the culture parameters compared to the medium with 40% CF. In this regard, this concentration can be considered as the minimum necessary for selection of oat somaclonal lines tolerant to toxins synthesized by fungi *F. sporotrichioides*, *F. poae* and *F. equiseti*. The addition of CF to the medium is probably a selective factor to select the samples with enhanced regeneration activity. The sam-

[7]*Piryazeva E.A., Malinovskaya L.S.* Prevalence of fungi of the genus *Fusarium Link*, affecting the grain of bread cereals in different regions of Eastern Siberia // Russian journal Problems of veterinary sanitation, hygiene and ecology, 2009, N 2 (2), pp. 14-19.

ples that were selected showed a frequency of regenerant formation 2-3 times higher than those cultured under non-stress conditions. This effect is especially pronounced on the media with *F. sporotrichioides* CF. The absence of such an effect of selective conditions on the medium with *F. oxysporum* CF requires additional studies.

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ОСОБЕННОСТИ РАЗМНОЖЕНИЯ ГИБРИДОВ КЛЮКВЫ КРУПНОПЛОДНОЙ (*OXYCOCCUS MACROCARPUS*) В КУЛЬТУРЕ *IN VITRO*

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Настоящее исследование направлено на разработку системы микроразмножения пяти межсортовых гибридов *Oxycoccus macrocarpus*, перспективных для выращивания на территории Западной Сибири. Все исследования по созданию методики размножения *in vitro* проведены на примере межсортового гибрида *O. macrocarpus* Bergman × Pilgrim. Гибриды Ben Lear × Bergman, Ben Lear × Pilgrim, Pilgrim × Bergman и Pilgrim × Ben Lear размножены *in vitro* по разработанной для Bergman × Pilgrim технологии. Всхожесть семян гибридов в культуре *in vitro* составила от 35,29 до 80,00%. На этапе массового размножения установлено, что концентрация 2-изопентиладенина 0–10 мкМ не влияет на коэффициент размножения. Тестируемые значения pH (4,5–7,5) не вызывали гибель гибрида Bergman × Pilgrim, что указывает на его устойчивость в данном диапазоне pH. Отмечено активное корнеобразование на средах с цитокинином (100,0%), в связи с чем отдельной стадии укоренения микропобегов не требовалось. На этапе адаптации к условиям *ex vitro* установлено, что использование в качестве субстрата сфагнового мха является эффективным приемом. Жизнеспособность растений составила 86,0–93,0%. Показаны достоверные различия после этапа адаптации: по количеству побегов – между гибридами Bergman × Pilgrim (1,21 шт./побег) и Ben Lear × Bergman (7,00 шт./побег), по длине корней – между Bergman × Pilgrim (19,7 мм), Ben Lear × Bergman (39,4 мм) и Pilgrim × Bergman (53,4 мм). Применение методов *in vitro* для размножения и отбора генотипов является эффективным подходом и может применяться в программах получения межсортовых гибридов *O. macrocarpus*.

Ключевые слова: клюква, гибриды, размножение *in vitro*, pH питательной среды

FEATURES OF LARGE CRANBERRY (*OXYCOCCUS MACROCARPUS*) HYBRIDS PROPAGATION IN *IN VITRO* CULTURE

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The present study is aimed at developing a micropropagation system for five intervarietal hybrids of *Oxycoccus macrocarpus* promising for cultivation in Western Siberia. All studies on the development of *in vitro* propagation techniques were carried out on the example of the intervarietal hybrid *O. macrocarpus* Bergman × Pilgrim. Ben Lear × Bergman, Ben Lear × Pilgrim, Pilgrim × Bergman, and Pilgrim × Ben Lear hybrids were propagated *in vitro* using the technology developed for Bergman × Pilgrim. Seed germination of the hybrids in *in vitro* culture ranged from 35.29 to 80.00%. At the mass reproduction stage, it was found that concentrations of 2-isopentyl adenine 0–10 μM did not affect the reproduction rate. The tested pH values (4.5–7.5) did not cause the death of Bergman × Pilgrim hybrid, indicating its stability in this pH range. Active root formation on the media with cytokinin (100.0%) was observed, and therefore a separate stage of rooting of microshoots was not required. During the *ex vitro* adaptation phase, it was found that the use of sphagnum moss as a substrate served as an effective technique. The plant viability was 86.0–93.0%. Significant differences after the adaptation stage were shown: in shoot number between Bergman × Pilgrim (1.21 pcs./shoot) and Ben Lear × Bergman (7.00 pcs./shoot) hybrids, in root length between Bergman × Pilgrim (19.7 mm), Ben Lear × Bergman (39.4 mm) and Pilgrim × Bergman (53.4 mm). The use of *in vitro* methods for propagation and selection of genotypes is an effective approach and can be applied in programs to obtain intervarietal hybrids of *O. macrocarpus*.

Keywords: cranberry, hybrids, *in vitro* propagation, nutrient medium pH

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INTRODUCTION

For almost 200 years of cultivation of large-fruited cranberry – *Oxycoccus macrocarpus* (Aiton) Pursh – more than 100 varieties have been developed as a result of selection in nature and intervarietal hybridization[1]. The territory of Western Siberia is characterized by a short growing season, insufficient heat in summer and harsh winters, so the creation of a regionalized assortment of cranberries on the basis of testing foreign varieties, as well as interspecific, inter- and intra-genus hybridization involving large-fruited cranberries is considered an urgent task.

As a result of research, it has been established that the most early-ripening, large-fruited and yielding introduced varieties of large-fruited cranberry in the south of Western Siberia are Bergman, Ben Lear and Pilgrim [1]. Creation of new intervarietal hybrids for Siberia on their basis is a promising direction in cranberry breeding. Such hybrids were created in the Central Siberian Botanical Garden of the Siberian Branch of the Russian Academy of Sciences (CSBG SB RAS).

Cloning of new selected cranberry specimens in *in vitro* culture has an advantage over traditional propagation methods, allowing rapid and mass multiplication of valuable breeding material. Although there are a number of works on *in vitro* propagation of various species of the genera *Vaccinium* L. and *Oxycoccus* Hill [2-6], only a few of them are devoted to the cultivation of *O. macrocarpus*. For propagation of the representatives of *Vaccinium* and *Oxycoccus* genera in *in vitro* culture, nutrient media according to Anderson (A)[2], Murashige and Skoog (MS)[3] and McCown (WPM)[4] supplemented with zeatin, thidiazuron or 2 isopentyladenine (IPA) are more often used. In addition to the composition of the basic nutrient medium and growth regulators, another factor affecting micropropagation of plants is the concentration of hydrogen ions in the medium (pH). Generally, a pH in the range of 5.5-5.8 is recommended for *in vitro* cultivation of most plant species. However, the most effective Ph value is specific to individual plant species and even cultivars and must be determined experimentally. For acidophilic plants,

[1]Introduction of non-traditional fruit, berry and vegetable plants in Western Siberia / ed. by I.Yu. Koropachinsky, A.B. Gorbunov. Novosibirsk: Geo, 2013, 290 p.

[2]*Anderson W.C.* Propagation of rhododendrons by tissue culture. Part 1: Development of a culture medium for multiplication of shoots // Combined Proceedings – International Plant Propagators′ Society, 1975, vol. 25, pp. 129–135.

[3]*Murashige T., Skoog F.* A revised medium for rapid growth and bioassays with tobacco tissue cultures // Physiologia Plantarum, 1962, vol. 15, N 43, pp. 473–497.

[4]*Lloyd G., McCown B.* Commercially-feasible micropropagation of mountain laurel, Kalmia latifolia, by use of shoot tip culture // Combined Proceedings – International Plant Propagators′ Society, 1980, vol. 30, pp. 421–427.

such as cranberries, the optimal soil pH value is less than 5.5 [7], which should be taken into account during in vitro cultivation. For example, it has been shown that shoot proliferation of *Vaccinium vitis-idaea* L. varieties Koralle and Red Pearl using single-node segments obtained *in vitro* was markedly affected by both varietal characteristics and medium pH[5]. Thus, screening of cranberries, including *in vitro* culture, for tolerance to different pH values is necessary in the development of new varieties adapted to high pH soils.

The purpose of the research was to study the peculiarities of *in vitro* reproduction and adaptation to *ex vitro* conditions of intervarietal hybrids of *O. macrocarpus* promising for cultivation in Western Siberia.

MATERIAL AND METHODS

The material for *in vitro* inoculation was hybrid seeds of *O. macrocarpus* obtained in combinations of intervarietal hybrids Bergman × Pilgrim (2018) and Ben Lear × Bergman, Ben Lear × Pilgrim, Pilgrim × Bergman, Pilgrim × Ben Lear (2020) at the experimental site of the Food Plant Introduction Laboratory of the CSBG SB RAS.

All studies on clonal micropropagation were conducted on the intervarietal hybrid *O. macrocarpus* Bergman × Pilgrim. The other hybrids were propagated and adapted according to a similar scheme (data are given only for seed germination and the stage of adaptation to *ex vitro* conditions).

Seeds from freshly harvested fruits were used. The seeds were sterilized with 20% m Domestos solution (Unilever, UK) for 20 min followed by three times rinsing with sterile distilled water. The seeds were germinated on 0.6% m water agar under the following conditions: temperature 24 ± 1°C, photoperiod - 16/8 h light/dark, illumination 2-3 klk. After one month of cultivation, seedlings were transferred to the nutrient medium A supplemented with 5 μM IPA, 3% y sucrose, and 0.6% m agar. To evaluate the effect of IPA on shoot formation, concentrations of 5, 10 and 15 μM were used. The control was hormone-free medium A. To evaluate the effect of pH on shoot and root growth and development, nutrient medium A supplemented with 5 μM IPA was used with different pH values (4.5; 5.5; 5.5; 6.5 and 7.5) and the addition of different amounts of agar (0.8; 0.6 and 0.4 g/l).

Adaptation of regenerant plants took place in plastic containers filled with sphagnum moss and installed on a rack in the adaptation room. Conditions: temperature 24 ± 1 °C, photoperiod - 16/8 h light/darkness, illumination 2-3 klk. Before planting into the substrate, the roots of hybrids were pinched for easy planting. During the first 14 days of adaptation, containers were covered with transparent lids to create high humidity. After 21 days of adaptation, weekly root feeding with Bona Forte preparation for azaleas (Beauty series, Rusinhim, Russia) in the concentration recommended by the manufacturer was carried out. After 1.5 months, the adapted plants were planted in a soil substrate consisting of neutral and acidic peat in the ratio of 2 : 1, and grown under greenhouse conditions.

Measurements were carried out in two repetitions of 30 microshoots per experiment after 60 days of cultivation. Statistical processing of the results and analysis of the obtained data were performed using Microsoft Excel 7.0 and Statistica 6.0 (Duncan's test, ANOVA factor analysis of variance, $p \leq 0.05$).

RESULTS AND DISCUSSION

The germination of hybrid seeds of *O. macrocarpus* in *in vitro* culture ranged from 35.29 to 80.00% (see Table 1). The lowest germination was characterized by the seeds with Ben Lear variety as the mother plant (35.29-36.84%).

Seed germination in in vitro culture first of all allowed to overcome the negative influence of various factors on seed germination and viability of seedlings at the initial stages of development, to preserve unique genetic material. In his study V.V. Chernik et al.[6] used modified nutrient me-

[5]*Ostrolucká M.G., Gajdošová A., Ondruskova E., Lateèková M., Libiaková G.* Effect of medium pH on axillary shoot proliferation of selected *Vaccinium vitis-idaea* L. cultivars // Acta Biologica Cracoviensia. Series Botanica, 2010, vol. 52 (2), pp. 92–96.

[6]*Chernik V.V., Chernik V.F., Morozov O.V*. Culture of hybrid seeds of *Oxycoccus macrocarpus* Pursch. × *Vaccinium vitis-idaea* L. *in vitro* // Bulletin of the Belarusian State University. Ser. 2: Chemistry. Biology. Geography, 1993, N 1, pp. 29-31.

Табл. 1. Число завязавшихся плодов, суммарное количество семян и процент их прорастания у межсортовых гибридов *O. macrocarpus* в культуре *in vitro*

Table 1. Number of the set fruit, total number of seeds and germination percentage in the intervarietal hybrids of *O. macrocarpus* in *in vitro* culture

Sample	Number of berries, pcs.	Total number of seeds, pcs.	Number of germinated seeds, pcs./%
Bergman × Pilgrim	2	43	28/65,12
Ben Lear × Bergman	3	17	6/35,29
Ben Lear × Pilgrim	4	38	14/36,84
Pilgrim × Bergman	1	21	16/76,19
Pilgrim × Ben Lear	2	15	12/80,00

dia A and MS and proved their effectiveness in germination of hybrid seeds of *O. macrocarpus* × *V. vitis-idaea* in *in vitro* culture. The efficiency of using 0.6% agar for germination of the seeds of three-species hybrids of *Vaccinium* genus has been noted [8].

At the *in vitro* propagation stage, we studied the effect of IPA on the growth and development parameters of *O. macrocarpus* (see Table 2). It was found that cytokinin concentration did not significantly affect any of the studied parameters. Active root formation was observed on all the tested media, including the medium with the maximum value of IPA (10 μM), active root formation was observed after 2 months of cultivation.

Earlier it was shown for *O. macrocarpus* cultivar Howes that the highest multiplication factor was obtained on the medium A with zeatin concentration of 1 mg/l, and further increase of concentration up to 2 mg/l had no noticeable effect on the number of shoots[7]. We noted active root formation in the studied hybrids on the media with cytokinin, in connection with which a separate stage of rooting of microshoots was not required. Similar data were obtained by S.C. Debnath[8], who proposed a one-stage method of cranberry propagation.

We evaluated the viability, growth and development of hybrid *O. macrocarpus* Bergman × Pilgrim at different pH values (see Table 3, figure). It was revealed that pH and agar content in the nutrient medium significantly affected the studied parameters. Thus, no root formation on microshoots was observed when pH was increased to 7.5, while in all other tested regimes this index amounted to 100.0%. The highest rates of development of the aboveground and underground parts were observed on the nutrient medium at pH 6.5 with the addition of 6 g/l agar. In

Табл. 2. Влияние концентрации ИПА на показатели роста и развития гибрида *O. macrocarpus* Bergman × Pilgrim в культуре *in vitro*

Table 2. Effect of 2-iP concentration on the growth and development performance of *O. macrocarpus* Bergman × Pilgrim hybrid in *in vitro* culture

Parameter	IPA concentration, μM			
	0	1	5	10
Number of shoots, pcs/expl.	1,24 ± 0,12 a	1,30 ± 0,45 a	1,45 ± 0,30 a	1,35 ± 0,10 a
Shoots height, mm	32,9 ± 5,3 a	30,0 ± 6,5 a	29,9 ± 4,7 a	31,6 ± 3,2 a
Number of leaves, pcs/shoot	11,33 ± 1,23 a	11,45 ± 2,01 a	10,63 ± 2,12 a	10,85 ± 1,90 a
Rooting ability, %	100 a	100 a	100 a	100 a
Number of roots, pcs/shoot	5,36 ± 1,24 a	4,12 ± 1,15 a	5,13 ± 2,05 a	4,67 ± 1,30 a
Average root length, mm	31,4 ± 2,8 a	28,1 ± 3,3 a	33,2 ± 3,2 a	27,5 ± 3,2 a

Note. Here and in Tables 3, 4: values followed by the same letter(s) are not significantly different at $p \leq 0.05$ according to Duncan's test.

[7] *Sedlak J., Paprstein F.* Micropropagation of cranberry (*Vaccinium macrocarpon*) through shoot tip cultures: Short communication // Horticultural Science, 2011, vol. 38, N 4, pp. 159–162.

[8] *Debnath S.C.* Zeatin-induced one-step *in vitro* cloning affects the vegetative growth of cranberry (*Vaccinium macrocarpon* Ait.) micropropagules over stem cuttings // Plant Cell, Tissue and Organ Culture, 2008, vol. 93, pp. 231–240.

general, the hybrid *O. macrocarpus* Bergman × Pilgrim showed good growth and development in the range of pH 4.5-6.5. Further increase in pH value resulted in a decrease in shoot height, number of leaves and viability (up to 69.2%).

Previously, for three species of the *Vaccinium* genus it was shown that the increase in the length of shoots and the number of nodes on the shoot occurs when the pH value increases to 6.0 [9], for *V. corymbosum* variety Liberty it was found that pH does not reliably affect the height of shoots [10]. According to the data of G. Staniene and R. Stanyte[9], substrate pH affects the length of cranberry microshoots both *ex vitro* and *in vitro*. According to the results of the previous studies, the growth parameters of *V. ashei* cultivar Climax and *V. corymbosum* cultivar Chaoyue 1 under *ex vitro* conditions were significantly reduced at pH 6.0 [11].

The nutrient medium A supplemented with minimum concentration of IPA (1 μM) was chosen by us as optimal and used for cultivation of the intervarietal hybrids *O. macrocarpus* Ben Lear × Bergman, Ben Lear × Pilgrim, Pilgrim × Bergman и Pilgrim × Ben Lear.

At the stage of adaptation to *ex vitro* conditions, the use of sphagnum moss as a substrate was found to be an effective technique (see Table 4). Plant viability in this case amounted to 86.0-93.0%. Significant differences in the number of the developed shoots were shown only between the hybrids Bergman × Pilgrim (1.21 pcs./shoot) and Ben Lear × Bergman (7.00 pcs./shoot), in the length of roots - between Bergman × Pilgrim (19.7 mm), Ben Lear × Bergman (39.4 mm) and Pilgrim × Bergman (53.4 mm). In general, it should be noted that at the stage of adaptation in sphagnum moss there is an increase in the number of roots, but not their average length (data not shown). Further plants were planted in cassettes with peat substrate and successfully grown in greenhouse conditions.

CONCLUSION

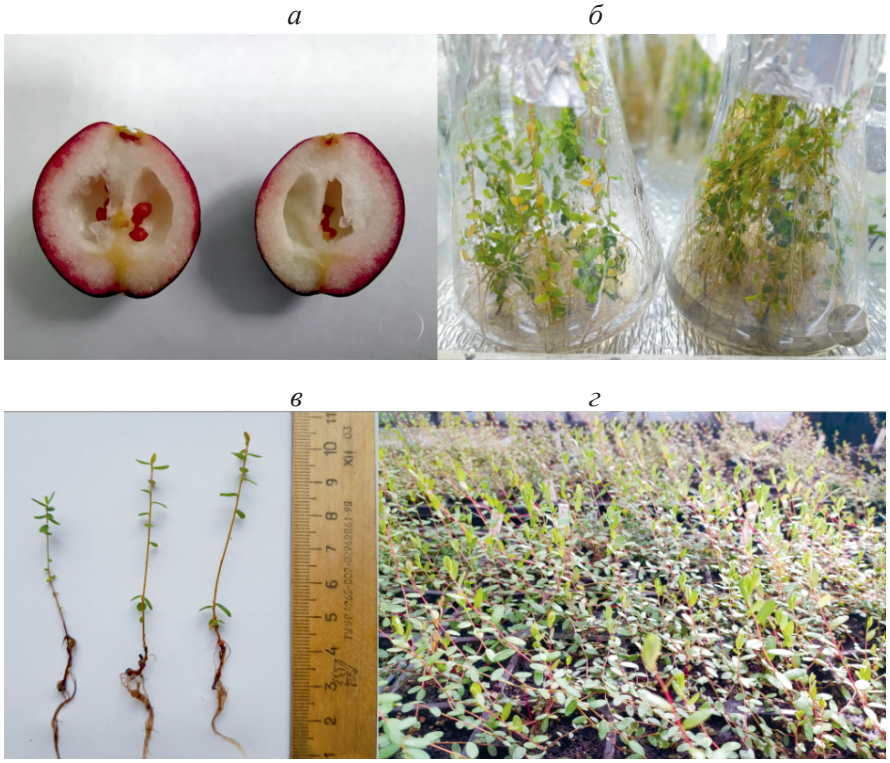
As a result of the study, a method of *in vitro* propagation and adaptation to *ex vitro* conditions was developed for five intervarietal hybrids of *O. macrocarpus*, promising for cultivation in Western Siberia. It is shown that the use of *in vitro* multiplication and genotype selection methods is an effective approach and can be used in

Табл. 3. Влияние pH питательной среды и концентрации агара на показатели роста и развития гибрида *O. macrocarpus* Bergman × Pilgrim в культуре *in vitro* (А + 5 мкМ ИПА)

Table 3. Effect of pH and agar concentration on the growth and development of *O. macrocarpus* Bergman × Pilgrim hybrid in *in vitro* culture (A + 5 μM 2-iP)

Parameter	pH						
	4,5		5,5	6,5		7,5	
	Agar, g/l						
	6	8	6	6	4	6	4
Viability, %	95,7	100	100	94,1	80,0	91,7	69,2
Number of shoots, pcs/expl.	1,18 ± 0,08 a	1,15 ± 0,08 a	1,17 ± 0,08 a	1,25 ± 0,11 a	1,25 ± 0,13 a	1,00 ± 0,00 a	1,22 ± 0,15 a
Shoots height, mm	19,3 ± 3,1 bc	22,9 ± 1,8 b	22,3 ± 2,8 bc	35,9 ± 5,6 a	14,4 ± 2,4 bc	10,4 ± 3,9 c	16,9 ± 5,1 bc
Number of leaves, pcs/shoot	7,36 ± 0,73 b	6,85 ± 0,37 bc	7,50 ± 0,84 b	10,00 ± 0,89 a	5,00 ± 0,39 c	4,82 ± 0,81 c	6,11 ± 0,89 bc
Rooting ability, %	100	100	100	100	100	0	0
Number of roots, pcs/shoot	2,41 ± 0,29 b	2,95 ± 0,26 b	2,83 ± 0,34 b	4,00 ± 0,32 a	2,42 ± 0,26 b	0 c	0 c
Average root length, mm	31,6 ± 1,8 b	28,3 ± 1,7 b	27,8 ± 2,5 b	39,0 ± 2,5 a	18,4 ± 2,1 c	0 d	0 d

[9] *Staniene G., Stanyte R.* Adaptation of American cranberry to substrate pH *in vitro* and *ex vitro* // Žemes ukio mokslai, 2007, vol. 14, pp. 40–44.



Этапы размножения *in vitro* и адаптации к условиям *ex vitro* гибрида *O. macrocarpus* Bergman × Pilgrim:
а – семена; *б* – микропобеги на среде А, дополненной 5 мкМ ИПА; *в* – растения-регенеранты в конце этапа адаптации в сфагновом мхе; *г* – растения на этапе выращивания в торфяном субстрате

Stages of *in vitro* propagation and adaptation to *ex vitro* conditions of *O. macrocarpus* Bergman × Pilgrim:
а – seeds; *б* – microshoots on the medium A supplemented with 5 μM 2-iP; *в* – regenerated plants at the end of the stage of adaptation in sphagnum moss; *г* – plants at the stage of cultivation in a peat substrate

Табл. 4. Параметры роста и развития межсортовых гибридов *O. macrocarpus* после адаптации к условиям *ex vitro* в сфагновом мхе

Table 4. Growth and development parameters of the intervarietal hybrids of *O. macrocarpus* after adaptation to *ex vitro* conditions in sphagnum moss

Hybrid	Viability, %	Number of shoots, pcs/expl.	Shoots height, mm	Number of leaves, pcs/shoot	Maximum root length, mm
Bergman × Pilgrim	93	1,21 ± 0,31 b	125,5 ± 6,1 a	23,13 ± 1,31 a	19,7 ± 5,4 c
Ben Lear × Bergman	87	7,00 ± 1,33 a	124,7 ± 7,9 a	21,14 ± 1,77 a	39,4 ± 4,1 b
Ben Lear × Pilgrim	86	6,20 ± 0,66 ab	118,6 ± 8,4 a	19,60 ± 2,01 a	42,0 ± 4,5 ab
Pilgrim × Bergman	90	5,40 ± 0,60 ab	132,3 ± 8,6 a	23,20 ± 1,16 a	53,4 ± 9,2 a
Pilgrim × Ben Lear	92	6,60 ± 0,75 ab	138,2 ± 7,2 a	22,60 ± 1,50 a	44,4 ± 1,4 ab

the programs for obtaining intervarietal hybrids of *O. macrocarpus*.

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ИНФОРМАЦИЯ ОБ АВТОРАХ

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АНАЛИЗ УРОЖАЙНОСТИ СОРТОВ ЯРОВОГО ЯЧМЕНЯ В УСЛОВИЯХ ИЗМЕНЧИВОСТИ ПРИРОДНОЙ СРЕДЫ

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В условиях возрастания континентальности климата последних десятилетий селекция ярового ячменя должна быть направлена на создание засухоустойчивых, скороспелых, высокоурожайных сортов с достаточно высокими технологическими качествами зерна. На стабилизацию урожайности кроме заложенных селекционерами хозяйственно-биологических свойств сорта в значимой степени оказывают влияние и внешние условия в регионе возделывания. Дана оценка изменчивости продуктивности сортов ячменя ярового по таким признакам, как стабильность, экологическая пластичность и адаптивность в различных эколого-географических условиях. Исследования проведены в 2020–2022 гг. на 17 сортах ярового ячменя в экологическом испытании в Самарской и Ростовской областях. Опыт заложен в четырехкратной повторности, площадь делянки 10 м². В годы проведения исследований фактор «регион выращивания» (98,7%) оказывал наибольшее влияние. Оценка индекса условий среды (*Ij*) выявила, что наилучшие условия для вегетации растений ярового ячменя сложились на опыте в Ростовской области (Зерноградский район) (*Ij* = +0,99). Урожайность сортов зависела не только от расположения сортоиспытательного участка, но и от года выращивания. Коэффициент линейной регрессии варьировал от 0,67 до 1,36, разделив сорта на отзывчивые, слабо отзывчивые и адаптивные к изменениям условий возделывания. Сорта Зерноградский 1717 и Зерноградский 1724 сформировали наибольшую урожайность на опытных участках и были классифицированы как стабильные при выращивании в различных почвенно-климатических условиях, с высокой селекционной ценностью, стрессоустойчивостью и уровнем стабильности сорта.

Ключевые слова: адаптивность, стабильность, экологическая пластичность, ячмень яровой, урожайность, сорт

YIELD ANALYSIS OF SPRING BARLEY VARIETIES UNDER CONDITIONS OF ENVIRONMENTAL VARIABILITY

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In conditions of increasing continentality of climate in recent decades, spring barley breeding should be aimed at creating drought-resistant, early-ripening, high-yielding varieties with sufficiently high technological qualities of grain. In addition to the economic and biological properties of the variety established by the breeders, external conditions in the region of cultivation also have a significant impact on the stabilization of the yields. The variability of productivity of spring barley varieties was assessed in terms of such traits as stability, ecological plasticity and adaptability in different ecological and geographical conditions. The research was conducted in 2020–2022 on 17 varieties of spring barley in ecological trial in Samara and Rostov regions. The experiment was laid in fourfold repetition with a plot area of 10 m². In the years of research, the "growing region" factor (98.7%) had the greatest influence. Evaluation of the index of environmental conditions (*Ij*) revealed that the best conditions for the vegetation of spring barley plants were formed in the experiment in the Rostov region (Zernogradsky district) (*Ij* = +0.99). The yield of the varieties depended not only on the location of the seed-trial ground but also on the year of cultivation. The linear regression coefficient ranged from 0.67 to 1.36, dividing the varieties into responsive, weakly responsive and adaptive to changes in the cultivation conditions. The varieties Zernogradsky 1717 and Zernogradsky 1724 formed the highest yield in the experimental plots and were classified as stable under cultivation under different soil and climatic conditions, with high breeding value, stress tolerance and level of variety stability.

Keywords: adaptability, stability, ecological plasticity, spring barley, yield, variety

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The authors declare no conflict of interest.

INTRODUCTION

Barley is one of the central grain crops not only in domestic but also in world agriculture. It occupies the leading place in terms of the diversity of its use and gross yields as a grain-forage crop. Protein in barley grain has a good balance in the composition of especially important amino acids, so about 65% of the grain is used for fodder purposes, including the production of mixed fodder[1] [1, 2].

Biochemical studies confirm the balanced content of nutrients in barley grain: 4,6-6,1% fiber, 11-13 - crude protein, 2,1-2,3 - fat, 61- 65 - nitrogen-free extractive substances, 2,8-3,6% ash and other elements. Because of the nutritional value cereals from processed barley (about 312 kcal/100 g) are successfully used in human diets both in case of obesity and diets [3–5].

During the growing season of spring barley plants, the formation of grain yield is significantly affected by various environmental conditions. Increased temperature with a prolonged lack of moisture has an extremely unfavorable effect on both the formation of yield and grain quality. Zonal technologies of cultivation of agricultural crops have been developed for many years, as each zone of cultivation has its own peculiarities of the natural environment. However, optimal zonal cultivation technologies are only a part of successful production of high and stable yields.

New varieties are needed, not only combining high yield and quality, but also having adaptive properties to changing natural conditions. In this regard, the development and introduction of the varieties that show tolerance to cultivation in different soil and climatic zones into agricultural production is very important. A modern variety should be not only plastic, but also highly resistant to the manifestation of environmental stress factors, while not losing quality [6–9].

The purpose of the study was to evaluate the variability of productivity of spring barley varieties in terms of such traits as stability, environmental plasticity and adaptability in different ecological and geographical conditions.

MATERIAL AND METHODS

Under zonal remoteness conditions, studies were conducted at three crop testing sites (CTS) with different climatic components between them:

– Bezenchuk CTS, Samara region, Samara district, Bezenchuk settlement (Samara Research Institute of Agriculture);

– Orlovsky CTS, Rostov region, Orlovsky district (OOO Seed Grower "Niva");

– Zernograd CTS, Rostov region, Zernograd district, Zernograd (ASC "Donskoy").

During the years of research (2020-2022), 17 varieties of spring barley, the originator of which is ASC "Donskoy", were analyzed (see Table 1).

The area of the registration plot was 10 m², seeding rate was 500 germinated grains/m². The varieties were sown in fourfold repetition on the sunflower forecrop. Comparison of the studied samples was carried out with the localized variety of spring barley Ratnik. Characteristics of soils of the experimental plots are presented in Table 2.

[1]*Filippov E.G., Bragin R.N., Dontsova A.A.* Estimation of ecological adaptability and stability of the promising winter barley varieties in a competitive variety testing // State and Prospects for the Development of Agribusiness – INTERAGROMASH 2020: E3S Web Conf. XIII International Scientific and Practical Conference, 2020, N 175, p. 6. DOI: 10.1051/e3sconf/202017501007.

Табл. 1. Характеристика изучаемых сортов и линий
Table 1. Characteristics of the studied varieties and lines

No. of items	Variety / line name	Origin	Type	Ripeness group
1	Ratnik (st.)	Zernogradsky 632 × Divny	Nutans	Medium-maturing
2	Azimut	Zernogradsky 1500 ×Vadim	»	Early-maturing
3	Zernogradsky 1763	Gris × Zernogradsky 1523	Submedicum	Medium-maturing
4	Zernogradsky 1768	Zernogradsky 1518 × Zernogradsky 1525	»	»
5	Zernogradsky 1719	Gris × Priazovsky 9	Nutans	Middle-early
6	Zernogradsky 1717	Schedry × CDC Dawn	»	Medium-maturing
7	Zernogradsky 1716	Leon × Zernogradsky 1547	Medicum	»
8	Zernogradsky 1701	Zernogradsky 1521 × (Thuringia × Sokol)	Nutans	Early-maturing
9	Zernogradsky 1756	Leon × Zernogradsky 1549	Submedicum	Middle-early
10	Zernogradsky 1755	Leon × Zernogradsky 1549	»	Medium-maturing
11	Zernogradsky 1754	Leon × Novik	Nutans	»
12	Zernogradsky 1752	Zernogradsky 141 × Zernogradsky 1539	»	Early-maturing
13	Zernogradsky 1685	Zernogradsky 1500 × Preria	»	Medium-maturing
14	Zernogradsky 1628	Leon × Gris	»	Middle-early
15	Zernogradsky 1726	Zernogradsky 1500 × Mamlyuk	»	»
16	Zernogradsky 1724	Vakula × Timofei	Ricotense	Medium-maturing
17	Zernogradsky 1721	Yula × Zernogradsky 1507	Nutans	Middle-early

Табл. 2. Характеристика почв экологических сортоиспытательных участков
Table 2. Characteristics of the soil types of the ecological seed-trial grounds

Crop testing site location	Soil type	Soil acidity, pH	Humus content, %	Content of basic nutrition elements, mg/kg		
				N	P	K
Bezenchuksky (Samara region)	Ordinary chernozem	6,4–6,7	3,8–4,0	128–142	156–162	199–208
Orlovsky (Rostov region)	Dark-chestnut	6,9–7,3	2,5–3,0	60–110	17,6	439
Zernogradsky (Rostov region)	Ordinary chernozem	7,0–7,1	3,0–3,5	70–110	15–20	300–500

The obtained data were evaluated according to the methodology of B.A. Dospekhov[2].

To analyze the yield of spring barley varieties by adaptability parameters, the methods that comprehensively evaluate the obtained data were used:

– indicator of environmental plasticity and stability – according to the calculations of S.A. Eberhart, W.A. Rassel edited by V.A. Zykin[3];

– breeding value (*Sc*) and homeostaticity (*Hom*) – by the method of V.V. Khangildin and N.A. Litvinenko[4];

– stress tolerance (*Y*min – *Y*max) and genetic flexibility ((*Y*max + *Y*min)/2) – according to the equations of A.A. Rosielle, J. Hamblin as presented by A.A. Goncharenko[5];

– responsiveness coefficient (*Kp*) according to the method of V.A. Zykin (see footnote 3);

– Variety Stability Index (VSI) – according to the equation of E.D. Nettevich[6].

Significant influence on the formation of the yield on crop testing sites was obtained due to variation of meteorological conditions.

In 2020, an increased amount of precipitation during the sowing period of spring barley (March-April) at the crop testing site of the Samara Research Institute of Agriculture (65.0 and 32.0 mm, respectively) and the absence of precipitation at the site of the ASC "Donskoy" was noted. At the time of booting (May), the amount of precipitation in the ASC "Donskoy" and the OOO SG "Niva" amounted to 81.2 and 75.2 mm, respectively, which is 4 times higher

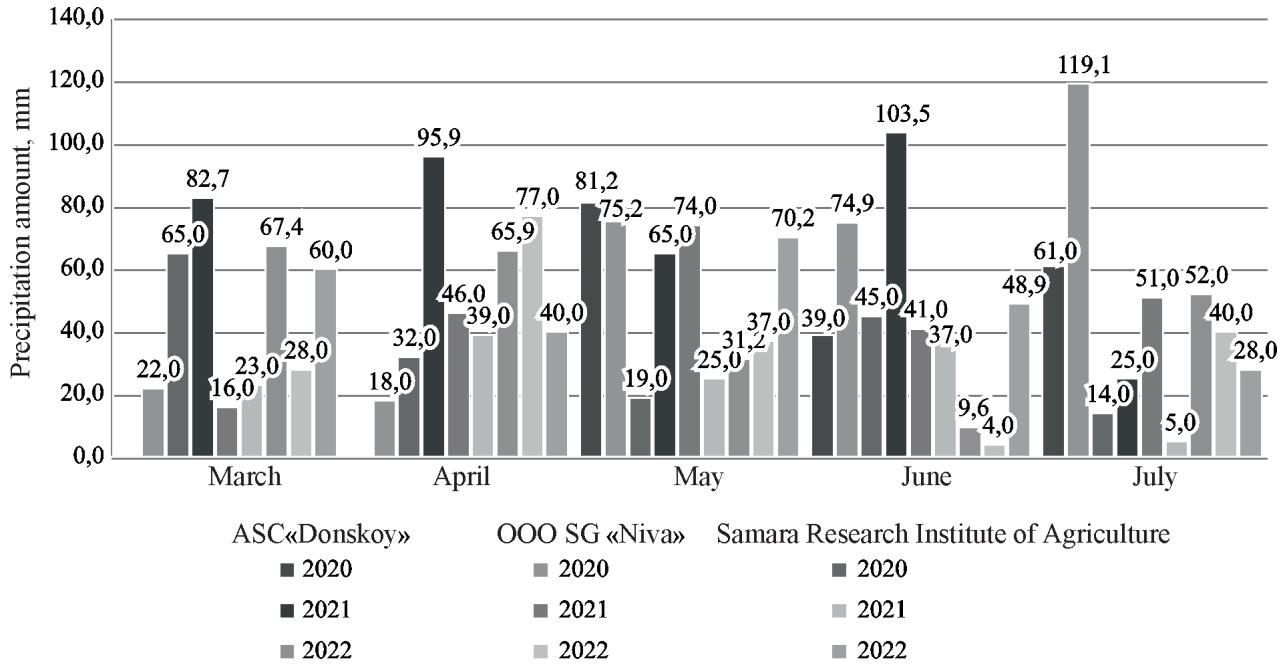


Рис. 1. Среднемесячное количество осадков за март – июль 2020–2022 гг., мм

Fig. 1. Average monthly amount of precipitation during March – July, 2020–2022, mm

[2]*Dospekhov B.A.* Methodology of field experiment (with the basics of statistical processing of the research results). Moscow: Alliance, 2014, 352 p.

[3]*Zykin V.A., Belan I.A., Yusov V.S.* Methodology of calculation and evaluation of the parameters of ecological plasticity of agricultural plants. Ufa: BashSAU, 2005, 100 p.

[4]*Khangildin V.V., Litvinenko N.A.* Homeostaticity and adaptability of winter wheat varieties // Scientific and Technical Bulletin of the All-Union Breeding and Genetics Institute, 1981, N 1, pp. 8-14.

[5]*Goncharenko A.A.* About adaptability and ecological stability of grain crop varieties // Vestnik of the Russian Agricultural Science, 2005, N 6, pp. 49-53.

[6]*Nettevich E.D.* Yield potential of spring wheat and barley varieties recommended for cultivation in the central region of the Russian Federation and its realization under production conditions // Reports of the Russian Academy of Agricultural Sciences, 2001, N 3, pp. 3-6.

than in the Samara Research Institute of Agriculture. In the periods of earing, ripening and grain filling (June and July), the highest amount of precipitation was observed at the OOO SG "Niva" (74.9 and 119.1 mm, respectively).

In 2021, relatively high precipitation was recorded at the ecological crop testing site of the ASC "Donskoy" during the periods of sprouting, tillering and earing (March, April and June) - 82.7; 95.9 and 103.5 mm, respectively, which significantly exceeded this indicator at other crop testing sites.

In 2022 a tendency of uneven distribution of precipitation by crop testing sites during the growing season was observed. In the spring period of sprouting, tillering (March – April) the crop testing site ASC "Donskoy" was leading on the sum of precipitation – 133.3 mm. This indicator amounted to 105.0 and 100.0 mm in the OOO SG "Niva" and the Samara Research Institute of Agriculture, respectively. During the period of booting and earing (May-June), the highest amount of precipitation was observed at the crop testing site of the ASC "Donskoy" - 70.2 and 48.9 mm, respectively, which showed an excess of this indicator by 2 times and more compared to other sites (see Fig. 1).

In the period of sprouting (March) in 2020-2022, the highest temperature regime was observed at the experimental plot of the ASC "Donskoy", low values of average daily air temperatures were observed at the site of the Samara Research Institute of Agriculture (2.7; -4.2 and -4.2 ºC, respectively). During tillering, booting, ripening (April, May and July) in the years of research, the average daily air temperature at the experimental plots of the Samara Research Institute of Agriculture and the ASC "Donskoy" was higher than in the OOO SG "Niva". During earing time (June), 2020 lower values of average daily air temperature were observed in the Samara Research Institute of Agriculture (17.9 ºC) (see Fig. 2).

Such distribution of weather conditions made it possible to analyze the adaptability indicators and identify the best spring barley varieties.

RESULTS AND DISCUSSION

Over the years of research, a fairly high level of variation in yields across crop testing sites

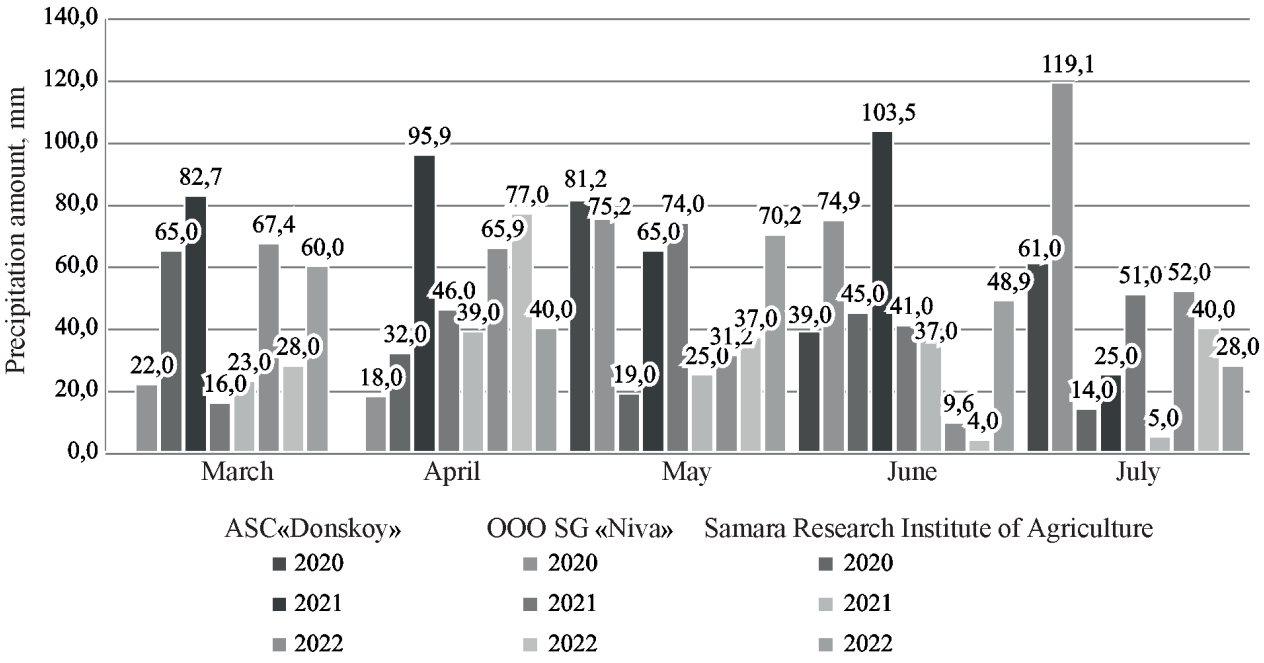


Рис. 2. Среднемесячная температура воздуха за март – июль 2020–2022 гг.
Fig. 2. Average monthly air temperature during March – July, 2020–2022

was noted. According to two-factor dispersion analysis, the formation of yields was mainly influenced by the factor "cultivation zone" – 98.7%, which is due to climatic data of the crop testing sites during the research period. The highest yields of spring barley varieties were obtained on the fields of the ASC "Donskoy" (4.80-5.53 t/ha). This experimental plot also revealed a high index of environmental conditions (*Ij* = +0.99). On average for the years of research in the fields of the ASC "Donskoy" reliable increase in yield in relation to the standard variety Ratnik (4.83 t/ha) was obtained in the varieties Zernogradsky 1755 – 5.53 t/ha (+0.70 t/ha), Zernogradsky 1726 – 5.47 (+0.64), Azimut – 5.43 (+0.60), Zernogradsky 1763 – 5.37 t/ha (+0.54 t/ha) (see Fig. 3).

On the fields of the Samara Research Institute of Agriculture and the OOO SG "Niva" the growing conditions were less favorable. The index of environmental conditions (*Ij*) at these crop testing sites was -0.58 and -0.41, respectively.

In the years of research, the yield on the experimental plot of the Samara Research Institute of Agriculture varied in the range of 3.13-4.18 t/ha. According to this trait the varieties Zernogradsky 1721 –4.18 t/ha (+0.94 t/ha), Zernogradsky 1724 and Zernogradsky 1717 – 4.05 t/ha (+0.81 t/ha) significantly exceeded the standard.

The yield on the experimental plot of the OOO SG "Niva" was noted from 3.25 t / ha in the standard variety Ratnik to 4.31 t / ha in the variety Zernogradsky 1685. On average over the years of research reliable yield increase in relation to the standard variety Ratnik was observed in the varieties Zernogradsky 1685 – 4.31 t / ha (+1.06 t / ha), Zernogradsky 1717 – 4, 24 (+0.99), Azimut – 4.17 (+0.92), Zernogradsky 1701 – 4.01 (+0.76), Zernogradsky 1726 – 3.89 (+0.64), Zernogradsky 1752 – 3.85 (+0.60), Zernogradsky 1754 – 3.83 (+0.58), Zernogradsky 1628 – 3.82 t/ha (+0.57 t/ha).

At different sites of ecological variety testing, six varieties significantly exceeded the standard Ratnik, forming the highest yield: Zernogradsky 1754 – 4.25 t/ha, Zernogradsky 1755 – 4.25, Zernogradsky 1724 – 4.26, Zernogradsky 1685 – 4.27, Azimut – 4.38, Zernogradsky 1717 – 4.47 t/ha, the excess was from 0.47 to 0.69 t/ha, respectively.

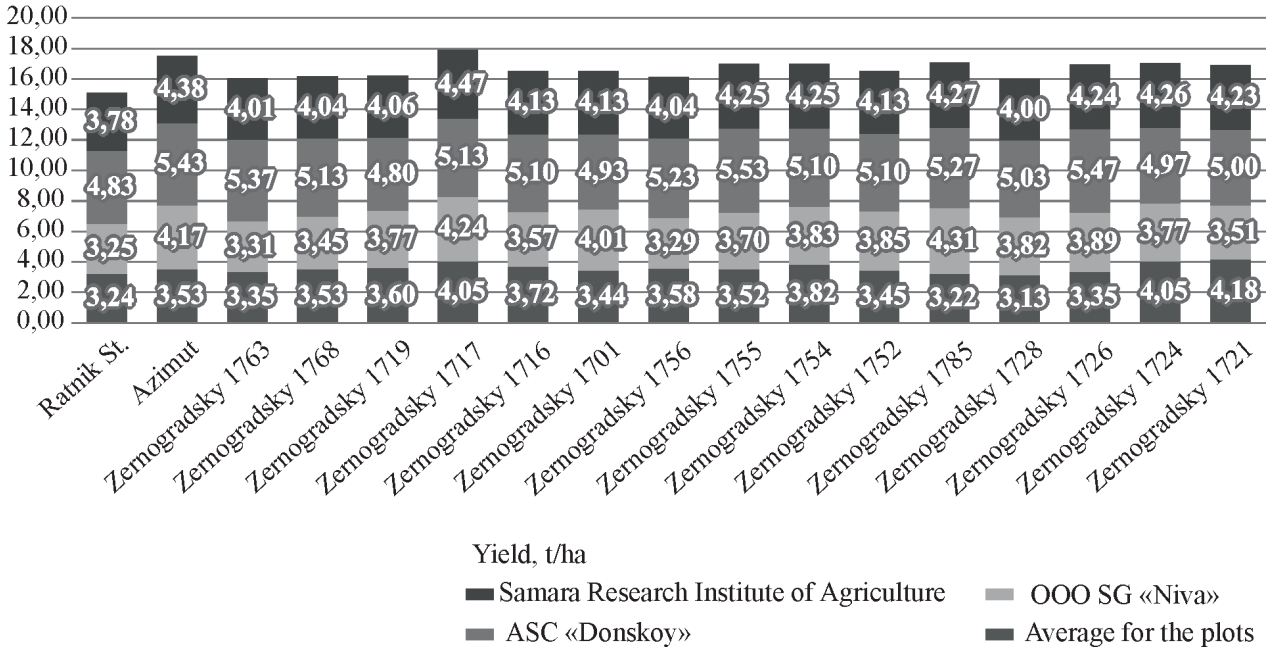


Рис. 3. Урожайность сортов ярового ячменя на участках экологического сортоиспытания (2020–2022 гг.), т/га

Fig. 3. Productivity of the spring barley varieties on the ecological variety testing plots (2020–2022), t/ha

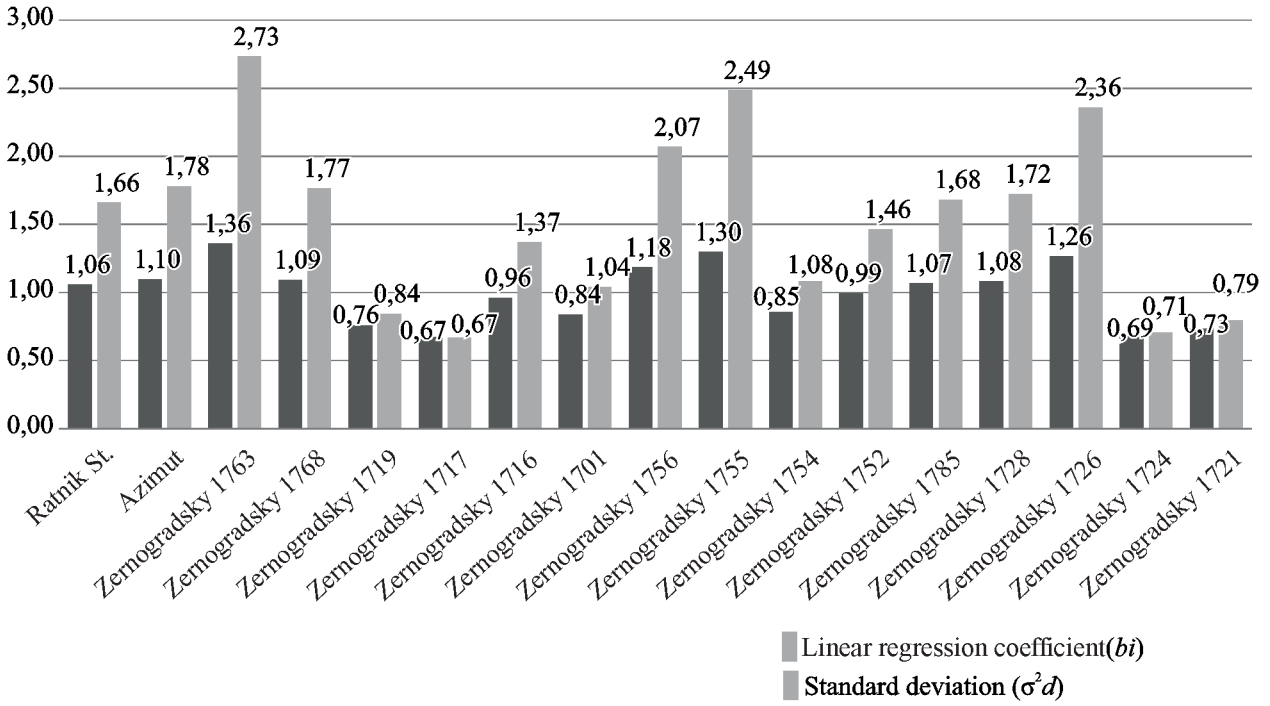


Рис. 4. Параметры адаптивности сортов ярового ячменя: коэффициент линейной регрессии и среднеквадратическое отклонение (2020–2022 гг.)

Fig. 4. Adaptability parameters of the spring barley varieties: linear regression coefficient and standard deviation (2020–2022)

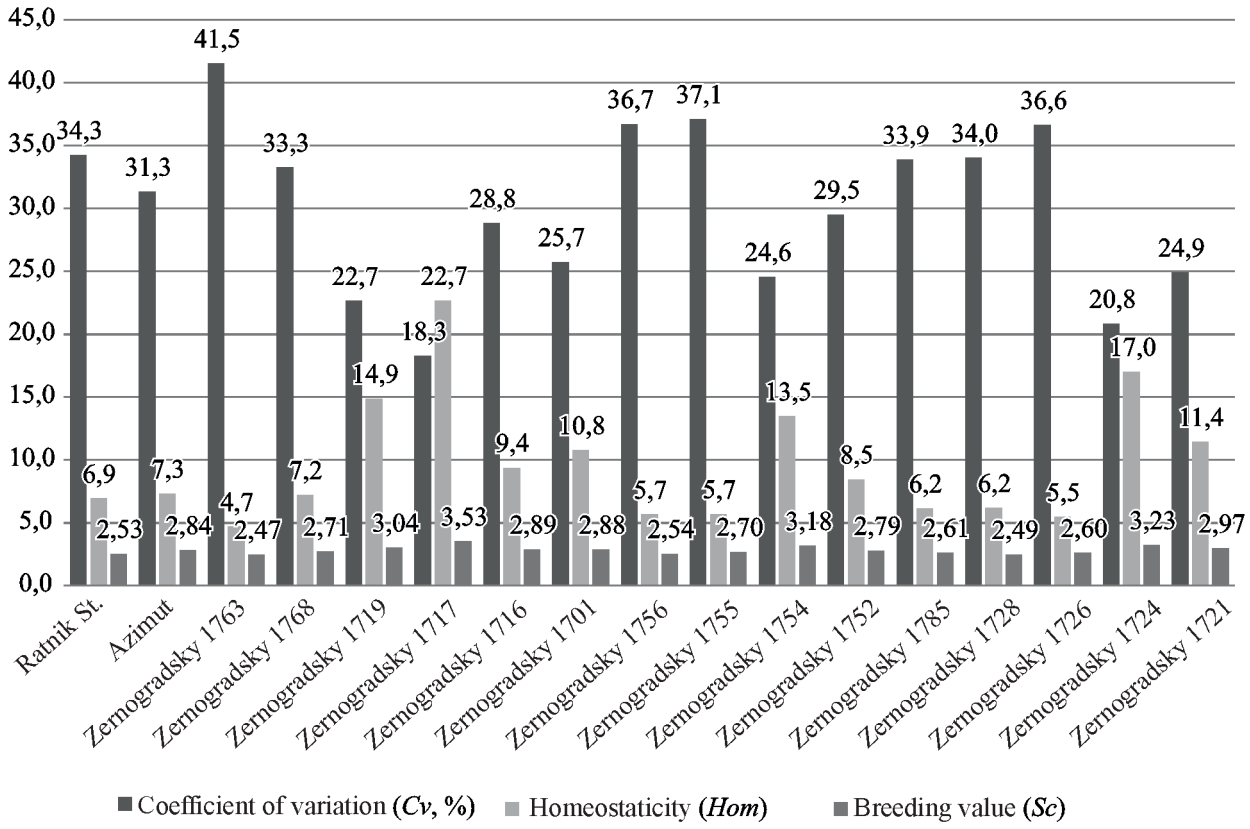
The linear regression coefficient (*bi*) as one of the important indicators of ecological plasticity calculation varied from 0.67 to 1.36 in the years of research. According to the methodology, the studied varieties were divided into three categories: weakly responsive ($bi < 1$), linearly responsive to changes in the growing conditions ($bi \approx 1$), responsive to improvement of environmental conditions ($bi > 1$). The lines Zernogradsky 1763 ($bi = 1.36$), Zernogradsky 1755 ($bi = 1.30$), Zernogradsky 1726 ($bi = 1.26$) and Zernogradsky 1756 ($bi = 1.18$) have high values of linear regression coefficient. Weak response to changes in the growing conditions, but stable yields even under the influence of stress factors were observed in the varieties Zernogradsky 1717 ($bi = 0.67$), Zernogradsky 1724 ($bi = 0.69$), Zernogradsky 1721 ($bi = 0.73$) and Zernogradsky 1719 ($bi = 0.76$). At the value of the linear regression coefficient close to one, a gradual relationship between the change in the yield and the change in the growing conditions was observed: Zernogradsky 1752 ($bi = 0.99$), Zernogradsky 1716 ($bi = 0.96$), Ratnik ($bi = 1.06$) (see Fig. 4).

The standard deviation ($\sigma^2 d$), which indicates the stability of the results obtained, ranged from 0.67 to 2.73.

The values of coefficient of variation (*CV*) in the studied varieties ranged from 18.3 to 41.5%. Since all varieties, except one, had the coefficient above 20%, this index indicates a strong variability. The least variability was observed in the variety Zernogradsky 1717 ($CV = 18.3\%$) (see Fig. 5).

In terms of homeostaticity, a relatively high value was observed in the variety Zernogradsky 1717 ($Hom = 22.7$). High values of this trait reflect the varieties possessing tolerance to the impact of negative stress factors of the environment and the ability to form high stable yields.

The parameters expressing the adaptability of the variety include the breeding value of the genotype (*Sc*), high values of which confirm the data of homeostaticity (*Hom*) in determining the most resistant samples in relation to the influence of unfavorable environmental conditions. Varieties Zernogradsky 1717 ($Sc = 3.53$), Zernogradsky 1724 ($Sc = 3.23$), Zernogradsky 1754 ($Sc = 3.18$) and Zernogradsky 1719 ($Sc =$



Puc. 5. Параметры адаптивности сортов ярового ячменя: коэффициент вариации, гомеостатичность, селекционная ценность (2020–2022 гг.)

Fig. 5. Adaptability parameters of the spring barley varieties: coefficient of variation, homeostaticity, breeding value (2020–2022)

3.04) had the highest values of this indicator.

Stress tolerance as one of the signs of ecological plasticity and adaptability (the difference between minimum and maximum yields) serves as a clear indicator of a variety's resistance to unfavorable factors, determining the range of possible use and introduction of the variety. Compensatory ability, or stress tolerance, determines the genetic flexibility of a variety, its response to the growing conditions. According to the methodology, higher indicators reflect the degree of resistance of the varieties to environmental stress factors. Varieties Zernogradsky 1717 (*Y*min - *Y*max = –1.08), Zernogradsky 1719 (*Y*min - *Y*max = –1.20) and Zernogradsky 1724 (*Y*min - *Y*max = –1.20) are classified as stress-resistant. High indices of compensatory ability were observed in the varieties Zernogradsky 1717 ((*Y*max + *Y*min)/2 = 4.59), Zernogradsky 1755 ((*Y*max + *Y*min)/2 = 4.53), Azimut ((*Y*max + *Y*min)/2 = 4.48), Zernogradsky 1754 ((*Y*max + *Y*min)/2 = 4.46), Zernogradsky 1726 ((*Y*max + *Y*min)/2 = 4.41) (see. Fig. 6).

The coefficient of responsiveness to the growing conditions (*Kp*) as one of the indicators determining the adaptability of the studied varieties, expresses the difference between the data obtained in a favorable and unfavorable environment. According to this characteristic, the varieties Zernogradsky 1685 (*Kp* = 1.63), Zernogradsky 1726 (*Kp* = 1.63), Zernogradsky 1763 (*Kp* = 1.62) were identified (see Fig. 7).

The Variety Stability Index (VSI) allows identifying the varieties with stable yields, which are capable of not significantly reducing yields under deteriorating cultivation conditions (see Figure 8).

According to the results of the analysis, the values of yield stability of the varieties ranged from 92.9 to 263.3%. The varieties Zer-

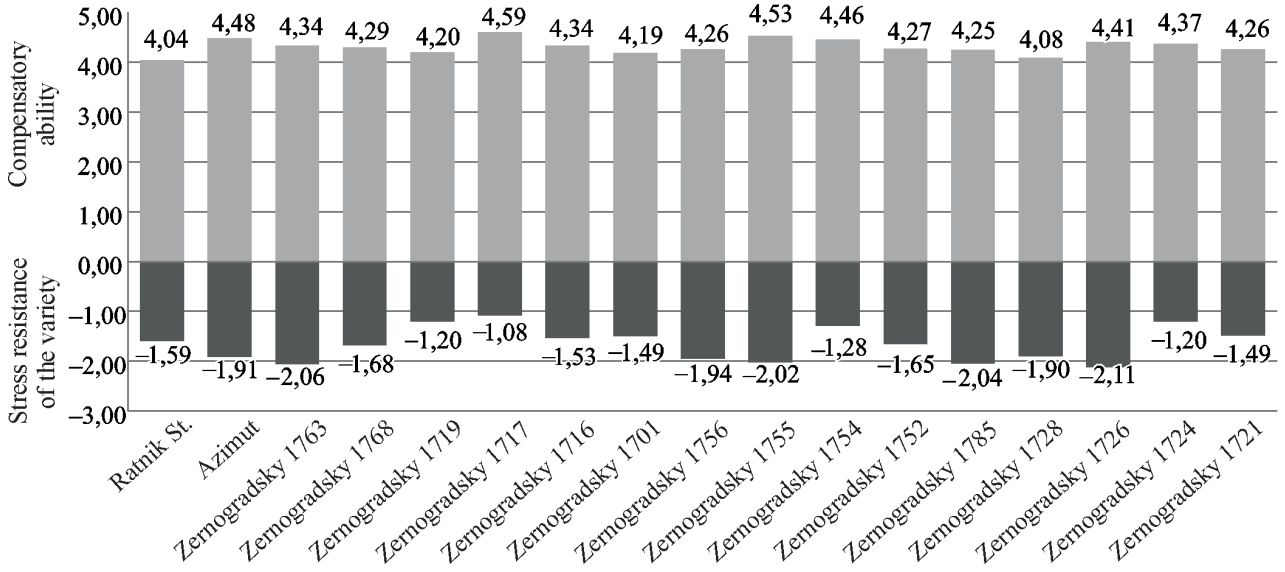


Рис. 6. Стрессоустойчивость (*Y*min – *Y*max) и компенсаторная способность ((*Y*max + *Y*min)/2) сортов ярового ячменя (2020–2022 гг.)

Fig. 6. Stress resistance (*Y*min – *Y*max) and compensatory ability ((*Y*max + *Y*min)/2) of the spring barley varieties (2020–2022)

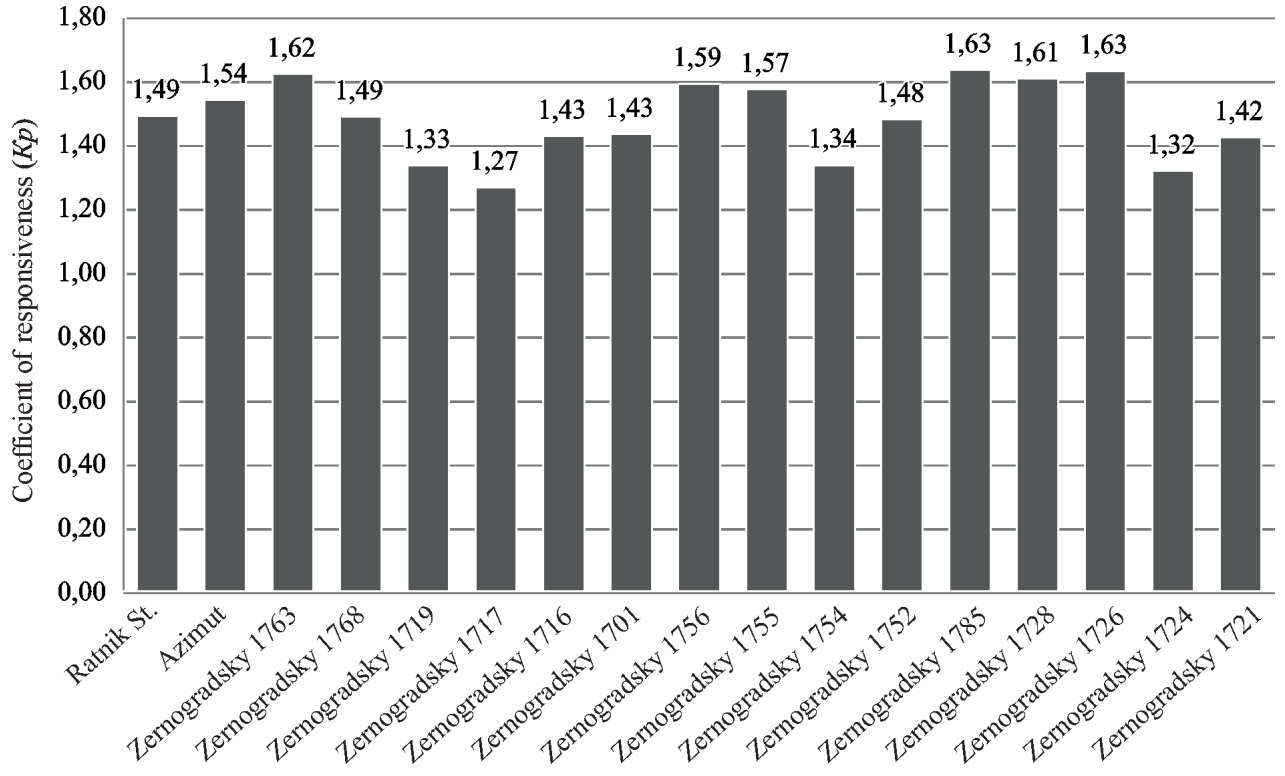


Рис. 7. Коэффициент отзывчивости сортов ярового ячменя (*Kp*) (2020–2022 гг.)

Fig. 7. Coefficient of responsiveness of the spring barley varieties (*Kp*) (2020–2022)

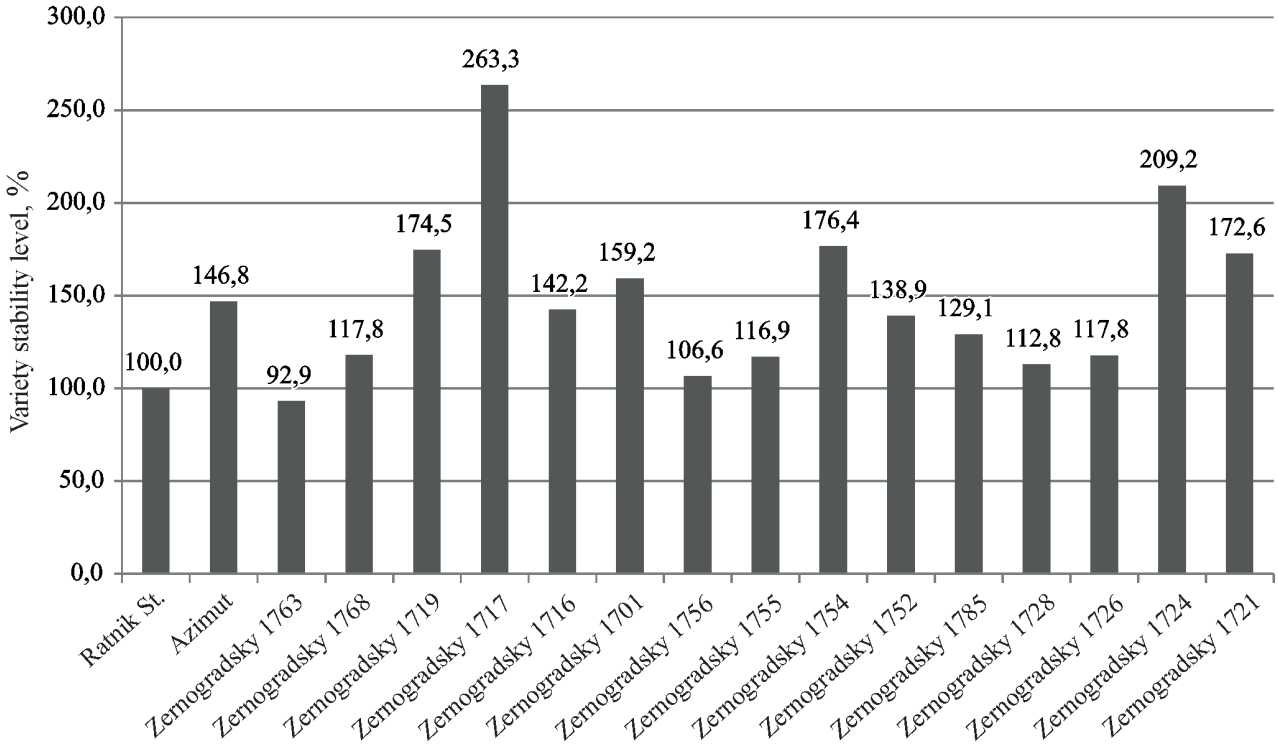


Рис. 8. Показатель уровня стабильности сортов ярового ячменя (ПУСС) (2020–2022 гг.)
Fig. 8. Indicator of spring barley varieties stability level (VSLI) (2020–2022)

nogradsky 1717 and Zernogradsky 1724 had the highest VSI values (263.3 and 209.2%, respectively).

CONCLUSION

According to the analysis of research results from 2020 to 2022 on the experimental plots the varieties possessing a complex of parameters of ecological plasticity in combination with high stable yield were selected. Varieties Zernogradsky 1717 and Zernogradsky 1724 formed high productivity and stability in different growing conditions (*bi* = 0.67 and 0.69), with high selection value (*Sc* = 3.53 and 3.23), stress tolerance (*Y*min – *Y*max = -1.08 and –1.20) and VSI (263.3 and 209.2), which allows them to be used to obtain high yields in conditions with increased risk of adverse environmental factors. Varieties Azimut and Zernogradsky 1685 showed high yield and adaptability to the growing conditions (*bi* = 1.10 and 1.07). The Azimut variety has a high index of genetic flexibility ((*Y*max + *Y*min)/2 = 4.48), while Zernogradsky 1685 was distinguished by a high level of responsiveness (*Kp* = 1.63), which characterizes them as the varieties capable of forming high yields under favorable environmental conditions.

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ВЛИЯНИЕ МИНЕРАЛЬНЫХ УДОБРЕНИЙ НА УРОЖАЙНОСТЬ СОРГОВЫХ КУЛЬТУР В ЮЖНОЙ ЛЕСОСТЕПИ ЗАПАДНОЙ СИБИРИ

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Представлены результаты изучения продуктивности сорговых культур в различных условиях минерального питания на лугово-черноземной почве южной лесостепи Западной Сибири. Исследование проводили в 2019–2022 гг. в Омской области в рамках длительного стационарного полевого опыта. Почва опытного участка лугово-черноземная среднемощная тяжелосуглинистая. Пахотный горизонт характеризуется нейтральной реакцией почвенного раствора (pH 7,0–7,2). Схема опыта двухфакторная, включает применение азотных ($N_{0, 30, 60}$) и фосфорных ($P_{0, 60}$) минеральных удобрений до посева сорговых культур. Динамика содержания влаги в метровом профиле почвы тесно связана с гидротермическими условиями вегетационных периодов. В наиболее благоприятный по увлажнению 2019 г. почвенный профиль имел более стабильное и равномерное увлажнение, особенно во втором полуметре. Последующие годы дефицит атмосферного увлажнения ярко проявился в содержании общей влаги как по профилю почвы, так и во времени. Иссушение метрового профиля даже в начальный период вегетации наблюдалось в 2022 г., что можно считать результатом низкого остаточного количества влаги в предшествующий, тоже засушливый, сезон. В контроле минеральное питание было ограничено невысоким содержанием подвижного фосфора. Исследования показали, что в условиях недостаточного и неустойчивого увлажнения, характерного для юга Западной Сибири, в полевом кормопроизводстве целесообразно возделывание сорговых культур, обладающих высокой отзывчивостью на применение минеральных удобрений. В среднем за два года максимальная урожайность зеленой массы сорго сахарного на интенсивном фоне составила 21,07 т/га, сорго-суданкового гибрида – 16,62 т/га, что выше контроля на 47,2 и 62,7% соответственно. Наиболее эффективным оказалось комплексное применение минеральных удобрений, которое обеспечило увеличение содержания сухого вещества у сорго сахарного от 3,97 до 6,08 т/га (53,0%), сорго-суданкового гибрида – от 2,81 до 4,73 т/га (68,3%).

Ключевые слова: лугово-черноземная почва, сорго, сорго-суданковый гибрид, биомасса, продуктивность

EFFECT OF MINERAL FERTILIZERS ON SORGHUM CROP YIELDS IN THE SOUTHERN FOREST-STEPPE OF WESTERN SIBERIA

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The results of studying the productivity of sorghum crops under different conditions of mineral nutrition on meadow-chernozem soil of the southern forest-steppe of Western Siberia are presented. The study was conducted in 2019–2022 in the Omsk region as part of a long-term stationary field ex-

periment. The soil of the experimental plot is meadow-chernozem moderately deep heavy loamy soil. The arable horizon is characterized by neutral reaction of the soil solution (pH 7.0–7.2). The scheme of the experiment is two-factor, includes application of nitrogen ($N_{0, 30, 60}$) and phosphorus ($P_{0, 60}$) mineral fertilizers before sowing sorghum crops. The dynamics of moisture content in the meter soil profile is closely related to the hydrothermal conditions of vegetation periods. In the most wetted year of 2019, the soil profile had a more stable and uniform moisture content, especially in the second half meter. In subsequent years, the atmospheric moisture deficit was clearly manifested in the content of total moisture both along the soil profile and in time. Drying out of the meter profile even in the initial growing season was observed in 2022, which can be considered as a result of low residual moisture in the preceding, also dry, season. In the control, mineral nutrition was limited by the low content of mobile phosphorus. The studies have shown that in conditions of insufficient and unstable moisture, typical for the south of Western Siberia, it is advisable to cultivate sorghum crops with high responsiveness to the use of mineral fertilizers in field fodder production. In the average of two years, the maximum yield of green mass of sugar sorghum on intensive background was 21.07 t/ha, sorghum-sudangrass hybrid – 16.62 t/ha, which is higher than the control by 47.2 and 62.7%, respectively. The most effective was the complex application of mineral fertilizers, which provided an increase in dry matter content of sugar sorghum from 3.97 to 6.08 t/ha (53.0%), sorghum-sudangrasas hybrid – from 2.81 to 4.73 t/ha (68.3%).

Keywords: meadow-chernozem soil, sorghum, sorghum-sudangrass hybrid, biomass, productivity

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The authors declare no conflict of interest.

INTRODUCTION

Productivity of livestock and realization of its genetic potential depend on the state of the fodder base [1, 2]. Bulky forages (silage, haylage) are the main element of the fodder base, they are 70.0% responsible for the efficiency of rumen digestion, thus affecting the level of animal productivity [3]. One of the important tasks of animal breeding is to provide livestock with high-grade and balanced fodder in terms of sugar-protein ratio in summer and winter stall periods [4, 5]. The use of sorghum silage in a mixture with leguminous crops allows to increase feed digestibility and to increase the average daily live weight gain of animals [6].

The main limiting factor of field fodder production is considered to be climate, changes in which can reduce the yields of even highly productive fodder crops [7, 8]. In the conditions of the southern forest-steppe zone of Western Siberia, the climate is sharply continental with high air temperature and uneven precipitation in summer [9]. Such features of the climate, taking into account the tendency to its further change towards the increase of extreme weather events, make it necessary to select agricultural crops that can adapt to different environmental conditions and provide high yields.

The use of drought-resistant crops, such as sugar and grass sorghum, sorghum-sudan hybrids in the system of field fodder production, provides high productivity of phytomass, including in dry years [10, 11]. Sorghum differs from other forage crops by its plasticity and unpretentiousness to growing conditions, responds positively to the optimization of mineral nutrition and moisture availability [12, 13].

Adaptive varieties and hybrids allow more efficient use of biological and genetic potential of the crop, providing high productivity of the

aboveground biomass, which is determined by foliage and leaf surface parameters, regrowth intensity and resistance to abiotic and biotic factors [14].

The purpose of the research is to study the yield of green mass and dry matter of sorghum crops under modeling of different conditions of mineral nutrition of meadow-chernozem soil.

MATERIAL AND METHODS

The study was conducted in 2019-2022 in the southern forest-steppe of Western Siberia (Omsk region) in the framework of long-term stationary field experiments on the basis of the laboratory of field fodder production of the Omsk Agrarian Scientific Center.

The object of research is sugar sorghum and sorghum-sudan hybrid growing on meadow-chernozem soil.

The soil of the experimental plot is meadow-chernozem medium heavy loamy. The thickness of the humus horizon is 45 cm. Arable horizon is characterized by neutral reaction of soil solution (pH 7.0-7.2). the ground water depth level determined by two observation wells was 3.5 m.

The experiment scheme was two-factor, including application of nitrogen and phosphorus mineral fertilizers before sowing sorghum crops (see Table 1). Ammophos (P_{60}) and ammonium nitrate (N_{30}) were applied locally by seeder SPP 3.6. Sowing was carried out in the III ten-day period of May. Seeding rate – 1 million germinating grains/ha. The plot size was 360 m^2, threefold repetition, systematic placement of plots.

The following crops were used as study crops in the experiment: in 2019 and 2020 - sugar sorghum (*Sorghum bicolor* (L.) Moench), variety Galia, in 2021 and 2022 - sorghum-sudan hybrid (*Sorghum xdrummondii* (Steud.) Millsp. & Chase), variety Navigator of the North Caucasus Federal Scientific Agrarian Center selection.

The climate of the Omsk region is characterized by sharp continentality, lack of precipitation, air dryness, cold and long winter, and hot summer. Growing periods in the years of research were characterized by different heat and moisture availability (see Table 2). Thus, in 2019 the largest amount of precipitation fell, the sum of which for the vegetation period amounted to 239 mm. At the same time in the initial period of vegetation (May and June) there was a uniform inflow of heat and moisture (104.0 – 165.0% of the norm). In 2020, the total precipitation amounted to 173 mm. In May, we observed a shortage of precipitation (56.0%) and increased air temperature (4.9 °C). June was relatively favorable in terms of heat and moisture. July was characterized by hot and dry weather. August and September were balanced in terms of heat and moisture availability.

May 2021 was dry. June was colder than a multiyear average and was characterized by a deficit of precipitation (86.0%). July and August were warmer than usual by 1.3 and 2.1 °C. Precipitation availability in these months was 51.0 and 76.0%, respectively. September was cool with precipitation close to the mean annual precipitation. The sum of precipitation for the vegetation period reached 168 mm.

In 2022, the total moisture inflow for May – September was the highest (256 mm) compared to the preceding period. The main amount of precipitation (more than 90 mm) fell on July 28 and 29. Harsh growing conditions were observed during the initial period of sorghum crops vegetation. May and practically the whole June were dry and hot. Similar conditions were observed in I and II ten-day periods of July. In August and September, the air temperature was close to the mean annual value, amounting to 65.0 and 133.0% of the norm, respectively.

Табл. 1. Схема полевого опыта
Table 1. Scheme of the field experiment

Fertilizer	Option
Phosphorus (factor A)	No fertilizers (P_0), control
	With the introduction of P_{60}
Nitrogen (factor B)	No fertilizers (N_0), control
	With the introduction of N_{30}
	With the introduction of N_{60}

Табл. 2. Среднемесячная температура воздуха и месячная сумма осадков в разные вегетационные периоды

Table 2. Average monthly air temperature and monthly sum of precipitation in different vegetation periods

Month	2019		2020		2021		2022	
	Temperature, °C	Precipitation amount, mm	Temperature, °C	Precipitation amount, mm	Temperature, °C	Precipitation amount, mm	Temperature, °C	Precipitation amount, mm
May	12,2	37	13,0	13	17,3	13	15,3	11
June	15,5	85	18,0	45	16,9	45	17,3	53
July	20,5	29	19,4	33	20,6	33	19,9	116
August	17,9	40	17,0	42	19,1	42	16,8	37
September	10,8	48	11,5	40	9,5	35	11,2	39
Total	–	239	–	173	–	168	–	256

Note. Compiled on the basis of the data from the Ob-Irtysh Department of Hydrometeorology and Environmental Monitoring.

RESULTS AND DISCUSSION

Drought conditions pose a serious threat to agricultural production, negatively affecting all stages of plant growth (especially the early phases of development) [15]. The water ratio in plants is largely determined by the content of available moisture in the soil, which directly affects the conductance of stomata, leaf area, CO_2 assimilation, light absorption and photosynthesis [16].

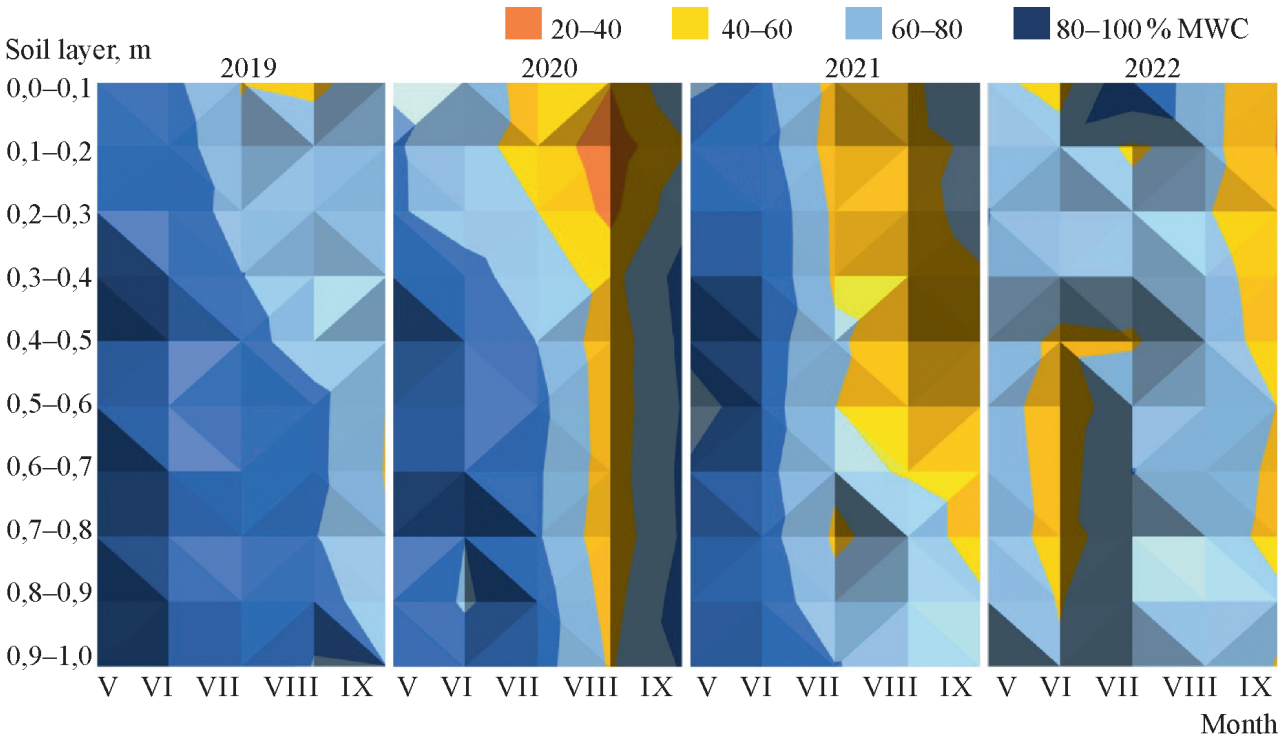
The content of total moisture in the soil is determined by the amount of heat and moisture during the growing season. The dynamics of total moisture content in the soil for the years of the study is presented in the figure. Thus, in 2019, the most favorable in terms of moisture content, the soil profile had a more stable and uniform moisture content, especially in the second half-meter. In subsequent years, the deficit of atmospheric moistening was vividly manifested in the content of total moisture both across the soil profile and over time. Depletion of the meter profile even in the initial period of vegetation was noted in 2022 as a consequence of low residual moisture in the preceding also dry season.

The initial nitrate nitrogen content in the arable layer (0.0-0.2 m) before sowing sugar sorghum after soybean was low (13.7 mg/kg), mobile phosphorus – medium (77.5 mg/kg), exchangeable potassium – very high (195.1 mg/kg). After harvesting, residual nitrate nitrogen was high regardless of the preceding cultural practices, which is a consequence of unstable moistening during the growing season and incomplete utilization of macronutrients by the crop (see Table 3). For phosphorus, the previously established differentiation with high content of mobile element at systematic application of phosphorus-containing fertilizers to crops of crop rotation is obvious.

Before sowing sorghum-sudan hybrid after fodder beans, nitrate nitrogen availability was estimated as high – 29.6 mg/kg. The content of mobile phosphorus and exchangeable potassium was medium and very high, respectively.

After harvesting sorghum-sudan hybrid the amount of nitrate nitrogen decreased, indicating a higher removal of it by the crop. Concentration of mobile phosphorus in the control was average, in the fertilized variant it was higher, which is also the result of a positive balance of phosphorus in the fertilized variants of the crop rotation. The content of mobile potassium was predominantly high, which is typical for this soil.

Under such conditions, sugar sorghum responded positively to the optimization of mineral nutrition conditions. Pre-sowing application of phosphorus fertilizers provided an increase in the yield by 1.25 t/ha (27.7%) on average for factor A. Pre-sowing application of nitrogen fertilizers increased dry matter content by 0.63-0.99 t/ha (13.7 – 21.6%) compared to the control (see Table 4).



Содержание общей влаги (% от наименьшей влагоемкости) в различных слоях лугово-черноземной почвы в период вегетации

Total moisture content (% of the minimum water capacity) in different layers of meadow-chernozem soil during the growing season

The most effective was the complex application of mineral fertilizers in sorghum crops, which provided an increase in the yield by 3.97-6.08 t/ha (53.0%). Sorghum-sudan hybrid also responded positively to the improvement of mineral nutrition conditions. Thus, application of P_{60} increased the yield by 0.72 t/ha (21.3%) on average for factor A (see Table 5). The positive effect of nitrogen fertilizers was noted due to the increase in dry matter content from 3.08 to 3.97– 4.23 t/ha (28.7– 37.3%). The combination of the studied factors increased the yield from 2.81 to 4.73 t dry matter/ha (68.3%).

Strengthening of fodder base is associated with the growth of fodder crop yields. In our field experiments, the maximum yield of sugar sorghum green mass on intensive background was 21.07 t/ha, sorghum-sudan hybrid – 16.62 t/ha, which is higher than the control by 47.2 and 62.7%, respectively.

Табл. 3. Содержание элементов минерального питания в пахотном слое почвы, мг/кг
Table 3. Content of mineral nutrition elements in the arable soil layer, mg/kg

Option	Before sowing			After harvesting		
	$N–NO_3$	P_2O_5	K_2O	$N–NO_3$	P_2O_5	K_2O
Sugar sorghum (2019 and 2020 average)						
No fertilizers	13,7	77,5	195,1	22,0	95,0	193,4
$N_{60}P_{60}$				17,6	162,5	125,1
Sorghum-sudan hybrid (average for 2021 and 2022)						
No fertilizers	29,6	95,6	204,8	10,2	68,4	163,5
$N_{60}P_{60}$				15,3	147,4	172,1

Табл. 4. Урожайность сорго в зависимости от изучаемых факторов, т сух. в-ва/га
Table 4. Sorghum yield depending on the studied factors, t/ha of dry matter

Fertilizers		Year		Average	Addition to the control	
phosphorus (factor A)	nitrogen (factor B)	2019	2020		t/ha	%
P_0	N_0 (control)	2,34	5,61	3,97	–	–
	N_{30}	2,70	7,66	5,18	1,21	30,4
	N_{60}	2,64	6,09	4,36	0,39	9,8
	Average	2,56	6,45	4,51	–	–
P_{60}	N_0	3,88	6,54	5,21	1,23	31,1
	N_{30}	3,92	8,04	5,98	2,01	50,6
	N_{60}	3,70	8,46	6,08	2,11	53,0
	Average	3,83	7,68	5,76	1,25	27,7
Background average	N_0	3,11	6,07	4,59	–	–
	N_{30}	3,31	7,85	5,58	0,99	21,6
	N_{60}	3,17	7,28	5,22	0,63	13,7
	Average	3,20	7,07	5,13	–	–
LSD_{05} for factor A		0,52	0,79	0,66	–	–
LSD_{05} for factor B		0,64	0,97	0,81	–	–
LSD_{05} for individual differences		0,90	1,38	1,14	–	–

Табл. 5. Урожайность сорго-суданкового гибрида в зависимости от изучаемых факторов, т сух. в-ва/га
Table 5. Yield of sorghum-sudangrass hybrid depending on the studied factors, t/ha of dry matter

Fertilizers		Year		Average	Addition to the control	
phosphorus (factor A)	nitrogen (factor B)	2021	2022		t/ha	%
P_0	N_0 (control)	2,78	2,84	2,81	–	–
	N_{30}	3,12	4,17	3,65	0,84	30,0
	N_{60}	4,28	3,19	3,73	0,93	33,1
	Average	3,39	3,40	3,40	–	–
P_{60}	N_0	3,60	3,11	3,36	0,55	19,6
	N_{30}	5,48	3,08	4,28	1,47	52,5
	N_{60}	5,59	3,86	4,73	1,92	68,4
	Average	4,89	3,35	4,12	0,72	21,3
Background average	N_0	3,19	2,97	3,08	–	–
	N_{30}	4,30	3,63	3,97	0,88	28,7
	N_{60}	4,93	3,53	4,23	1,15	37,3
	Average	4,14	3,38	3,76	–	–
LSD_{05} for factor A		1,57	0,68	1,13	–	–
LSD_{05} for factor B		1,92	0,84	1,38	–	–
LSD05 for individual differences		2,72	1,19	1,96	–	–

CONCLUSION

As a result of the study, it was found that sorghum crops are well adapted to different growing conditions, therefore, they are suitable for use in field forage production under insufficient and unstable moisture, typical for the south of Western Siberia. High responsiveness of sorghum crops to the use of mineral fertilizers was revealed. The low cost of agrotechnology of this crop is due to a small seeding rate (20 kg/ha) and good resistance to diseases.

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ВЛИЯНИЕ РАЗЛИЧНЫХ СИСТЕМ ЗАЩИТЫ НА ФИТОСАНИТАРНУЮ СИТУАЦИЮ В ПОСАДКАХ ЦВЕТНЫХ СОРТОВ КАРТОФЕЛЯ

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Представлены результаты исследований по влиянию различных систем защиты на фитосанитарную ситуацию в посадках цветных сортов картофеля в условиях Новосибирской области. Установлено, что химический протравитель Селест Топ более эффективно снижает развитие ризоктониоза в сравнении с биопрепаратом Бактофорт. В среднем данный показатель при использовании химической системы был в 4,8 раза достоверно ниже в фазу всходов и в 2,0 раза – в период бутонизации – начала цветения культуры. Установлено значимое влияние оптимизации минерального питания для биологического препарата Бактофор, в этом случае на фоне с минеральными удобрениями развитие ризоктониоза в 1,2 раза ниже. В фазе бутонизации – начала цветения развитие болезни на удобренном фоне при использовании химической системы защиты отмечено достоверно выше в 1,4 раза в сравнении с фоном естественного плодородия, при биологизированной системе в этот период данный показатель не имеет различий. Численность колорадского жука при использовании химической системы была существенно ниже (в 3,6 раза) в сравнении с биологизированной. Оптимизация минерального питания при использовании химической системы защиты достоверно повышала численность вредителя в 5,0 раза в сравнении с фоном естественного плодородия, при биологизированной системе данный показатель не имеет существенных различий. Продуктивность культуры достоверно выше при использовании химической системы защиты в сравнении с биологизированной в 1,5 раза. На удобренном фоне при использовании химической системы защиты продуктивность картофеля существенно выше (в 1,2 раза) в сравнении с фоном естественного плодородия, при биологизированной системе данный показатель не имеет значимых различий. Отмечена индивидуальная реакция сортов на изученные защитные приемы. Среди четырех изученных сортов выделен All Red, у которого развитие ризоктониоза на стеблях было наименьшим среди всех сортообразцов на обеих системах защиты при обоих уровнях минерального питания. Менее всего поражены колорадским жуком сорта All Red и Фиолетовый – в среднем 0,50–0,55 экз./растение. Наибольший урожай получен при выращивании сорта Rosemaria (в среднем по фактору 22,3 т/га). Для борьбы с ризоктониозом и колорадским жуком на картофеле можно использовать биологизированные системы защиты, но с учетом биологических особенностей сортов.

Ключевые слова: цветные сорта картофеля, ризоктониоз, колорадский жук, система защиты растений, фитосанитарная ситуация

INFLUENCE OF DIFFERENT PROTECTION SYSTEMS ON PHYTOSANITARY SITUATION IN PLANTINGS OF COLORED POTATO VARIETIES

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The results of the studies on the influence of various protection systems on the phytosanitary situation in planting colored potato varieties in the conditions of the Novosibirsk region are presented. It

has been established that the chemical protectant Celest Top more effectively reduces the development of rhizoctoniosis (black scab) in comparison with the biological preparation Bactofort. On average, this indicator when using the chemical system was significantly lower by 4.8 times in the germination phase, and 2.0 times lower in the period of budding-beginning of flowering of the culture. A significant influence of the optimization of mineral nutrition for the biological preparation Bactofort was established, in this case, against the background of mineral fertilizers, the development of rhizoctoniosis is 1.2 times lower. In the phase of budding – the beginning of flowering the disease development on the fertilized background with the use of chemical system of protection is marked significantly higher by 1.4 times in comparison with the background of natural fertility, with the biological system in this period this indicator has no differences. The number of the Colorado potato beetle when using the chemical system was significantly lower by 3.6 times in comparison with the biologized one. Optimization of mineral nutrition with the use of a chemical protection system significantly increased the number of the pest by 5.0 times in comparison with the background of natural fertility, while with a biological system this indicator does not have significant differences. The productivity of the culture is significantly higher when using a chemical protection system in comparison with a biologized one by 1.5 times. On a fertilized background, when using a chemical protection system, the productivity of potatoes is significantly higher by 1.2 times in comparison with the background of natural fertility. At the same time, with a biologized system, this indicator does not have significant differences. Individual reaction of the varieties to the studied protective techniques has been noted. Among the four varieties studied, All Red should be singled out, in which the development of rhizoctoniosis on the stems on both protection systems at both levels of mineral nutrition was generally the smallest among all variety samples. The varieties All Red and Violet were the least populated by the Colorado potato beetle – an average of 0.50–0.55 ind./plant. The highest yield was obtained when growing the Rosemaria variety (average factor 22.3 t/ha). To control rhizoctoniosis and Colorado potato beetle on potatoes, it is possible to use biological protection systems, but taking into account the biological characteristics of the varieties.

Keywords: colored potato varieties, black scab, Colorado potato beetle, system of plant protection, phytosanitary situation

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The authors declare no conflict of interest.

INTRODUCTION

Development of various methods of plant protection aimed at providing the population of the Russian Federation with ecologically safe food products, in particular potatoes, is one of the important directions in the branch of agriculture.

The most promising link in the development of modern plant protection is research aimed at studying the peculiarities of natural self-regulation of the number of harmful and useful species, at quantitative assessment of the parameters of biocenotic processes under the influence of various anthropogenic impacts in agrobiogeocenoses. The basis of any system of optimization of phytosanitary situation should be ecologically safe and economically effective methods of regulation of harmful species[1] [1–3].

[1]*Aliev Sh.A., Shakirov V.Z.* Biologization of farming - the requirement of time // Agrochemical Herald, 2000, N 4, pp. 21-23.

Potato is one of the most important agricultural crops, but the annual shortage of its yield from pests is about 25– 30%, in some years – 50% and more. Currently existing systems of measures to control potato diseases and pests are mainly based on intensive use of chemical preparations. Their use increases every year, which leads to negative impact on agrocenoses and human health. The use of biological preparations alone does not give the same high protective effect against pathogens as the use of chemical pesticides. Not a single known potato variety has absolute resistance to pests, especially infections caused by fungal pathogens. In this regard, the integrated use of modern pest control agents (biological preparations and chemical pesticides - less toxic and with low rates of consumption), new tolerant varieties, as well as various resistance inducers is becoming increasingly important in optimizing the phytosanitary situation in potato plantings.

One of the most environmentally safe and economically beneficial ways to stabilize the phytosanitary condition of potato plantings is a properly selected variety, which due to its biological characteristics and anthropogenic influences fully realizes its potential in the soil and climatic conditions of the region of cultivation.

For example, varieties Charodey and Skazka in the conditions of the northern forest-steppe of the Tyumen region were the most resistant to diseases. They yielded 28.3– 28.5 t/ha (higher than the standard Lina by 3.9– 4.1 t/ha and higher than foreign varieties Colomba and Red Scarlet by 7.6– 7.9 t/ha), which makes it possible to effectively cultivate them both with the use of chemical plant protection products and biological preparations [4].

Biological features of the variety can also be used to optimize the phyto-sanitary condition of potato plantings from pests, such as Colorado potato beetle. For this purpose, it is possible to use low-attractive for phytophage, hardy to the pest and yielding zoned and widespread varieties. Thus, in the conditions of the Novosibirsk region, such varieties include Adretta, Zhukovsky ranniy, Svitanok Kievsky, and Yugana[2].

Plant protection is one of the important reserves in increasing potato yields and quality of products. However, the reaction of varieties to the means of chemicalization can be different, as they react differently to the damage caused to them by phytophages and phytopathogens [4, 5]. Varieties, having unequal resistance to the impact of harmful organisms, specificity of ecological relations with the environment, require an individual approach when choosing each agrotechnical method of cultivation, including the system of protective measures [6, 7].

Potato cultivation and obtaining high yields are nowadays mainly associated with the use of chemical plant protection products. However, the effects of pesticides are not unambiguous: these substances can be toxic, carcinogenic and mutagenic. At the same time, biopreparations have a pronounced selectivity of action, quickly decompose in soil, water, under the influence of sunlight, do not cause, unlike chemical preparations, the effect of resistance. Therefore, one of the directions of improvement of potato production and its quality is stabilization of phytosanitary condition of potato plantings at the expense of resistant, tolerant and low-attractive varieties, as well as expansion of biological preparations and improvement of methods of their use [8–12].

Bio-ecological features of the main organisms harmful to potatoes in Western Siberia are such that the use of separate protective measures is ineffective. In this case, an integrated approach to their control is necessary, including the use of varieties, agrotechnical measures, as well as chemical and biological methods of plant protection. The use of these basic elements will optimize the phytosanitary situation in potato production, including colored varieties, which are new for Western Siberia, as well as to obtain environmentally safe products of proper quality.

The purpose of the study was to investigate the effect of different plant protection systems on the phytosanitary situation in plantings of

[2]Potato variety as a way to optimize the phytosanitary condition of crop plantings in relation to Colorado potato beetle / A.A. Malyuga, N.S. Chulikova, N.A. Omelchenko. Novosibirsk: Rosselkhozakademia. SibNIIZIKh, 2012, 16 p.

colored potato varieties with respect to rhizoctoniose and Colorado potato beetle.

MATERIAL AND METHODS

The studies were conducted in 2020, 2021 in soil and climatic conditions typical for the forest-steppe zone of Western Siberia.

Meteodata of the growing seasons 2020 and 2021 differed from mean annual values both in temperature regime and precipitation amount (see Table 1). May in both seasons was particularly distinguished by temperature and moisture regime. The air temperature in this month exceeded the mean multiyear values by 5.9 and 4.0 ºC for the second and third ten-day periods in 2020 and 2021, respectively; the atmospheric moisture inflow was on average 1.3 times higher than the multiyear average (in 2020) and 1.2 times lower (in 2021) than the mean multiyear values. In both years in June and July, the average monthly temperature indices were close to the norm. The amount of precipitation on average in June 2020 was 2.4 times below the multiyear average, in 2021 – 1.3 times above the multiyear average. In July 2020 the amount of precipitation was 1.2 times higher than the long-term average, in 2021 – 3.2 times lower. August was quite warm in both years – the average monthly air temperature exceeded the mean annual values by 2.2–3.0 ºC. Atmospheric moisture inflow for the month in 2020 was 1.2 times higher than the multiyear average, while in 2021 precipitation was at the level of mean annual values.

Soil cover of the research site is represented by typical for the region chernozem leached medium loamy with agrochemical characteristics of arable layer of soil (0-30 cm): humus (according to Tyurin) – about 5.0%; content of total nitrogen – 0.34% (according to Kjeldahl), phosphorus and potassium (according to Chirikov) – 29.0 and 13.0 mg per 100 g of soil respectively; pH = 6,7–6,8.

The main elements of potato cultivation technology correspond to those generally accepted for this region[3].

Табл. 1. Метеоданные вегетационного периода 2020, 2021 гг. (ГМС «Огурцово» Новосибирского района Новосибирской области)

Table 1. Meteorological data for the growing season 2020, 2021 (HMS Ogurtsovo, Novosibirsk district, Novosibirsk region)

Month	10-day period	Air temperature, ºC			Precipitation, mm		
		2020	2021	Long-time average annual	2020	2021	Long-time average annual
May	II	19,7	14,8	10,0	1,4	13,3	12,0
	III	15,2	16,4	13,2	32,0	8,5	13,0
	Average/total	17,5/	15,6/	11,6/	/33,4	/21,8	/25,0
June	I	13,9	16,6	15,4	16,0	21,9	13,0
	II	16,2	17,3	16,7	7,8	2,3	20,0
	III	19,7	14,6	18,1	0,0	48,9	25,0
	Average/total	16,6/	16,2/	16,7/	/23,8	/73,1	/58,0
July	I	21,2	20,4	19,1	32,0	18,0	19,0
	II	21,2	18,8	18,9	8,9	4,1	26,0
	III	17,0	20,0	18,9	44,0	0,3	27,0
	Average/total	19,8/	19,7/	19,0/	/84,9	/22,4	/72,0
August	I	21,5	19,7	17,9	14,0	25,1	24,0
	II	18,9	16,8	16,0	43,0	36,8	20,0
	III	16,0	17,6	13,5	25,0	5,4	22,0
	Average/total	18,8/	18,0/	15,8/	/82,0	/67,3	/66,0

[3]Vegetable crops and potatoes in Siberia / compilers: G.K. Mashyanova, E.G. Grinberg, T.V. Steinert. Novosibirsk: RAAS. SibNIIRS, SSI SRO, 2010, pp. 496-507.

The experiment was three-factor: factor A – mineral nutrition level (no fertilizer and $N_{40}P_{40}K_{80}$); B – color potato variety (Purple, Purple Majesty, All Red and Rosemaria); C – plant protection (biological and chemical). Repetition of the experiment was 2-fold. Planting density 35.7 thousand plants/ha.

In the biological system of potato protection, the seed material was treated before planting with the biopreparation Bactofort, L (content of live cells of bacteria *Bacillus subtilis*, *B. amiloliquefaciens* not less than 5.0×10^9 CFU/ml of viable cells by the end of storage, consumption rate 2.0–2.5 l/t); during the growing season Bactofort, L (consumption rate 2.0–3.0 l/ha) was also applied 3 times with an interval of 7–10 days).

Under the chemical system of protection, spring dressing of planting tubers with insecticide Celest Top, SC (262.5 g/l + 25 g/l + 25 g/l, application rate 0.4 l/t) was carried out; during the growing season, plantings were treated with fungicide Revus Top, SC (250.0 g/l + 250.0 g/l, application rate 0.6 l/ha).

In both protection systems, weed control was carried out using herbicides Metrifar 70, WSG (700 g/kg, application rate 0.7– 1.4 l/ha) and Boxer, EC (800 g/l, application rate 3– 5 l/ha). During vegetation after flowering, the crop was treated 3 times (10-15 days apart) with a complex water-soluble microfertilizer Polygro Universal ($N_{19}P_{19}K_{19}$ + 1 Mg + 0.02 B, 0.011 Cu, 0.130 Fe, 0.05 Mn, 0.007 Mo, 0.015 Zn, application rate 5 – 6 kg/ha).

Observations on the dynamics of pests were conducted on a natural background (sclerotial index of seed tubers in Purple Majesty variety was 1.2, Purple – 1.6, All Red – 2.6 and Rosemaria – 2.2). Rhizoctoniose development was determined according to Frank's method[4], Colorado potato beetle abundance was determined according to generally accepted methods[5, 6].

The results of the experiments were processed using the application program package Snedecor[7].

RESULTS AND DISCUSSION

The development of rhizoctoniose on flowering varieties grown with the use of chemical plant protection products is significantly lower than with the use of biopreparations (see Table 2).

On average, this indicator when using the chemical system was significantly lower in 4.8 times in the sprouting phase, and in 2.0 times – in the period of budding – the beginning of flowering of the crop.

Infection of stolons by potato rhizoctoniose pathogen was also lower when using chemical dressing Celest Top in comparison with biological preparation Bactofort, but this difference was insignificant and amounted to an average of 4.0% during the growing season.

On average, the mineral nutrition background factor can be noted that it does not affect the effectiveness of chemical dressing agent against rhizoctoniose at the first stages of ontogenesis.

At the same time, a significant influence of mineral nutrition optimization for biological preparation Bactofort was established, in this case on the background with mineral fertilizers the development of rhizoctoniose was 1.2 times lower. In the future (budding phase - beginning of flowering) the development of the disease on the fertilized background with the use of chemical protection system was significantly higher in 1.4 times compared to the background of natural fertility, while in this period with the biological system this indicator has no differences.

Individual response of the varieties to the studied protection methods should also be noted. Thus, among the four varieties studied, All Red should be singled out, in which the development

[4]*Frank J., Leach S.S., Webb R.E.* Evaluation of potato clone reaction to *Rhizoctonia solani* // Plant dis. Reporter, 1976, vol. 60, N 11, pp. 910–912.

[5]Methodology of research on potato culture. Moscow: SRIPF, 1967, 264 p.

[6]Methodological recommendations on indication and monitoring of adaptation processes of Colorado potato beetle to genetically modified potato varieties. St. Petersburg, 2005, 48 p.

[7]*Sorokin O.D.* Applied statistics on the computer. Novosibirsk, 2012, 282 p.

Табл. 2. Влияние сорта и комплекса агротехнологических приемов на развитие ризоктониоза (средние за 2020, 2021 гг.), %

Table 2. Influence of the variety and the complex of agrotechnological techniques on the development of black scab (average for 2020, 2021), %

Option	Mineral nutrition background							
	No fertilizers				Fertilizer $N_{40}P_{40}K_{80}$			
	Variety							
	PM	AR	P	RM	PM	AR	P	RM
Full sprouting phase								
CPS	0,0	3,9	11,1	8,9	0,0	0,0	18,4	12,3
BPS	46,3	10,4	61,6	25,5	42,6	29,2	28,0	20,0
LSD_{05}	By factors: mineral nutrition – 1.2, variety – 1.7, protection – 1.2, partial averages – 3.4							
Budding phase - beginning of flowering								
CPS	13,5	13,1	23,6	27,1	19,5	16,4	30,2	42,5
BPS	48,2	40,8	52,1	45,5	45,6	41,6	55,8	39,7
LSD_{05}	By factors: mineral nutrition – 4.0, variety – 5.7, protection – 4.0, partial averages – 11.4							

Hereafter, PM is the potato variety Purple Majesty, AR is All Red, P is Purple, and RM is Rosemaria, CPS - chemical protection system, BPS - biological protection system.

of rhizoctoniose on the stems on both systems of protection at both levels of mineral nutrition was generally the lowest among all the varieties.

On average, the number of Colorado potato beetle when using the chemical system was significantly lower (3.6 times) compared to the biological system. On average for mineral nutrition background, it can be noted that on fertilized background when using chemical system of protection, the number of the pest is significantly higher in 5.0 times compared to the background of natural fertility, while with biological system this indicator does not have significant differences. The least infested by Colorado potato beetle was the variety All Red (average factor 0.5 specimens / plant), Purple differed little from the above variety – this indicator was 0.55 specimens / plant, on Rosemaria and Purple Majesty it was significantly higher (1.3–1.5 and 1.7–1.9 times, respectively) in comparison with the first two varieties. The chemical dressing Celest Top was more effective against the phytophagus, significantly reducing the pest abundance by 3.4 times (average factor 0.3 specimens / plant) compared to the bioinsecticide Fitoverm (1.1 specimens / plant). The combined effect of variety characteristics and protection variant on Colorado potato beetle abundance is additive on average. In most cases, the number of the pest was higher on the varieties grown with the use of biological protection system. Thus, the number of phytophagus was significantly higher when plants were treated with bioinsecticide (Purple Majesty – 1.5 times, Purple – 6.3 times, Rosemaria – 8.7 times and All Red – 9.0 times) compared to chemical insecticide. The exception was Purple Majesty variety, where the number of insects was the same on both protection systems when using Fitoverm insecticide (see Table 3).

On average for the factor of protection system, the crop yield was also significantly higher with the use of chemical protectant 1.5 times (chemical protectant Celest Top - 19.5 t/ha, bioinsecticide Fitoverm - 12.8 t/ha).

On average for the background of mineral nutrition it can be noted that on fertilized background when using chemical protection system potato productivity is significantly higher (1.2 times) compared to the background of natural fertility. At the same time at the biologized system this indicator has no significant differences. The highest yield was obtained when growing

the variety Rosemaria (average factor 22.3 t/ha). In the varieties All Red and Purple this indicator was significantly less than the above-mentioned variety in 1.5 and 1.3 times, respectively, in Purple Majesty – in 1.8 times. The joint influence of variety features, mineral nutrition and protection variant on average has an additive character. In most cases, crop productivity was higher on the varieties grown with the use of chemical protection system. Thus, this indicator was significantly lower when potatoes were treated with bioinsecticide (Purple Majesty – 1.6 times, Purple – 2.7 times, Rosemaria – 1.2 times and All Red – 1.5 times) in comparison with chemical insecticide. Rosemaria variety should be emphasized, which turned out to be the most tolerant, yield losses in this case amounted to 16.1%. In the varieties Purple, Purple Majesty and All Red this indicator amounted to 63.1; 38.8 and 34.9% (see Table 4).

CONCLUSION

Chemical plant protection agents used to optimize the phytosanitary situation in plantings of colored potato varieties reduced the development of rhizoctoniosis in 2.0–4.8 times compared to biological ones. Biological preparations (at the first stages of ontogenesis) at optimization of mineral nutrition of plants allow to reduce the development of this disease in 1.2 times in comparison with the background of natural fertility. In the variety All Red the development of rhizoctoniose on the stems on both systems of protection at both levels of mineral nutrition was the lowest among all the studied variety samples.

The number of Colorado potato beetle when using the chemical system was significantly lower in 3.6 times compared to the biological system. On the fertilized background when using the chemical system of protection, the number of the pest was significantly higher in 5.0 times

Табл. 3. Влияние сорта и комплекса агротехнологических приемов на среднюю за вегетацию численность колорадского жука (имаго и личинки) (средние за 2020, 2021 гг.), экз./растение

Table 3. Influence of the variety and the complex of agrotechnological techniques on the average number of Colorado potato beetles (imago and larvae) during the growing season (average for 2020, 2021), specimen/plant

Option	Mineral nutrition background							
	No fertilizers				Fertilizer $N_{40}P_{40}K_{80}$			
	Variety							
	PM	AR	P	RM	PM	AR	P	RM
	Full sprouting phase							
CPS	0,1	0,1	0,1	0,1	1,4	0,1	0,2	0,2
BPS	0,9	1,0	0,8	1,4	1,4	0,8	1,1	1,2
LSD_{05}	By factors: mineral nutrition – 0.2, variety – 0.2, protection – 0.2, partial averages – 0.5							

Табл. 4. Влияние сорта и комплекса агротехнологических приемов на урожайность картофеля (средние за 2020, 2021 гг.), т/га

Table 4. Influence of the variety and the complex of agrotechnological techniques on potato yield (average for 2020, 2021), t/ha

Option	Mineral nutrition background							
	No fertilizers				Fertilizer $N_{40}P_{40}K_{80}$			
	Variety							
	PM	AR	P	RM	PM	AR	P	RM
	Full sprouting phase							
CPS	14,5	16,5	18,2	22,5	16,9	19,8	21,6	26,0
BPS	11,4	11,9	8,4	18,1	7,7	11,8	10,7	22,6
LSD_{05}	By factors: mineral nutrition – 0.8, variety – 1.1, protection – 0.8, partial averages – 2.3							

compared to the background of natural fertility, while with the biological system this indicator does not have significant differences. The number of Colorado potato beetle on the varieties All Red and Purple was significantly lower (1.3-1.9 times) compared to the varieties Rosemaria and Purple Majesty. Chemical protection system significantly increased crop yield by 1.5 times.

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УСТОЙЧИВЫЕ ОБРАЗЦЫ КУКУРУЗЫ К ВОСТОЧНОМУ КУКУРУЗНОМУ МОТЫЛЬКУ В ПРИМОРСКОМ КРАЕ

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Изучено 65 образцов экологического питомника кукурузы с целью определения их устойчивости к восточному кукурузному мотыльку (*Ostrinia furnacalis* Guenee) на естественном фоне заселения вредителем для селекции на энтоиммунитет и производственных целей. Эксперимент проведен в 2019–2021 гг. в условиях Приморского края. Изучены три составляющие устойчивости образцов кукурузы к вредителю. В результате исследований выделились 30 гибридов кукурузы как менее поврежденные (отмеченные стеблевой устойчивостью). Дана характеристика наиболее устойчивых из них (по баллу общей поврежденности). По привлекательности растений кукурузы для яйцекладущих самок мотылька выделились 2 гибрида с наименьшей заселенностью (10%). Как менее привлекательные отмечены гибриды Ньютон и Р 9300. Выносливостью к повреждениям вредителя (с незначительным сломом стебля и ножки початка) характеризовались 12 образцов кукурузы. Из них наиболее толерантными оказались гибриды LK-0,5 и Р 9300. В результате исследований выделены перспективные сорта и гибриды отечественной селекции НУР, Ладожский 301 АМВ, Ладожский 410 МВ, Ньютон, Байкал. Эти гибриды экологического питомника кукурузы отличаются не только устойчивостью к повреждениям вредителя, но и к другим биотическим и абиотическим стрессам в условиях Приморского края. Урожайность выделенных гибридов варьировала от 4,2 до 7,4 т/га, районированного сорта Славянка – в среднем 5,5 т/га. Стандартный сорт кукурузы Славянка отмечен как толерантный. По степени поврежденности он относится к группе среднеустойчивых образцов. Устойчивые гибриды кукурузы составили группу раннеспелых и среднеранних образцов.

Ключевые слова: кукуруза, восточный кукурузный мотылек, устойчивость, экологический питомник, сорта, гибриды, селекция

CORN SPECIMENS RESISTANT TO ASIAN CORN BORER IN THE PRIMORSKY TERRITORY

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Sixty-five samples of ecological corn nursery were studied to determine their resistance to the Asian corn borer (*Ostrinia furnacalis* Guenee) on the natural background of pest infestation for selection for entoimmunity and production purposes. The experiment was conducted in 2019–2021 in the conditions of the Primorsky Territory. Three components of pest resistance of corn samples were studied. As a result of the research, 30 corn hybrids were singled out as less damaged (marked by stalk resistance). Characterization of the most resistant of them (by total damage score) is given. According to the attractiveness of the corn plants for egg-laying female moths, there were 2 hybrids with the lowest pest colonization (10%). Hybrids Newton and P 9300 were noted as less attractive. Twelve corn accessions were characterized by tolerance to pest damage (with insignificant stem and cob stem breakage). Of these, hybrids LK-0.5 and P 9300 were the most tolerant. As a result of research, prom-

ising varieties and hybrids of domestic selection NUR, Ladozhsky 301 AMV, Ladozhsky 410 MV, Newton, Baikal were identified. These hybrids of ecological corn nursery are characterized not only by resistance to pest damage, but also to other biotic and abiotic stresses in the conditions of Primorsky Territory. Yields of the selected hybrids varied from 4.2 to 7.4 t/ha, the released variety Slavyanka – on average 5.5 t/ha. The standard corn variety Slavyanka was noted as tolerant. According to the degree of damage, it belongs to the group of medium resistant samples. Resistant corn hybrids made up the group of early-ripening and middle-early specimens.

Keywords: corn, Asian corn borer, resistance, ecological plant nursery, varieties, hybrids, breeding

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INTRODUCTION

At present, the area under corn for grain is increasing, which indicates an increased interest in the cultivation of this crop in the different districts of the Primorsky Territory. For this reason, the selection of hybrids and varieties of this crop is actively carried out. The objectives of corn breeding are to increase the stability of the varieties in a variety of environmental conditions of cultivation and to increase their ability to maintain maximum yield in different growing conditions. According to scientists, breeding only for high productivity does not provide an opportunity to obtain stable crop yields under unfavorable weather conditions. In this regard, no less important direction of breeding is to achieve a combination of high yield with resistance to natural (biotic and abiotic) stresses [1, 2].

Pests have a significant impact on the yield and quality of corn. One of the most dangerous and widespread pests of corn in the world is the European corn borer (*Ostrinia nubilalis* Hbn.). The caterpillars gnaw out passages and cavities in stalks, damage cobs, as a result of which grain yield losses can reach 30–40% [3–10]. Asian corn borer (*Ostrinia furnacalis Guenee*) is also a potentially dangerous pest that causes great harm to corn in the Far East. Expansion of corn crops in the Primorsky Territory contributes to the dispersal of this pest. High air humidity and optimum temperatures lead to an increase in the number of *Ostrinia furnacalis Guenee* in different districts [11].

Various effective pest control measures are being developed to reduce pest damage and abundance. One of such methods is the development of varieties with high productivity, ecological plasticity and resistance to phytophage damage. This allows to obtain grain in large volumes and high quality, to reduce the number of chemical sprays in crops and to solve the environmental issue. Resistant varieties contribute to improving the phytosanitary condition of fields and obtaining a quality guaranteed harvest [2, 12].

The purpose of the study is to evaluate corn samples of ecological nursery, and to select resistant forms to pest damage from it for breeding and production purposes.

MATERIAL AND METHODS

The samples of ecological corn nursery of the Laboratory of Corn Breeding and Primary Seed Production of the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K. Chaiki were evaluated for their resistance to the pest on the natural background of plant infestation by the phytophage according to the methods of the Federal Research Center "N.I. Vavilov All-Russian Institute of Plant Ge-

netic Resources" (VIR) and the All-Russian Institute of Plant Protection (VIZR)[1–3].

10 plants of each sample were evaluated in the nursery. Damage was noted on the registered plants: number of passages in the stem, broom and stem breakage, cob and cob pedicel damage. After that, the following parameters were determined: pest infestation of the plants, %; average number of passages per plant, pcs; number of plants with broken panicle, %; number of plants with broken stem, %; number of plants with damaged cob, %; number of plants with damaged cob stem, %. The degree of attractiveness was estimated according to the scale of pest infestation of the plants (by the number of damaged plants): up to 25% – weak damage; 25-50% – medium damage; 50-75% – strong damage; over 75% – very strong damage. To assess the degree of *Zea mays* resistance to corn moth, the scale of total plant damage (in points) was used. According to this scale, the samples are classified as actually resistant (1–2 points); medium resistant (2.1–3.5 points); insufficiently resistant (3.6–5.0 points); unstable (over 5 points).

Before harvesting evaluation of corn stalk resistance to the Asian corn borer was carried out using the scale according to the method of I.D. Shapiro (see footnotes 2, 3): 1 point – number of moves less than 5; 2 – number of moves 5 and more (panickle breakage, cob lesion); 3 – cob stem lesion; 4 – stem breakage. Then the scores were summarized for each sample, the average was found and the resistance of the hybrid or variety was evaluated according to the scale of total damage.

RESULTS AND DISCUSSION

In 2019-2021 the evaluation of the varieties and hybrids of ecological corn nursery to the Asian corn borer on the background of natural infestation by the phytophage was carried out.

Pest resistance is represented by three components: attractiveness (infestation) of plants to egg-laying females of the pest, antibiosis (protective response of the plants to damage) of forage plants, and varietal hardiness (tolerance) of the crop (see footnote 3).

The attractiveness was evaluated by the presence of corn damage by the local pest population under free choice of feed. The total damage background for the whole period of the studies in the ecological nursery averaged 42.7%. According to the attractiveness scale, this is the average damage (see footnote 1). The lowest attractiveness across the nursery over the study years was 10% in the Newton and R 9300 (2021) specimens. Stem resistance (stem and cob antibiosis) was assessed by the score of total plant damage by the pest (see Fig. 1).

In 2019, of 30 hybrids under study, 8 samples were classified as weakly damaged (see Fig. 1). The table reflects the detailed characterization of damage and stem resistance of the ecological nursery samples that are weakly damaged by corn moth. According to the results of 2019, the most resistant (0–1.0 points) was hybrid LK-0.5 (0.6 points). Ladoga 410 MV hybrid can be noted, which was also characterized by the least damage (1.3 points).

Under 2020 conditions, 11 out of 19 hybrid samples under study showed maximum resistance to the pest. Of these, the lowest score (0.9) was observed in the hybrids PR01 and Ladoga 410 MV. The samples Mashuk 172 MV, R 0074, Ladoga 181 MV, Ladoga 301 AMV were also characterized by low damage (1.0 –1.5 points).

Specimens of the ecological nursery 2021 Newton, Baikal, R 8521, R 9300, and R 9160 showed the greatest resistance. Their damage score varied from 0 to 1.0. The first group of resistance (0–2.0 points) was also composed of 5 hybrids and the standard variety-population Slavyanka.

It is known that resistance of corn stalk and cob stem to breakage contributes to the endurance of the crop plants to this pest (see Fig. 2).

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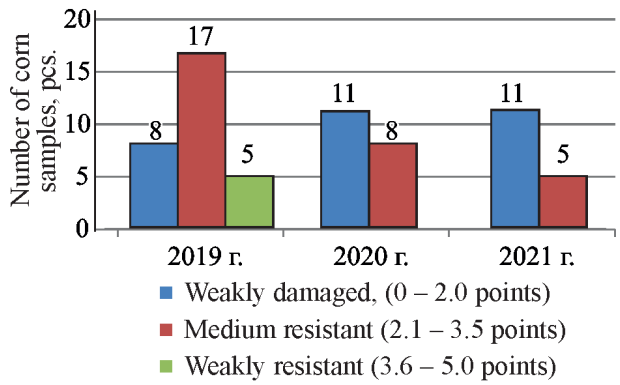

Рис. 1. Результаты оценки устойчивости гибридов и сортов кукурузы питомника экологического сортоиспытания к восточному кукурузному мотыльку (2019–2021 гг.)

Fig. 1. Results of resistance evaluation of the ecological variety testing nursery corn hybrids and varieties to the Asian corn borer (2019–2021)

The mechanical strength of stalk and cob stem was characterized by all the hybrids and varieties of the nursery presented in the table. Damage to the stems of these corn samples amounted to 0-13.3%, cob stalks to 0-13.3% – 0–7,0%.

Hybrids LK-0.5 and R 9300 can be noted, which had no stem and cob stalk breakage (0%). The sample R 9300 was characterized by only a minor panicle breakage (3%).

A dense wrapper, high degree of cob covering by leaves, as well as structural features of starch endosperm of the cob protect the cob from corn damage by corn borer and diseases (see Fig. 3). Such cob properties were possessed by most of the corn samples studied. Their cob damage varied from 0% (Ladoga 301 AMV, Ladoga 410 MV, Baikal) to 20% (R 8500).

CONCLUSION

A number of samples proposed as the breeding material for resistance to the Asian corn borer have been identified during the period of study of the varieties and hybrids of the nursery of ecological varietal testing of corn on the background of natural infestation by the phytophage in 2019-2021. The selected varieties and hybrids of domestic breeding - NUR, Ladoga 301 AMV, Ladoga 410 MV, Newton, Baikal - can also be recommended for production purposes as the

Перспективные и наиболее устойчивые к вредителю образцы кукурузы экологического питомника за период 2019–2021 гг.
Prospective and most pest-resistant corn samples from an ecological nursery for the period 2019–2021

No. of items	Sample	Average lesion score	Number of affected stems, pcs.	Affected, %			
				panickle breakage	stem breakage	cobs	cob stalks
			2019				
1	LK-0,5	0,6	17	17	0	7	0
2	Ladoga 410 MV	1,3	33	30	10	0	0
			2020				
3	PR01	0,9	23	7	10	7	0
4	Ladoga 301 AMV	1,2	33	17	13	0	3
5	Ladoga 410 MV	0,9	20	3	13	0	0
			2021				
6	Newton	0,6	10	3	7	7	0
7	Baikal	0,9	20	7	13	0	0
8	NUR	1,2	33	13	10	10	0
9	P 8500	1,1	23	3	10	20	0
10	P 8521	0,7	20	3	3	7	7
11	P 9300	0,2	10	3	0	3	0
12	P 9160	0,8	20	7	7	3	3
13	P 9874	1,1	27	7	7	13	7

а

б

Рис. 2. Повреждения восточным кукурузным мотыльком стебля (*б*) и ножки початка (*а*) кукурузы

Fig. 2. The stalk (*б*) and stalk of the corn cob (*а*) damage by the Asian corn borer

Рис. 3. Повреждение початка кукурузным мотыльком

Fig. 3. Corn cob damage by the Asian corn borer

most productive and ecologically resistant to changes (stresses) of natural conditions of the Primorsky Territory.

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ОСОБЕННОСТИ РАСПРОСТРАНЕНИЯ И ПРОЯВЛЕНИЯ КРИПТОСПОРИДИОЗА ТЕЛЯТ НА МОЛОЧНЫХ КОМПЛЕКСАХ СИБИРИ

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Представлены результаты исследования особенностей распространения и клинического проявления криптоспоридиоза крупного рогатого скота в ассоциации с возбудителями вирусной и бактериальной природы. С 2014 по 2023 г. исследовали 666 проб биоматериала (слизистая оболочка трахеи, легкие, средостенный и брыжеечный лимфатические узлы, содержимое сычуга и кишечника), отобранных от павших и вынужденно убитых телят в возрасте до 6 мес с признаками энтеритов и респираторных болезней. Обследовали 94 хозяйства шести областей, двух краев Сибирского региона и Республики Казахстан. Результаты исследований подтверждают широкое распространение криптоспоридий среди телят. Чаще всего выявлялись ооцисты *Cryptosporidium parvum,* которые присутствовали в 34 (5,1%) пробах биологического материала от телят в 22 (23,4%) обследованных хозяйствах. Установлено, что ооцисты в моноварианте у животных присутствовали редко (22,7%), чаще (77,3%) обнаруживались в ассоциациях с вирусами и бактериями во время вспышек вирусно-бактериальных инфекций. К инфицированию наиболее восприимчив молодняк до 30-дневного возраста. Новорожденные телята наиболее чувствительны к заражению ооцистами, а переболевшие животные становятся пожизненными источниками возбудителя для восприимчивых животных. Криптоспоридиоз является самостоятельным заболеванием и протекает независимо от наличия вирусов и бактерий в организме и не имеет с ними синергитического взаимодействия, однако наличие и размножение в организме животных этого возбудителя способствует усилению тяжести течения энтеритов у телят и приводит к трудностям в проведении лечебно-профилактических мероприятий. Присутствие криптоспоридий в организме животных необходимо учитывать при проведении комплексных противоэпизоотических мероприятий.

Ключевые слова: крупный рогатый скот, телята, криптоспоридии, энтериты, ассоциации возбудителей, вирусы, бактерии

SPECIFIC FEATURES OF DISTRIBUTION AND MANIFESTATION OF CRYPTOSPORIDIOSIS OF CALVES ON DAIRY COMPLEXES IN SIBERIA

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The results of the study of specific features of distribution and clinical manifestation of bovine cryptosporidiosis in association with pathogens of viral and bacterial nature are presented. From 2014 to 2023, 666 samples of biomaterial (tracheal mucosa, lungs, mediastinal and mesenteric lymph nodes, contents of rennet and intestine) collected from fallen and forcefully killed calves under 6 months of age with signs of enteritis and respiratory diseases were examined. 94 farms of six regions, two territories of the Siberian region and the Republic of Kazakhstan were surveyed. The findings confirm the widespread prevalence of Cryptosporidium in calves. *Cryptosporidium parvum* oocysts were most frequently detected and were present in 34 (5.1%) samples of biological material from calves in 22

(23.4%) of the surveyed farms. It was found that oocysts were rarely (22.7%) present in monovariant in animals, more often (77.3%) they were found in associations with viruses and bacteria during outbreaks of viral-bacterial infections. Young animals under 30 days of age are most susceptible to infection. Newborn calves are most susceptible to infection with oocysts, and those animals that have had the disease become lifelong sources of the pathogen for susceptible animals. Cryptosporidiosis is an independent disease and runs independently of the presence of the viruses and bacteria in the body and has no synergistic interaction with them, but the presence and multiplication in the body of animals of this pathogen contributes to the severity of the course of enteritis in calves and leads to difficulties in the treatment and preventive measures. The presence of Cryptosporidium in animals should be taken into account when carrying out complex anti-epizootic measures.

Keywords: cattle, calves, cryptosporidium, enteritis, pathogen associations, viruses, bacteria

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INTRODUCTION

The most common clinical syndrome in calves on livestock complexes is diarrhea of infectious nature, the list of causative agents of which may include viruses, bacteria and parasites [1, 2].

Representatives of the genus *Cryptosporidium* (*Apicomplexa, Protozoa*) are capable of causing parasitic diarrhea. Diseases caused by Cryptosporidium are widespread throughout the world, including the Russian Federation. They can infect a variety of hosts, including humans, domestic and wild animals. Infection of cattle leads to clinical symptoms such as diarrhea, colic, vomiting and weight loss[3] [1–3].

Cryptosporidiosis in cattle is currently recognized to be caused by four main pathogen species: C. *parvum, C. andersoni, C. ryanae* and *C. bovis*. However, other species, including *C. suis, C. hominis, C. serpentis, C. xiaoi, C. ubiquitum, C. meleagridis, C. muris* and *C. felis,* are also found in cattle [4–8] [4].

Infection of calves with Cryptosporidium occurs at or immediately after birth by ingestion or inhalation of oocysts, which multiply on the

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mucous membranes of the rennet, intestine and respiratory organs (most commonly the trachea). According to Hamidinejat H. et al., cryptosporidia were present in 0.5% of fecal samples, as well as in 0.5% of trachea of newborn calves. The same authors reported detection of the pathogen simultaneously in feces and trachea in 0.3% of cases[9].

It was found that *C. andersoni* in cattle mainly causes damage to the gastric mucosa, whereas infection with *C. parvum*, *C. ryanae* and *C. bovis* leads to atrophy of villi, shortening of microvilli and destruction of the intestinal mucosa[10].

Clinical signs of the disease are more often manifested in calves of different ages in the form of depression of general condition, severe diarrhea, anorexia and dehydration, which leads to significant economic losses associated mainly with reduced weight gain and the use of palliative and prophylactic treatment. Some animals recover in 4-6 weeks[11]. Lethality in calves up to 30 days old can reach 35.5%. After recovery, animals become parasite carriers and serve as a source of pathogen for newborn calves[12].

The prevalence of Cryptosporidium spp. in cattle herds varies from 50.5 to 96%[13–19]. For example, the prevalence of cryptosporidiosis in cattle was 1.5% in Japan, 35.7 in Vietnam, 20.6 in Turkey, 40.6 in Canada and 40.6% in the USA (see footnote 9).

The risk of infection with Cryptosporidium is higher in newborn calves (see footnotes 16, 17) [5], in calves before weaning the infection rate can reach 19.5%, in young animals after weaning - 9.0%. Cryptosporidiosis has also been detected in 4.94% of adult cattle [6].

It has been established that *C. parvum* can be transmitted to humans by fecal-oral route after direct or indirect contact with infected animals[20, 21]. Cattle are recognized as the main reservoir of the parasite and a source of zoonotic infection in humans in industrialized countries, especially among immunocompromised individuals, children and the elderly[22].

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Currently, the mortality rate of newborn calves on dairy farms due to diarrhea remains high[23-25]. In addition to *C. parvum*, enteritis is known to be caused by bovine viral diarrhea virus (BVDV), bovine rotavirus A (BRV-A), bovine coronavirus (BCoV), Salmonella spp. and pathogenic Escherichia coli [7-9]. Regarding BVDV, it is known to rarely cause diarrhea in colostrally immune newborn calves, but may be associated with perinatal and neonatal mortality due to intrauterine infections[26] [10].

We found no data in the available literature on the spread of bovine cryptosporidiosis among the calves at dairy complexes in Siberia, especially in association with other pathogens.

The purpose of the work is to study the peculiarities of distribution and clinical manifestation of cryptosporidiosis in calves on dairy complexes in Siberia in association with viruses and bacteria.

MATERIAL AND METHODS

From 2014 to 2023, 666 samples of biomaterial (tracheal mucosa, lungs, mediastinal and mesenteric lymph nodes, contents of rennet and intestine) taken from fallen and slaughtered calves under 6 months of age with the signs of enteritis and respiratory diseases were examined. 94 farms of six areas, two territories of the Siberian region and the Republic of Kazakhstan were surveyed. Sampling of biological material was carried out not later than 2 hours after the animals were killed, immediately frozen and transported to the laboratory for no more than 12 hours, where they were stored at minus 80 °C until examination.

The obtained tests were simultaneously analyzed for the presence of viruses of infectious rhinotracheitis (IRT), viral diarrhea – mucous membrane disease (VD-MMD), respiratory syncytial infection (RSI), coronavirus infection (CVI), parainfluenza-3 (PI-3), rotavirus infection (RVI) in cattle by polymerase chain reaction using test systems developed by us. Bacteriological studies were also carried out using the following nutrient media: FMH-agar, Endo agar, bismuth-sulfite agar, MacConkey agar, Schaedler's agar. Culture, morphological and biochemical properties of microorganisms were studied using generally accepted methods, pathogenicity and toxigenicity - on mongrel white mice using intramuscular and subcutaneous administration of bacterial suspension.

Morphological method was used to diagnose cryptosporidiosis. For this purpose, scrapings from the mucous membranes of the trachea and intestine, intestinal contents were taken, which were mixed 1 : 1 with isotonic sodium chloride solution, thin smears were prepared on slides, which were fixed with methyl alcohol, dried and first stained with carbolic fuchsin according to Ziehl-Neelsen, then with 5% solution of malachite green. In addition, lung smears were made, which were fixed and stained in the same way. Prepared preparations were viewed under a microscope at a magnification of 1000.

RESULTS AND DISCUSSION

Cryptosporidium parvum oocysts were detected in 34 (5.1%) samples of biological material from calves in 22 (23.4%) farms of Novosibirsk, Tyumen, Kemerovo, Omsk regions, Altai Territory and the Republic of Kazakhstan. At microscopy Cryptosporidium oocysts represented rounded formations 4-5 microns in diameter, bright red in color of different shades, had a well-defined paries (see the figure). The associated microflora and the surrounding background were stained green.

Respiratory, mixed (respiratory + gastrointestinal) and gastrointestinal syndromes were registered in the calves from which biological

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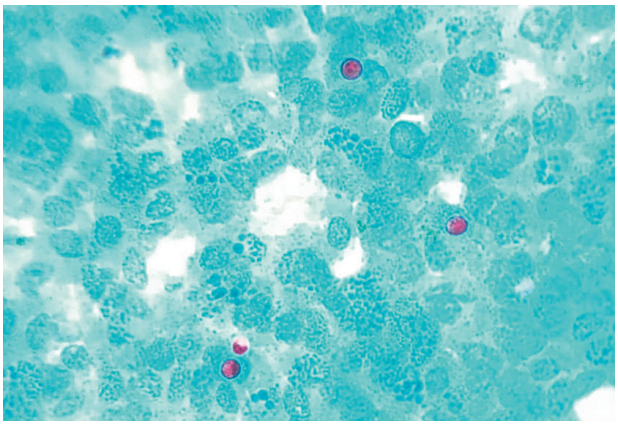
material was sampled (see Table 1). The highest number of positive samples of biomaterial was detected in the group of animals with gastrointestinal form of the disease (12.2%), the lowest number was found in the calves with mixed clinical form of the disease (2.5%). Differences in the number of positive biomaterial samples detected in the calves of different age groups were found. The highest number of positive samples (23.9%) was detected in the calves from 10 days to 1 month, the lowest (2.9%) – in the calves up to 10 days old, although some researchers believe that Cryptosporidium is detected most often in the calves of this age [6]. In the calves with respiratory form of the disease, the number of positive samples detected averaged 3.4% by age groups of animals. Cryptosporidium oocysts were found in scrapings from tracheal mucosa and in the lungs. The data obtained by us coincide with the results of other researchers (see footnote 9).



Ооцисты *Cryptosporidium parvum*. × 1000
Cryptosporidium parvum oocysts. × 1000

Oocysts in monovariant were rarely present in the animals (22.7%). The frequency of their detection in associations with viruses and bacteria during outbreaks of virus-bacterial infections was 77.3%.

Viruses and bacteria in various combinations were detected in the samples of biological material from animals simultaneously with *C. parvum* oocysts (see Table 2).

Table 2 shows that in calves with respiratory form of the disease, viruses of infectious rhinotracheitis and respiratory syncytial infection of cattle were detected simultaneously with cryptosporidium. In the group of animals with mixed clinical form of the disease three associations of pathogens were detected: two viruses (RSI and BVD); IRT virus and *S. dublin* bacterium; IRT, cattle BVD and *S. dublin* viruses The greatest diversity of microorganism associations was found in the animals with the gastrointestinal form of the disease. Most often cryptosporidium was detected simultaneously with *S. dublin* bacterium, as well as in association with BVD virus and *S. dublin*. In addition, in some samples of the biomaterial there were BCoV and BRV viruses of cattle, as well as the bacterium *C. perfringens.*

CONCLUSION

The results of the studies confirm the widespread distribution of Cryptosporidium among calves at dairy farms in Siberia. The highest prevalence was *C. parvum* oocysts, which were present in 5.1% of the biological material samples from calves in 23.4% of the surveyed farms. Oocysts of this Cryptosporidium species were rarely present in animals in mono-variant

Табл. 1. Клинические формы заболевания у телят, при которых выявлены ооцисты *Cryptosporidium parvum*
Tabl 1. Clinical forms of the disease in calves in which oocysts of *Cryptosporidium parvum* are detected

Age of calves	Clinical form of the disease					
	respiratory		respiratory + gastrointestinal		gastrointestinal	
	Tests examined	Number of positive / %	Tests examined	Number of positive / %	Tests examined	Number of positive /%
Up to 10 days	60	1 / 1,7	100	1 / 1,0	68	2 / 2,9
Older than 10 days – 1 month	60	1 / 1,7	100	5 / 5,0	46	11 / 23,9
Older than 1–6 months	57	4/7,0	125	2 / 2,0	50	7 / 14,0
Total	177	6/3,4	325	8 / 2,5	164	20 / 12,2

Табл. 2. Ассоциации микроорганизмов, выявленных в пробах биоматериала от больных телят, у которых обнаружены ооцисты *C. parvum*

Tabl 2. Associations of microorganisms identified in the biomaterial samples from sick calves with oocysts of *C. parvum*

Clinical form of the disease	*Cryptosporidium parvum* + virus/bacterium	Number of positive tests
Respiratory	RSI	3
	IRT	2
Respiratory + gastrointestinal	IRT + VD + *Salmonella dublin*	4
	IRT + *Salmonella dublin*	2
	VD + RSI	3
Gastrointestinal	*Salmonella dublin*	6
	VD	3
	CVI	2
	CVI + *Salmonella dublin*	2
	VD + *Salmonella dublin*	4
	VD + CVI + *Salmonella dublin*	1
	Clostridium perfringens	1
	RVI	1
Total		34

form and were more often found in associations with viruses and bacteria during outbreaks of viral-bacterial infections. Young animals up to 30 days of age are most susceptible to Cryptosporidium infection. Newborn calves are most sensitive to infection with oocysts, and infected animals become lifelong sources of the pathogen for susceptible animals. Cryptosporidiosis is an independent disease and runs independently of the presence of viruses and bacteria in the body and has no synergistic interaction with them, but the presence and multiplication in the body of animals of this pathogen contributes to the severity of enteritis, especially in calves up to 30 days of age, and leads to difficulties in the treatment and preventive measures. The presence of Cryptosporidium in the body of animals should be taken into account when carrying out complex anti-epizootic measures.

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КУЛЬТИВИРОВАНИЕ ЛИЧИНОК ЧЕРНОЙ ЛЬВИНКИ В СУБСТРАТАХ, СОДЕРЖАЩИХ АНТИБИОТИКИ

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Использование антибиотиков в сельском хозяйстве для лечения и профилактики инфекционных заболеваний, а также для стимуляции роста приводит к тому, что антибиотики накапливаются в тканях и отходах животных. Дальнейшее использование таких отходов животноводства вызывает рост количества бактерий, обладающих антибиотикорезистентностью. Одним из перспективных способов переработки навоза, приводящего к снижению концентрации антибиотиков и получению полезной биомассы из органических отходов, может стать биоконверсия с помощью насекомых, в частности черной львинки (*Hermetia illucens*) (двукрылые: львинки). Важно знать, как наличие антибиотиков в кормовом субстрате влияет на насекомых и их характеристики, необходимые для их дальнейшего использования. Изучено влияние добавления антибиотиков цефтриаксона, колифлокса, левофлоксацина и их смесей в кормовые субстраты на рост личинок черной львинки. При содержании цефтриаксона, колифлокса и левофлоксацина в концентрации 1–100 мг/кг корма отмечено увеличение средней массы личинок по сравнению с контрольной группой после 5 дней культивирования. При концентрации антибиотиков 500–1000 мг/кг данный эффект компенсируется, предположительно, негативным воздействием антибиотика на микробиоту пищеварительной системы насекомых. При концентрации антибиотиков 2000 мг/кг корма рост личинок *Hermetia illucens* замедляется. Влияния антибиотиков на жирнокислотный состав, влажность и зольность насекомых не обнаружено. Результаты показывают, что использование черной львинки для переработки отходов животноводства возможно, однако следует учитывать вероятное негативное влияние на рост насекомых при больших концентрациях антибиотика.

Ключевые слова: черная львинка, антибиотик, переработка отходов животноводства, цефтриаксон, колифлокс, левофлоксацин

CULTIVATION OF BLACK SOLDIER FLY LARVAE IN SUBSTRATES CONTAINING ANTIBIOTICS

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The use of antibiotics in agriculture to treat and prevent infectious diseases and to stimulate growth results in antibiotics accumulating in animal tissues and wastes. Further utilization of such animal waste causes an increase in antibiotic-resistant bacteria. One of the promising ways of manure processing leading to reduction of antibiotic concentrations and obtaining useful biomass from organic waste may be bioconversion with the help of insects, particularly black soldier flies (*Hermetia illucens*) (Diptera: Stratiomyldae). It is important to know how the presence of antibiotics in the feeding substrate affects the insects and their characteristics for further utilization. The effect of adding the antibiotics ceftriaxone, coliflox, levofloxacin and their mixtures to feed substrates on the growth of black soldier fly larvae was studied. When ceftriaxone, coliflox and levofloxacin were given at a concentration of 1–100 mg/kg feed, an increase in mean larval weight was observed compared to the control group after 5 days of culturing. At antibiotic concentrations of 500–1000 mg/kg, this effect was

compensated, presumably by the negative effect of the antibiotic on the microbiota of the insect digestive system. At antibiotic concentrations of 2000 mg/kg feed, growth of *Hermetia illucens* larvae was retarded. No effect of antibiotics on fatty acid composition, moisture and ash content of insects was found. The results indicate that the use of black soldier fly for the treatment of animal waste is feasible, but the likely negative effect on insect growth at high antibiotic concentrations should be considered.

Keywords: black soldier fly, antibiotic, manure composting, ceftriaxone, coliflox, levofloxacin

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INTRODUCTION

Antibiotics are used in agriculture to treat animals, prevent infectious diseases and stimulate growth [1]. Up to 90% of some of them are excreted from animal organisms without being metabolized, and as a result they accumulate in waste [2]. The concentrations of residual antibiotics in farm animal manure can vary over a wide range (0-115.5 mg/kg) [3]. The use of such animal wastes as fertilizer leads to soil contamination and spread of antibiotic resistance in soil bacteria [4]. From soil, antibiotics can enter surface and ground water and can be absorbed by plants [2]. Thus, their use in agriculture leads to an increase in the number of bacteria with antibiotic resistance [5].

To reduce the impact of veterinary antibiotics on the environment, animal waste should be processed before use or disposal. A promising way to process waste is bioconversion using insects, in particular, larvae of the black soldier fly (*Hermetia illucens*) (dipterans: soldier flies) [6]. *Hermetia illucens* larvae are able to process pig, chicken and cow manure: in 18–26 days they reduced the amount of dry mass of pig manure by 28.8-53.4%, chicken manure – by 31.8 –61.7, cow manure – by 34.6-57.8%[1]. The authors [6] showed that rearing black soildier fly larvae on such substrates as chicken manure, spent grain and kitchen waste affects the composition of insects, but the high content of protein (41% when reared on chicken manure), calcium (3.2 g per 1 kg dry weight of larvae) and vitamins is retained. In [7] it was shown that the black soildier fly is able to process the antibiotic oxytetracycline. Moreover, the efficiency of its processing in the substrate with larvae is significantly higher than without them.

When considering the bioconversion of waste containing antibiotics by insects, it is necessary to study the effect of these drugs on the insects themselves in order to show the possibility of processing residual antibiotics by the black soldier fly while maintaining its viability and growth rate. The three antibiotics chosen for this study are ceftriaxone, coliflox and levofloxacin. Coliflox and levofloxacin are veterinary drugs and can be found in the manure of cattle, pigs

[1]*Zhou F., Tomberlin J. K., Zheng L., Yu Z., Zhang J.* Developmental and Waste Reduction Plasticity of Three Black Soldier Fly Strains (Diptera: Stratiomyidae) Raised on Different Livestock Manures // Journal of Medical Entomology, 2013, vol. 50 (6), pp. 1224–1230. DOI: 10.1603/ME13021.

and poultry. Ceftriaxone is mainly used for human treatment, with large amounts being excreted unmetabolized from the body [8].

The purpose of this work is to study the effect of antibiotics on black soldier fly larvae.

The objectives of this work were to investigate the effect of antibiotics ceftriaxone, coliflox and levofloxacin on growth, fatty acid composition, moisture and ash content of *Hermetia illucens* larvae.

MATERIAL AND METHODS

The larvae for the study were taken from the mother colony of the black soldier fly insect contained in the insectarium of the All-Russian Research Institute of Food Additives (St. Petersburg). Before the experiment, larvae were reared at 25 ± 2 °C and 50 ± 10% relative humidity on chicken mixed fodder PK 1-3- 58292/503 (GOST 51851 – 2001, feed mill, Kirov).

25 g of dry chicken feed and 50 ml of an aqueous solution of ceftriaxone were placed in 200 ml light-tight containers (achieving such a concentration that the antibiotic content in the substrate was 0.1; 1; 10; 500; 1000 mg/kg feed); coliflox (with concentrations of 100, 1000, 2000 mg/kg feed); levofloxacin (with concentrations of 100, 1000, 2000 mg/kg feed); ceftriaxone and coliflox, mg/kg: 100 + 100; 100 + 1000; 1000 + 1000; 1000 + 100, respectively; ceftriaxone and levofloxacin, mg/kg: 100 + 100; 100 + 1000; 1000 + 100; 1000 + 100; 1000 + 1000, respectively, or 50 ml of deionized water (control group).

50–100 larvae aged 12–14 days were placed in each container. Then all containers were covered with gauze cloth and placed in the thermostat TS-80M and kept at 29 °C for 5 days. Every 1– 2 days, the average larval weight gain in each substrate tested was monitored by weighing 10– 20 individuals on a GR-200 analytical scale (AND, Japan). Then larvae were returned to the feeding substrate. On the last day of the study, all larvae were counted, weighed, washed with distilled water, air-dried, and frozen at – 80 °C in a ULT Premium U410 freezer (Eppendorf, Germany). Three parallel experiments were performed for each concentration of antibiotic or antibiotic mixture.

The fatty acid composition of dried samples (dried in a vacuum drying oven (Vacuum Oven OV-12, JEIO TECH, Korea) at 40 °C) was determined by gas chromatography on a Varian 450-GC chromatograph with a Varian 240-MS mass spectrometric detector (Varian, USA) using a Varian WCOT fused silica 50M X 0. 25MM ID Coating CP-WAX 58 (FFAP)-CB DF = 0.2 (Varian, USA) and fatty acid methyl ester standards (CRM18918 F.A.M.E. Mix, C8-C24, USA).

To determine moisture content, insect samples were placed on pre-weighed glass Petri dishes and dried in a convection desiccator (UF110plus Memmert, Germany) at 105 °C to constant weight. Moisture was calculated as follows: moisture = $m_{sample\ before\ drying} - m_{\text{sample after drying}} / m_{sample\ before\ drying} \times 100\%$.

The ash content of larvae was estimated by weighing samples of dried larvae before and after burning in a muffle furnace (SNOL 8.2/1100, Lithuania) in a crucible previously calcined to constant mass. The following mode of calcination of insect samples was chosen: 60 min at 250 °C + 6 h at 550 °C. The calculation was performed according to the following equation: ash content = $m_{\text{sample after combustion}} / m_{\text{sample before combustion}} \times 100\%$.

Moisture and ash content studies were performed for insect samples from two parallel experiments, then the mean and confidence interval were calculated for each antibiotic concentration using Microsoft Office Excel 2016 software.

RESULTS AND DISCUSSION

The results of the study of the effect of ceftriaxone on the growth of black soldier fly larvae showed that the antibiotic at the lowest concentration (0.1 mg/kg) had no effect on the average mass of one larva (see Fig. 1). At concentrations of 1 and 10 mg/kg, a slight increase in larval mass was observed. The acceleration of mass gain by the insects with the addition of antibiotic may be due to the suppression of unfavorable microflora [9]. At a relatively high content of ceftriaxone (500 and 1000 mg/kg), an increase in the average weight of insects compared to the

control groups was observed in the first 2 days of the experiment, but further growth slowed down. At the end of the experiment, larvae had a mass approximately equal to the mass of the insects in the control group. The slowdown in biomass growth common to all groups of larvae, starting from the third day of the experiment, is associated with the transition of insects to the pre-pupal stage [10]. In an additional experiment, it was shown that the addition of ceftriaxone at a concentration of up to 100 mg/kg to the feeding substrate of black soldier flies had no effect on the survival rate of the insects (data were not presented).

The effect of adding antibiotics to the feed on the composition of insects is currently poorly studied. Our work shows that the fatty acid composition of black soldier fly larvae did not depend on the ceftriaxone content in the substrate when cultured for 5 days (see Table 1). The fatty acid content in Table 1 is given as a percentage of the total fat extracted from the larvae in the assay. Future studies should be conducted in which the larvae are exposed to the antibiotic for longer periods of time.

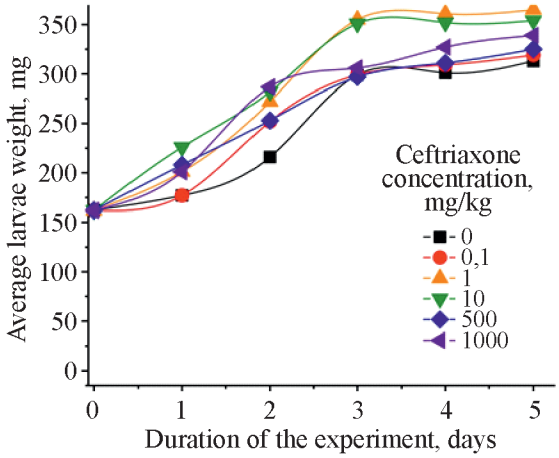

Рис. 1. Изменение средней массы одной личинки, культивируемой в корме, содержащем различные концентрации цефтриаксона

Fig. 1. Change in the average weight of one larva cultured in feed containing different concentrations of ceftriaxone

The results of the study of the change in larvae weight during culturing in substrates containing coliflox (see Fig. 2, *а*) and levofloxacin (see Fig. 2, *б*) are presented. Similarly, to the results of the experiment with ceftriaxone, a slight increase in the average weight of one larva was observed at an antibiotic concentration of 100 mg/kg; at a concentration of 1000 mg/kg the values were similar to the control experiment in which the feed did not contain antibiotics; at a concentration of 2000 mg/kg of feed a decrease in the average weight of the insect was observed. A similar dependence was observed for another antibiotic: gentamicin at concentrations of 4, 40, 400 μg/ml had no effect on the mass of *Phaenicia sericata* larvae, but at the antibiotic concentration of 4000 μg/ml the mass of the larvae decreased significantly[2].

Insect growth retardation at high concentrations of antibiotic in the substrate is probably due to the suppression of the microflora of the gastrointestinal tract of insects, as well as the microflora of the substrate [7]. In support of this, a number of studies have shown that pre-sterilization of the feeding substrate leads to a slowdown in the growth of insects. For example, [12] a decrease in the growth rate of black soldier fly larvae when the substrate was sterilized with an electron beam was noted in the work. In addition, the authors [13] showed that sterilization of feed led to a decrease in the weight and size of silkworm larvae *Bombyx mori*.

Animal wastes may contain mixtures of antibiotics with different mechanisms of action, so the effect of this mixture on the growth of *Hermetia illucens* larvae was considered. In the course of the experiments, patterns similar to those described above were obtained (see Fig. 3, а). However, it should be noted that levofloxacin and ceftriaxone alone (see Fig. 1 and 2, *б*) and their mixture with a concentration of 1000 mg/kg each had no effect on the average weight of one larva after 5 days of feeding (see Fig. 3, *б*). In the study [14] another dependence was shown: a mixture of ceftriaxone and levofloxacin slowed down the growth of *Callipho-*

[2]*Sherman R.A., Wyle F.A., Thrupp L.* Effects of Seven Antibiotics on the Growth and Development of *Phaenicia sericata* (Diptera: Calliphoridae) Larvae // Journal of Medical Entomology, 1995, vol. 32 (5), pp. 646–649. DOI: 10.1093/jmedent/32.5.646.

Табл. 1. Жирнокислотный состав личинок черной львинки после кормления в течение 5 дней субстратом, содержащем цефтриаксон

Table 1. Content of fatty acids in the black soldier fly larvae cultivated for 5 days in substrates containing ceftriaxone

Sample	Control	Ceftriaxone content, mg/kg				
		0,1	1	10	500	1000
C 5 : 0	1,3 ± 0,2	1,2 ± 0,2	1,5 ± 0,2	1,5 ± 0,2	0,4 ± 0,1	1,1 ± 0,2
C 6 : 2	3,7 ± 0,6	4,3 ± 0,6	3,8 ± 0,6	3,0 ± 0,5	1,5 ± 0,2	2,5 ± 0,4
C 8 : 0	6,6 ± 1,0	6,0 ± 0,9	2,2 ± 0,3	1,1 ± 0,2	3,5 ± 0,5	4,0 ± 0,6
C 9 : 0	1,5 ± 0,2	1,6 ± 0,2	1,7 ± 0,2	0,8 ± 0,1	0,5 ± 0,1	0,5 ± 0,1
C 10 : 0	2,3 ± 0,3	2,3 ± 0,3	1,8 ± 0,3	2,2 ± 0,3	2,6 ± 0,4	3,0 ± 0,4
C 11 : 0	0,3 ± 0,0	0,3 ± 0,0	0,4 ± 0,1	0,3 ± 0,0	0,3 ± 0,0	0,2 ± 0,0
C 11 : 1	0,5 ± 0,1	0,2 ± 0,0	0,2 ± 0,0	0,1 ± 0,0	0,1 ± 0,0	0,3 ± 0,0
C 14 : 1	2,9 ± 0,4	3,4 ± 0,5	1,6 ± 0,2	4,9 ± 0,7	3,9 ± 0,6	4,7 ± 0,7
C 15 : 0	4,7 ± 0,7	3,4 ± 0,5	4,7 ± 0,7	3,8 ± 0,6	4,7 ± 0,7	3,3 ± 0,5
C 16 : 1	7,4 ± 1,1	7,6 ± 1,1	5,4 ± 0,8	13,0 ± 1,9	3,8 ± 0,6	5,9 ± 0,9
C 16 : 2	3,0 ± 0,5	5,7 ± 0,9	4,9 ± 0,7	6,4 ± 1,0	7,4 ± 1,1	4,8 ± 0,7
C 17 : 0	8,6 ± 1,3	6,9 ± 1,0	12,2 ± 1,8	6,0 ± 0,9	8,4 ± 1,3	6,6 ± 1,0
C 17 : 1	4,7 ± 0,7	5,8 ± 0,9	10,2 ± 1,5	4,1 ± 0,6	4,2 ± 0,6	3,1 ± 0,5
C 18 : 1	2,2 ± 0,3	7,3 ± 1,1	0,6 ± 0,1	6,6 ± 1,0	4,6 ± 0,7	9,7 ± 1,5
C 18 : 2	7,0 ± 1,1	6,6 ± 1,0	5,1 ± 0,8	7,2 ± 1,1	3,4 ± 0,5	8,9 ± 1,3
C 18 : 3	12,3 ± 1,8	18,9 ± 2,8	12,3 ± 1,8	19,7 ± 3,0	19,5 ± 2,9	21,1 ± 3,2
C20 : 0	6,6 ± 1,0	6,0 ± 0,9	8,1 ± 1,2	4,6 ± 0,7	6,7 ± 1,0	5,1 ± 0,8
C 20 : 1	7,9 ± 1,2	1,9 ± 0,3	9,1 ± 1,4	4,8 ± 0,7	7,3 ± 1,1	4,8 ± 0,7
C 20 : 2	5,2 ± 0,8	1,9 ± 0,3	2,1 ± 0,3	3,0 ± 0,4	4,1 ± 0,6	1,4 ± 0,2
C 21:0	0,4 ± 0,1	0,5 ± 0,1	0,8 ± 0,1	0,3 ± 0,0	0,6 ± 0,1	0,5 ± 0,2
C 22:0	4,3 ± 0,6	3,1 ± 0,5	4,6 ± 0,7	2,9 ± 0,4	4,0 ± 0,6	3,3 ± 0,5
C 23 : 0	5,4 ± 0,8	2,9 ± 0,4	4,3 ± 0,7	2,8 ± 0,4	6,8 ± 1,0	2,8 ± 0,4
C 24 : 0	1,2 ± 0,2	1,9 ± 0,3	2,5 ± 0,4	1,0 ± 0,1	1,8 ± 0,3	2,5 ± 0,4
Σ SFA, %	43,1 ± 6,5	36,2 ± 5,4	44,9 ± 6,7	27,2 ± 4,1	40,2 ± 6,0	32,8 ± 4,9
Σ MUFA, %	25,6 ± 3,8	26,3 ± 3,9	27,0 ± 4,0	33,5 ± 5,0	23,9 ± 3,6	28,5 ± 4,3
Σ PUFA, %	31,2 ± 4,7	37,5 ± 5,6	28,2 ± 4,2	39,2 ± 5,9	35,9 ± 5,4	38,8 ± 5,8

Note. Total amount: Σ SFA – saturated fatty acids; Σ MUFA – monounsaturated fatty acids; Σ PUFA – polyunsaturated fatty acids.

ra vomitoria larvae, while the antibiotics in the same concentrations had no effect separately. In addition, levofloxacin with a concentration of 2000 mg/kg feed contributed to the reduction in the mean larval weight, whereas the mixture of levofloxacin + ceftriaxone with concentrations of 1000 mg/kg each had no effect on the larval weight of *Hermetia illucens*. This supports the conclusion that the effect of antibiotics on insects depends on both the insect species and the type of antibiotic [11, 15].

Moisture and ash content were determined for larval samples obtained from the experiments with coliflox, levofloxacin and their mixtures with ceftriaxone (see Table 2). The table shows that the addition of antibiotics to the feed substrate had no effect on these parameters.

CONCLUSION

The effect of antibiotics ceftriaxone, coliflox and levofloxacin and their mixtures on the growth of black soldier fly larvae was studied. Feeding of larvae aged 12-14 days was carried out for 5 days. It was shown that ceftriaxone with a concentration of 0.1 mg/kg of feed had no effect on insect growth. At the content of cef-

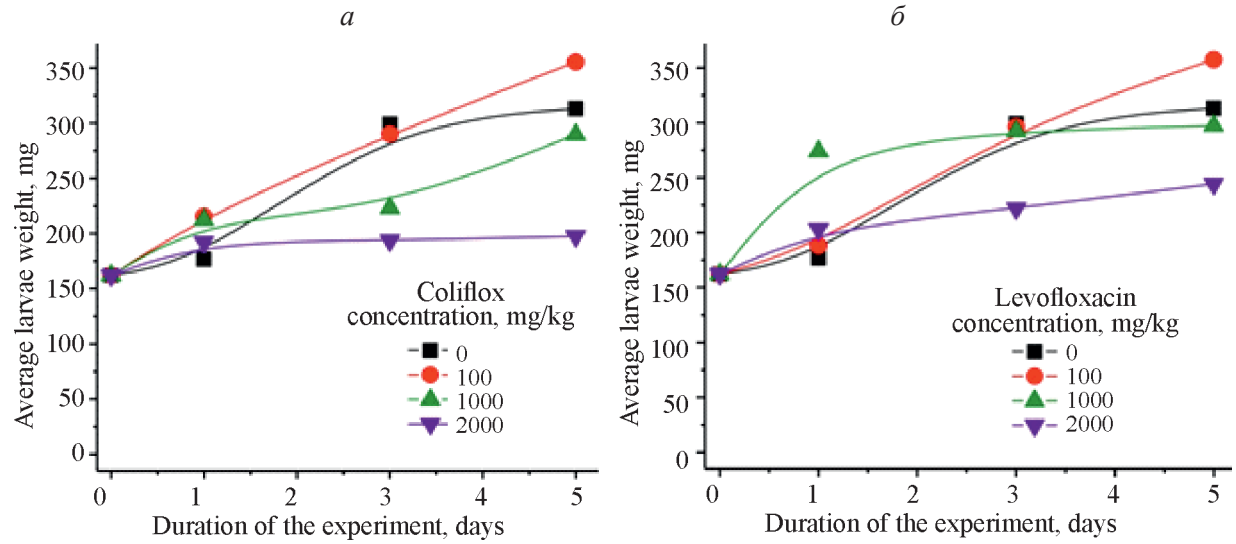

Рис. 2. Изменение средней массы одной личинки, культивируемой в корме, содержащем различные концентрации колифлокса (*а*) и левофлоксацина (*б*).

Fig. 2. Changes of the average weight of one larva cultivated in substrates containing various concentrations of coliflox (*а*) and levofloxacin (*б*)

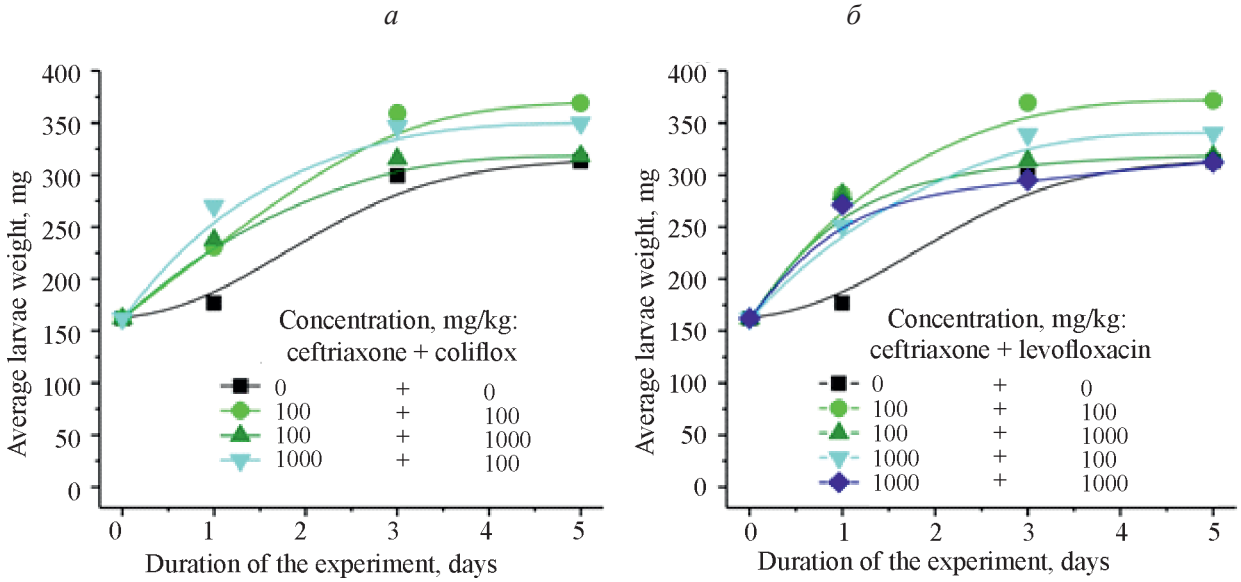

Рис. 3. Изменение средней массы одной личинки, культивируемой в корме, содержащем смеси антибиотиков:
а – колифлокс с цефтриаксоном; *б* – левофлоксацин с цефтриаксоном

Fig. 3. Changes of the average weight of one larva cultivated in substrates containing mixtures of antibiotics:
а – coliflox and ceftriaxone; *б* – levofloxacin and ceftriaxone

triaxone, coliflox and levofloxacin 1-100 mg/kg, an increase in the average weight of larvae was observed compared to the control experiment. At antibiotic concentrations of 500-1000 mg/kg, the growth rate of the insects was comparable to that of the insects with no antibiotics in the diet. Higher content of coliflox and levofloxacin (2000 mg/kg) led to slow growth of larvae. In the presence of a mixture of two antibiotics in the feed substrate, a similar concentration dependence was observed. The possibility of processing livestock waste containing antibiotics ceftriaxone, coliflox and levofloxacin with concentrations less than 2000 mg/kg of feed with the help of black soldier fly larvae with preservation of important characteristics of the insects

Табл. 2. Влажность и зольность личинок черной львинки после кормления в течение 5 дней субстратом, содержащим цефтриаксон, колифлокс и левофлоксацин

Table 2. Moisture and ash content of the black soldier fly larvae cultivated for 5 days in substrates containing ceftriaxone, coliflox and levofloxacin

Antibiotic	Control	Coliflox			Levofloxacin		
Concentration, mg/kg	0	100	1000	2000	100	1000	2000
Moisture content, %	69,6 ± 5,0	67,1 ± 0,8	67,7 ± 7,5	73,2 ± 2,7	66,4 ± 6,9	66,6 ± 13,4	68,7 ± 21,6
Ash content, %	14,0 ± 2,9	13,1 ± 0,6	13,9 ± 7,3	15,6 ± 14,1	11,5 ± 11,7	15,0 ± 2,3	15,5 ± 2,6
Antibiotic	Ceftriaxone + coliflox			Ceftriaxone + levofloxacin			
Ceftriaxone concentration, mg/kg	100	100	1000	100	100	1000	1000
Coliflox or levofloxacin concentration, mg/kg	100	1000	100	100	1000	100	1000
Moisture content, %	67,0 ± 2,67	68,5 ± 9,5	66,5 ± 6,7	67,8 ± 1,7	66,8 ± 3,8	66,8 ± 2,5	68,0 ± 13,1
Ash content, %	14,3 ± 8,1	14,0 ± 8,3	15,1 ± 0,1	14,2 ± 5,2	15,4 ± 1,3	16,6 ± 9,4	13,9 ± 9,2

themselves: weight, moisture, ash content and fatty acid composition was shown.

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ВЛИЯНИЕ РАЗЛИЧНЫХ ДОЗ КОБАЛЬТА НА РУБЦОВОЕ ПИЩЕВАРЕНИЕ КРУПНОГО РОГАТОГО СКОТА

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Оптимизация минерального питания является необходимой мерой, направленной на поддержание высокой продуктивности мясного скота, в кормах которого часто не хватает минералов. Инновационной базой в данном случае могут выступать ультрадисперсные частицы эссенциальных элементов, характеризуемые высокой биологической доступностью в малой дозе. Изучено действие ультрадисперсных частиц Co_3O_4 на переваримость сухого вещества корма в системе *in vitro* (искусственный рубец), количество летучих жирных кислот, формы азота (общий, небелковый, аммиачный, мочевинный, белковый) и на аминокислотный состав (аргинин, лизин, метионин, аланин, глицин) рубцовой жидкости животных. Исследования проведены в 2023 г. В качестве объекта исследования использовали крупный рогатый скот казахской белоголовой породы в возрасте 11–12 мес средней массой 265–275 кг. Установлено, что в ходе исследований *in vitro* переваримость сухого вещества корма была выше на 9,0% при концентрации ультрадисперсных частиц Co_3O_4 0,36 г/мл. Анализ концентрации летучих жирных кислот показал, что данная дозировка увеличивает количество уксусной, пропионовой, масляной, валерьяновой, капроновой кислот. Внесение ультрадисперсных частиц Co_3O_4 повысило содержание белкового азота и общего азота у опытных животных, что свидетельствует об интенсификации микробиоценоза рубца. При введении ультрадисперсных частиц Co_3O_4 отмечены сдвиги в показателях аминокислотного состава рубцового содержимого, что может быть вызвано изменениями в характере превращения азотистых веществ в пищеварительном тракте. Сделан вывод, что использование ультрадисперсных частиц Co_3O_4 оказывает позитивное влияние на процессы пищеварения в рубце.

Ключевые слова: ультрадисперсные частицы, рубцовая жидкость, окись кобальта, крупный рогатый скот, летучие жирные кислоты, количество азота, аминокислоты

EFFECT OF DIFFERENT DOSES OF COBALT ON RUMEN DIGESTION IN CATTLE

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Optimization of mineral nutrition is a necessary measure to maintain high productivity of beef cattle which often lack minerals in their feed. The innovative base in this case can be ultrafine particles of essential elements characterized by high bioavailability in a small dose. The effect of ultrafine Co_3O_4 particles on the digestibility of dry matter of feed in the *in vitro* system (artificial rumen), the amount of volatile fatty acids, nitrogen forms (total, non-protein, ammonia, urea, protein) and on the amino acid composition (arginine, lysine, methionine, alanine, glycine) of animal rumen fluid was studied. The research was conducted in 2023. Cattle of the Kazakh white-headed breed aged 11-12 months with an average weight of 265-275 kg were used as an object of research. It was found that in *in vitro* studies, dry matter digestibility of feed was 9.0% higher at a concentration of 0.36 g/mL of Co_3O_4 ultrafine particles. Analysis of volatile fatty acid concentration showed that this dosage increases acetic

acid, propionic acid, butyric acid, valerianic acid, and caproic acid. The introduction of ultrafine Co_3O_4 particles increased the content of protein nitrogen and total nitrogen in the experimental animals, indicating the intensification of rumen microbiocenosis. At introduction of ultrafine Co_3O_4 particles, shifts in the amino acid composition of the rumen contents were observed, which may be caused by the changes in the nature of nitrogenous substances transformation in the digestive tract. It is concluded that the use of ultrafine Co_3O_4 particles has a positive effect on the digestive processes in the rumen.

Keywords: ultrafine particles, rumen fluid, cobalt oxide, cattle, volatile fatty acids, nitrogen amount, amino acids

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Conflict of interest
The authors declare no conflict of interest.

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INTRODUCTION

With the rapidly increasing demand for animal products worldwide, improving livestock utilization efficiency has become a defining parameter for the success of agricultural producers [1]. Feed additives provide a safe and physiologically sound way to improve animal performance and health. Among the catalysts of metabolic processes, trace elements occupy a special place. They are able to stimulate the rumen microbiome, influence digestion and utilization of structural carbohydrates [2]. At the same time, protozoa and bacteria, on the one hand, are used in animal husbandry as an indicator of adaptation mechanisms in response to changes in the diet, and on the other hand, management of their activity is a promising tool to improve the productivity and quality of livestock products [3].

In the rumen microorganisms perform trophic functions of cleavage and chemical transformation of many food substrates, affecting the overall metabolism. By influencing the functional activity of microbiota, trace elements indirectly modulate the biochemical cascade of reactions, including the formation of volatile fatty acids, pH and other parameters, fermentation and digestion processes [4].

Cobalt as one of the essential elements in ruminant diets improves digestibility of feed fiber in the rumen[1, 2] [5], improves immunity and increases the concentration of vitamin B_{12} in tissues[3] [6]. The norm of cobalt in the diet of fattening cattle is 30-60 μg per 1 kg of live weight, but there is no ranking of the need with regard to the level of productivity.

The purpose of the study was to investigate the effect of different dosages of ultrafine cobalt oxide particles (UFP Co_3O_4) on rumen digestion.

MATERIAL AND METHODS

The research was conducted at the Center for Collective Use of the Federal Research Centre

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of Biological Systems and Agrotechnologies of the Russian Academy of Sciences.

The object of the study was rumen fluid obtained from bulls of Kazakh white-headed breed with average weight of 265– 275 kg at the age of 11–12 months. Chemically pure for analysis (99%) ultrafine particles of cobalt oxide (UFP Co_3O_4) (SP "Khisamutdinov R.A.", Russia) in the amount of 0.36; 0.73; 0.18 g/l were used in the experiment, which were dispersed by ultrasound in 1 ml of distilled water for 0.5 h at a temperature of 25 °C (Sapphire 4.0 ultrasonic sonicator, Russia).

The research was approved by the Ethics Committee (minutes № 4 of 5.12.2022). Measures to minimize animal suffering and limit the number of experimental samples under study were ensured during the experimental work.

This experiment was performed *in vitro* using the ANKOM DaisyII incubator (Ankom Technology Corp., Macedon, NY) according to a special method. Before use, samples of rumen fluid were filtered through four layers of gauze and added to buffer solution in the ratio of 1 : 4. The buffer solution is chemically similar to saliva and maintains the acidity of the "artificial rumen" close to physiological. During mixing, the buffer solution was heated to 39 °C and filled with carbon dioxide.

The amount of volatile fatty acids (VFA) in the rumen contents was identified by gas chromatography on a gas chromatograph "Kristall-LUX-4000" (SDB "Chromatek", Russia). Duration of the operation was 40 min, sample input was 1 mm^3. Solutions of acid mixtures with concentrations of 10, 25 and 50 $\mu g/cm^3$ were used as a standard for calibration. All samples of rumen fluid were analyzed in duplicate, starting with a small dosage.

Total and residual nitrogen were determined by the Kjeldahl method, protein nitrogen was determined by calculating the difference of total and residual nitrogen. The Kjeldahl method consists of three parts: first, samples are solidified using enriched H_2SO_4, K_2SO_4, and $CuSO_4$; next, ammonia separation in a flask with a standard solution of boric acid; finally, the mass fraction of nitrogen is detected by titration (Millab, Italy).

The mass fraction of arginine, lysine, methionine, alanine and glycine was taken into account when studying the amino acid composition of the rumen fluid. When preparing the rumen fluid samples, the material was homogenized (TissueLyser LT, "Qiagen N.V.", Germany). Upon completion of acid cleavage, the samples were filtered, after alkaline decomposition no filtration was performed. The supernatant was studied by capillary electrophoresis using a drop system (Lumex-Mar-marketing LLC, Russia; GOST 55569-2013).

The data obtained for the study group was compared with the control group to determine statistical significance by the Student's t-test ($p \leq 0{,}05$; $p \leq 0{,}01$; $p \leq 0{,}001$).

RESULTS AND DISCUSSION

The use of 0.18 g/ml UFP Co_3O_4 in the feed composition did not affect dry matter digestibility. However, increasing the concentration of UFP Co_3O_4 to 0.36 g/ml increased the digestibility value by 9.0%. The higher concentration had no statistically important effect on feed digestibility, which may be due to the inhibitory effect of ultrafine particles on the bacterial ecosystem of the rumen (see Table 1).

In vitro studies showed that different doses of Co_3O_4 UFPs did not result in the same volatile fatty acid content in the samples (see Table 2).

At the dosage of 0.73 g/mL there was a decrease in acetic acid concentration by 25.2% ($p \leq 0.05$), 0.18 g/ml – by 13.8% ($p \leq 0.05$) relative to the control. However, the average load-

Табл. 1. Переваримость сухого вещества кормовых добавок *in vitro* (48-часовая инкубация в искусственном рубце с РЖ)

Table 1. Digestibility of dry matter of feed additives *in vitro* (48-hour incubation in artificial rumen with rye)

Substrate	Dose, g/ml	Digestibility, %
Control (wheat bran)	–	58,67 ± 8,110
Wheat bran + UFP Co_3O_4	0,36	67,67 ± 0,657
	0,73	57,27 ± 6,666
	0,18	49,85 ± 18,324

ing of 0.36 g/ml increased its concentration by 9.0%. The amount of propionic acid decreased in all experimental groups from 5.6 to 47.3%, and reliable changes ($p \leq 0.05$) were characteristic of low and medium dose loading.

Active synthesis of the studied volatile fatty acids, exceeding the control values, was observed at the average (0.36 g/ml) dose load: oily - by 8 mg/dm^3, valerian - by 0.7 and caproic - by 0.10 mg/dm^3. At the same time, cobalt application at a dose of 0.18 g/ml contributed to an increase in the concentration of acids, except acetic acid, compared to the initial sample.

Total nitrogen in the experimental groups increased in relation to the control by 15.4-18.1%. Thus, the dose of 0.36 g/ml UFP Co_3O_4 contributed to the highest production of total nitrogen with a difference with the control by 18.2% ($p \leq$ 0.01), non-protein nitrogen by 45.5, and protein nitrogen by 9.8%.

The difference in the concentration of ammonia and urea nitrogen was insignificant between the groups. Having tested the experimental samples among themselves, it was concluded that the dose of 0.36 g/ml promoted an increase in the content of total, non-protein and protein nitrogen in the rumen fluid compared to other doses of UFP Co_3O_4 (see Table 3).

Table 4 shows that the groups did not differ significantly in the sum of amino acids. However, the content of essential amino acids in the rumen fluid at the dosage of 0.36 g/ml was higher compared to the control: methionine - 2 times, arginine - 2.1 times.

The rumen fluid with low dosage of UFP Co3O4 contained less lysine, arginine, methionine, glycine and alanine; when the dose was increased 4-fold (to 0.73 g/ml), the concentration of arginine exceeded the control value.

The use of ultrafine particles of trace elements in animal nutrition has several advantages: small size and, consequently, high bioavailability allow, at minimal cost, to increase the efficiency of growth and physiological functions, reduce feed consumption and improve the quality of agricultural products [7]. However, in case of incorrectly selected dose, oxidative stress may occur, accompanied by geno- and cytotoxic effects [8].

It is known that the use of trace elements increases the total amount of volatile fatty acids [9]. In our experiment, high values of volatile fatty acids and amino acids were observed when using UFP Co_3O_4 at a dosage of 0.36 g/ml. The activity of microorganisms capable of converting the urea form of nitrogen into ammonia was indicated by the presence of microbial proteins

Табл. 2. Концентрация летучих жирных кислот в рубцовой жидкости *in vitro* при применении различных доз УДЧ Co_3O_4, моль/л

Table 2. Concentration of volatile fatty acids in the rumen fluid *in vitro* when using different doses of UFP Co_3O_4, mol/l

Sample	Dose, g/ml	Volatile fatty acids, mg/dm^3				
		acetic	propionic	oleic	valerianic	caproic
Wheat bran	–	20,2 ± 0,45	10,5 ± 0,25	10,1 ± 0,05	0,93 ± 0,06	0,23 ± 0,02
Wheat bran + UFP Co_3O_4	0,73	15,1 ± 0,60**	9,90 ± 0,20	12,1 ± 0,25**	0,94 ± 0,05	0,24 ± 0,02
Wheat bran + UFP Co_3O_4	0,36	22,0 ± 0,65	14,8 ± 0,90*	18,2 ± 0,15***	1,64 ± 0,35	0,33 ± 0,02*
Wheat bran + UFP Co_3O_4	0,18	17,4 ± 0,35**	11,7 ± 0,15*	14,6 ± 0,45***	1,18 ± 0,19	0,30 ± 0,01

Note. Here and in Table 3: in comparison with the control group:
*$p \leq 0,05$,
**$p \leq 0,01$,
***$p \leq 0,001$.

Табл. 3. Количество азота в рубцовой жидкости *in vitro* при различных дозах УДЧ Co_3O_4
Table 3. The amount of nitrogen in the rumen fluid *in vitro* at different doses of UFP Co_3O_4

Sample	Dose, g/ml	Nitrogen, mg /%				
		total	non-protein	ammonia	urea	protein
Wheat bran	–	118,9 ± 0,42	29,0 ± 0,22	0,004 ± 0,0007	4,72 ± 0,16	89,9 ± 0,35
Wheat bran + UFP Co_3O_4	0,73	137,3 ± 0,55*	41,7 ± 0,30*	0,003 ± 0,0002	4,35 ± 0,15	95,9 ± 0,05*
Wheat bran + UFP Co_3O_4	0,36	140,5 ± 0,50**	42,2 ± 0,25*	0,003 ± 0,0007	4,78 ± 0,10	98,7 ± 0,70**
Wheat bran + UFP Co_3O_4	0,18	99,1 ± 0,40*	39,8 ± 0,65***	0,003 ± 0,0003	4,74 ± 0,15	60,1 ± 0,60*

Табл. 4. Содержание аминокислот в образцах рубцовой жидкости
Table 4. Amino acid content in the rumen fluid samples

Sample	Dose, g/ml	Amino acid composition, %				
		Arginine	Lysine	Methionine	Alanine	Glycine
Wheat bran	–	0,18 ± 0,010	0,12 ± 0,015	0,04 ± 0,01	0,16 ± 0,007	0,11 ± 0,015
Wheat bran + UFP Co_3O_4	0,73	0,21 ± 0,020	0,09 ± 0,015	0,04 ± 0,006	0,13 ± 0,015	0,07 ± 0,015
Wheat bran + UFP Co_3O_4	0,36	0,38 ± 0,175	0,13 ± 0,010	0,08 ± 0,015	0,21 ± 0,025	0,15 ± 0,050
Wheat bran + UFP Co_3O_4	0,18	0,17 ± 0,002	0,11 ± 0,020	0,05 ± 0,012	0,15 ± 0,011	0,08 ± 0,002

[10]. In this study, the addition of UFP Co_3O_4 at a dosage of 0.18 g/ml decreased the concentration of protein nitrogen. At the same time, the addition of UFP Co_3O_4 at a dosage of 0.73 g/ml promoted a decrease in the urea form of nitrogen with a simultaneous increase in the proteinogram. The increase in the concentration of protein nitrogen and total nitrogen indicates that there is an active work of rumen microflora and nitrogen transfer into the rumen fluid.

Amino acids are the breakdown products of blood plasma proteins; absorbed amino acids are transported through the blood to the organs and tissues, where they are used for synthesis or as a source of nutrition. Proteins and their breakdown products constantly make a circular movement between the organs and tissues, on the one hand, and the gastrointestinal tract - on the other. There is a constant exchange and recombination of amino acids of substances in the body [11].

Amino acids required by growing young animals include methionine, lysine and arginine. In ruminants, the need for amino acids is primarily related to the level of productivity [12].

It is believed that discrepancies in the content and ratio of amino acids in the diet are smoothed due to microbial integrity of proteins and their excretion from digestive juices and blood plasma. This results in an amino acid composition in the rumen that is important for tissue metabolism and its own protein synthesis (animal proteins) [11].

Methionine is a powerful antioxidant. It is known to enhance immunomodulatory properties due to its participation in the synthesis of glutathione[4]. Arginine takes part in the synthesis

[4]*Hall W.L., Millward D.J., Long S.J., Morgan L.M.* Casein and whey have different effects on plasma amino acid profile, gastrointestinal hormone secretion, and appetite // Br. J. Nutr., 2003, vol. 89, pp. 239–248.

of connective tissue cells and hormones, stimulates kidney and heart function, reduces blood pressure, activates immune and anti-cancer work of the organism[5].

According to the authors' observations[6], the intensity of amino acid absorption occurs in the following order: alanine, cystine, glutamic acid, valine, methionine, leucine, tryptophan. Unequal absorption rate of different amino acids may be due to different rates of their deamination, different size and structure of molecules, as well as peculiarities of the course of biochemical processes in the gastrointestinal tract.

The shifts in the amino acid composition of the rumen contents are apparently related to their biological role in the organism and, to a certain extent, reflect the intensity of transformation of nitrogenous substances in the digestive tract. Shifts in the concentrations of essential and substituted amino acids in the rumen of ruminants can be considered as an adaptive reaction of the organism aimed at more complete satisfaction of the organism's needs in certain amino acids. Thus, the amino acid composition of rumen fluid of ruminants at different doses of UFP Co_3O_4 is represented by the same amino acids, but in different quantitative ratios. Consequently, the protein composition of the rumen fluid is dynamic and depends on both feed factors and doses of feed additive.

CONCLUSION

Our study showed that the use of additional additives of UFP Co_3O_4 in different concentrations is accompanied by ambiguous digestibility of feed substrate. At the concentration of 0.36 g/ml, the digestibility of the dry matter of feed increased by 9.0%. On the basis of the above-mentioned data, it can be concluded that UFP Co3O4 do not have a negative effect on digestive processes, therefore, can be safely used as a feed additive. The most optimal concentration is 0.36 g/ml.

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ОБМЕН АЗОТА В ОРГАНИЗМЕ И ИНТЕНСИВНОСТЬ РОСТА РЕМОНТНЫХ ТЕЛОК ПРИ СКАРМЛИВАНИИ ИМ ЭКСТРУДАТА РЖИ

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Целью исследования являлось изучение влияния разных доз экструдата зерна озимой ржи на обмен азота в организме и интенсивность роста ремонтных телок в возрасте 12–15 мес голштинизированной черно-пестрой породы в условиях молочного комплекса. Телки контрольной группы получали рацион, концентратная часть которого состояла на 50,0% (1,0 кг) из типового комбикорма КР-3 (ГОСТ 9268–2015), на 50,0% (1,0 кг) – из плющеного ячменя. Животные 1–3-й опытных групп получали тот же набор объемистых кормов, что и в контрольной группе, но в содержание концентратной части был дополнительно введен экструдат зерна озимой ржи (12,5; 25,0 и 50,0% соответственно). Продолжительность учетного периода в опыте составила 92 дня. Установлено, что телки опытных групп использовали поступавший с кормом азот более рационально. Ими было отложено в теле: поступившего азота – на 0,82; 1,16 и 3,52% больше, переваренного – на 0,19; 0,94 и 4,31% больше. По завершении эксперимента в крови представителей 3-й группы отмечено увеличение общего белка в плазме на 6,51%, γ-глобулинов – на 8,54% ($p < 0,5$).

Ключевые слова: абсолютный прирост, рацион, сахар, мочевина, экструдат, озимая рожь, сахаропротеиновое отношение

NITROGEN EXCHANGE AND GROWTH RATE OF REPLACEMENT HEIFERS FED ON RYE EXTRUDATE

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The purpose of the research was to study the effect of different doses of winter rye grain extrudate on nitrogen metabolism in the body and growth intensity of replacement heifers at the age of 12–15 months of the Holsteinized black-and-white breed in the conditions of the dairy complex. Heifers of the control group received a diet, the concentrate part of which consisted of 50.0% (1.0 kg) of standard mixed fodder KR-3 (GOST 9268–2015), 50.0% (1.0 kg) – of rolled barley. Animals of the 1st-3rd experimental groups received the same set of voluminous feeds as in the control group, but the extrudate of winter rye grain was additionally introduced in the content of the concentrate part (12.5; 25.0 and 50.0%, respectively). The duration of the registration period in the experiment amounted to 92 days. It was found that heifers of experimental groups used nitrogen supplied with feed more rationally. They deposited in the body: incoming nitrogen by 0.82; 1.16 and 3.52% more and digested nitrogen by 0.19; 0.94 and 4.31% more. At the end of the experiment there was an increase of total protein in plasma by 6,51%, γ-globulins – by 8,54% ($p < 0,5$).

Keywords: absolute gain, diet, sugar, urea, extrudate, winter rye, sugar-protein ratio

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INTRODUCTION

One of the main tasks of modern cattle breeding in Russia in the formation of a highly productive dairy herd is to achieve the breed standards in terms of live weight of young animals. Biologically adequate feeding of repair heifers is considered to be a strategically important direction that determines their successful breeding, allowing to realize not only the genetic potential of the herd in terms of productivity, but also to preserve the other most important economically useful trait - the ability to reproduce. For this purpose, it is necessary to ensure the fullest possible provision of nutrient and biologically active substances, taking into account the specified zootechnical norms for milk productivity of cows [1]. The formation of a certain type of physique in heifers is influenced by the intensity of their growth. Heifers that receive increased feed and are raised under loose housing conditions are more massive, have a pronounced broad and deep chest, flat and wide butt, and wide limb placement. Such heifers are adapted to long terms of productive use. With regard to cattle, it is scientifically substantiated that there is a direct correlation between the growth intensity and subsequent milk productivity [2–4].

It is established that sugar and starch, being the main energy nutrients for the animal organism, are food for rumen microorganisms of ruminants acting as the basis for the formation of bacterial protein. As a result of feeding with extrusion-treated grain fodders, there is an increase in the provision of animals with sugar, which contributes to a more efficient utilization of fatty acids extracted from the fat depot, activates the process of microbial transformation of organic matter in the rumen, increases the level of nitrogen utilization in the body [5–8].

The factor determining the low specific weight of rye grain in the concentrate part of the diet of farm animals (5.0-30.0%) is the presence of anti-nutritive substances in it. When the share of unprocessed rye grain in the diet increases, the consumption of mixed fodder sharply decreases, sometimes there is even a complete refusal of its consumption by animals, which causes a decline in productivity. Rye grain contains about 17.5% of non-starch polysaccharides, among which 6.0-8.0% are pentosates, 7.0-8.5% – peptides, 3.5-4.5% – glucose. Rye grain is inherent in the specific structure of starch grains, manifested in their strong and rapid swelling in the gastrointestinal tract of animals. In addition, rye grain may be contaminated with biological organisms of animal origin, microscopic fungi (ergot). Viscosity of the water extract of winter rye grain is 22 times higher than that of wheat grain [9, 10].

The rate of productivity growth in animal husbandry depends on the introduction of the modern methods of preparation of grain forage for feeding. One of such methods is extrusion [11-13]. During processing at extrusion plants, grain is subjected to a combined effect of pressure of 40–60 atmospheres and temperature of 170–190 ºC. As a result, the biochemical composition of feed changes: there is an intensive dextrinization and gelatinization of starch with the formation of starch gel, dextrins and sugars [14-16], there is a partial hydrolysis of fiber, the biological structure of toxic substances

is practically destroyed, disinfection from mold and fungi is carried out, there is a significant decrease in the kinematic viscosity of the aqueous extract, the taste qualities are improved[1, 2]. After eating forages containing barohydrothermally treated (BHTO) wheat grain, cows showed a decrease in the content of degradable protein in the rumen from 78.9 to 24.2% (more than 3 times). Protein degradability of barley, rye, peas and fodder beans after BHTO decreased 1,5-3,0 times. Heat treatment causes denaturation of protein, which becomes inaccessible for the enzymes of proteolytic microorganisms of the rumen, which makes the protein of grain fodder less soluble in the rumen fluid[3]. After extrusion treatment of forages their digestibility and digestibility increase.

When feeding extruded grain fodder, the volume of growth of young animals increases, the quality of products (milk, meat) improves. Neutralization of anti-nutritive properties and change of biochemical composition of winter rye grain by extrusion processing allow to increase its content in the structure of typical mixed fodders [17–19].

Further research on the use of rye extrudate in the feeding of farm animals should be directed to the study of protein and starch digestibility of extruded feed in the rumen of ruminants, the degree of influence of extrudate on the biochemical composition of rumen fluid of different age groups with the subsequent identification of metabolic correction, as well as on the productivity.

The purpose of the study was to determine the effect of different amounts of winter rye grain extrudate, included in the concentrate part of the diet, on the organism of young cattle: utilization of nitrogenous substances supplied with feed, changes in the level of metabolism, growth rate.

MATERIAL AND METHODS

The experiment was conducted in 2021 at a dairy complex located in the Perm region. The object of the study was 12–15-month-old heifers of Holsteinized Black- and-White breed. The staged live weight of the animals used in the study was in the range 301,4–301,8 kg, i.e. the difference in weight of individuals did not exceed 1,10% (amounted to 0,99%), which confirms the correctness of pair-analogues selection. Scientific and economic experience consisted of two periods: preparatory (equalizing) – 15 days, registration – 92 days. The animals were kept on tie-up housing.

Heifers were combined into four groups (one control and three experimental groups) of 11 animals each. Within the framework of the generally accepted methodology, the groups of animals were formed according to the principle of pair-analogs, taking into account age, live weight and lineage[4].

The heifers of the control group received the basic diet (BD), which consisted of: 2.90 kg of cereal-legume hay (cocksfoot + meadow clover); 14.50 kg of cereal-legume silage (awnless brome + Eastern galega); the concentrate part consisted of 50.0% (1.0 kg) of standard mixed fodder KR 3 (GOST 9268–2015), 50.0% (1.0 kg) – of rolled barley (see Table 1). Heifers of the three experimental groups received the same set of voluminous feeds as those in the control group, but the concentrate part was additionally supplemented with winter rye grain extrudate in the amount of 12.5; 25.0 and 50.0%, respectively.

The concentration of metabolizable energy and crude protein in the dry matter of the diets of experimental animals during the study period was within the recommended norms [1] and corresponded to 0.97-0.98 MJ and 16.1- 16.5%. The sugar-protein ratio was within 0.62-0.75 (the norm for heifers is 0.70).

[1]*Ačkar Đ., Babić J., Jozinović A., Miličević B., Jokić S., Miličević R., Rajič M., Šubarić D.* Starch Modification by Organic Acids and Their Derivatives: A Review // Molecules, 2015, N 20 (10), pp. 19554–19570.

[2]*Chen B., Chen Yu., Junfei L., Yuling Y., Xinchun Sh., Shaowei L., Xiaozhi T.* Physical properties and chemical forces of extruded corn starch fortified with soy protein isolate // International Journal of Food Science and Technology, 2017, N 52 (12), pp. 2604–2613.

[3]*Pogosyan D.G., Chudaykin V.V.* Protein degradability in the rumen and utilization of nitrogenous substances of feed in growing steers at chemical and barohydrothermal treatment of feed // Problems of Productive Animal Biology, 2011, N 2, pp. 79-86.

[4]*Ovsyannikov A.I.* Fundamentals of experimental work in animal breeding. Moscow: Kolos, 1976, 304 p.

During 7 days, physiological experiments were conducted on three 15-month-old heifers from each group to determine the digestibility of the fodder of a given diet based on the generally accepted methodology of M.F. Tomme[5]. Once a day at the same time samples of feed and its residues, as well as feces and urine were taken. Common zootechnical methods were used to study the obtained material[6].

Morphobiochemical parameters of the blood in heifers (three animals from each group) were analyzed according to the established method[7]. Rumen contents were taken during physiological experiments 1 h before morning feeding and 3 h after it with a probe (three animals per group). The value of total and non-protein nitrogen in the samples of rumen fluid filtered through four layers of gauze was determined by the Kjeldahl method, protein nitrogen - by the difference between total and non-protein nitrogen, and ammonia nitrogen - by the microdiffusion method in Convey cups[8].

All varying quantitative characteristics were subjected to statistical processing[9]. Reliability of the effects was assessed on the basis of the Student's *t* criterion[10]. Necessary calculations were performed using Microsoft Excel.

RESULTS AND DISCUSSION

The level of metabolizable energy in rye extrudate amounted to 12.34 MJ/kg. The crude protein content in the extrudate compared to winter rye grain decreased by 0.41%, amounting to 14.67% in absolute dry matter. The amount of sugar in the rye extrudate compared to the grain increased 2.46 times and amounted to 12.44% per 1 kg absolute dry matter. The amount of crude fiber and starch in the dry matter of extrudate compared to rye grain decreased by 3.48 and 5.62%, amounting to 6.93 and 43.12%, respectively.

Increased consumption of nitrogen from daily ration was observed in the heifers of 1–3 experimental groups compared to the control: they consumed it by 6.56; 8.48 and 16.85 g (3.85; 4.98 and 9.90%) more ($p < 0.01$). Nitrogen utilization in the bodies of heifers of the control group was less rational. Heifers of the experimental groups deposited in the body: input nitrogen – by 0.82; 1.16 and 3.52% more, digested nitrogen – by 0.19; 0.94 and 4.31% more (see Table 2).

In the heifers of groups 1-3 the volume of nitrogen deposited in the body increased compared to the control by 6.42; 8.67 ($p < 0.05$) and

Табл. 1. Схема научно-хозяйственного опыта ($n = 11$)
Table 1. Scheme of the scientific and economic experience ($n = 11$)

Period	Group			
	control	1st	2nd	3rd
Preparatory – 15 days	BD	BD	BD	BD
Registration – 92 days (from 366th to 458th day of cultivation)	50,0% typical mixed fodder + 50.0% mashed barley*	50,0% typical mixed fodder + 37,5% mashed barley + 12,5% winter rye grain extrudate*	50,0% typical mixed fodder + 25,0% mashed barley + 25,0% winter rye grain extrudate*	50,0% typical mixed fodder + 50,0% winter rye grain extrudate*

*The composition of the concentrate part of the basic ration is indicated

[5]*Tomme M.F.* Methods of determining the digestibility of forages and rations. Moscow, 1969, 37 p.

[6]*Toporova L.V., Arkhipov A.V., Tishenkov P.I., Andreev V.V., Shelest V.M., Kurilova N.M.* Methods of zootechnical analysis of fodder: textbook. Moscow, 2013, 55 p.

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[8]*Kurilov N.V., Sevastyanova N.A.* Study of digestion in ruminants: method. instructions. Borovsk, 1987, 39 p.

[9]*Merkurieva E.K., Shangin-Berezovsky G.N.* Genetics with the basics of biometry. Moscow: Kolos, 1983, 400 p.

[10]*Plokhinsky N.A.* Manual on biometrics for zootechnicians. Moscow: Kolos, 1969, 256 p.

21.53% ($p < 0.01$), respectively. It can be stated that feeding young cattle with extrudate of winter rye grain in different amounts favorably influenced the use of nitrogen supplied with feed.

In the rumen contents 1 h before feeding the level of nitrogenous fractions was practically at the same level (see Table 3). In the rumen fluid taken 3 h after feeding, the level of total nitrogen was higher in the heifers of experimental groups compared to the control: in group 1 – by 2.47%, in group 2 – by 11.90% ($p < 0.05$), in group 3 - by 21.39% ($p < 0.01$). At the same time, the amount of ammonia in the heifers of experimental groups decreased relative to the control by 3.74; 16.64 and 23.47% ($p < 0.05$), respectively. We believe that this is primarily due to an increase in the sugar-protein ratio in the diet.

According to the results of the analysis of nitrogen metabolism data in the rumen fluid of replacement heifers (see Table 3), it can be noted that in our experiment the level of protein nitrogen was characterized by an increase in the heifers of groups 1–3 by 4.26; 19.91 ($p < 0.001$) and 34.51% ($p < 0.001$), respectively, compared with the control group. Earlier it was scientifi-

Табл. 2. Среднесуточный баланс азота и уровень его использования подопытными животными ($n = 3$; $X \pm S_x$)

Table 2. Average daily nitrogen balance and its utilization by experimental animals ($n = 3$; $X \pm S_x$)

Indicator	Group			
	control	1st	2nd	3rd
Intake with feed, g/head/day	170,08 ± 2,65	176,64 ± 1,67	178,56 ± 1,87	186,93 ± 3,39**
Excreted with feces, g/head/day	67,63 ± 0,18	67,97 ± 0,61	69,08 ± 0,39*	71,43 ± 0,92**
Digested, g/head/day	102,45 ± 0,44	108,67 ± 0,34***	109,48 ± 1,41**	115,50 ± 2,17**
Excreted with urine, g/head/day	44,23 ± 0,33	44,52 ± 1,15	46,06 ± 0,43*	46,81 ± 0,95
Deposited in the body, g/head/day	56,52 ± 1,15	60,15 ± 0,87	61,42 ± 1,19*	68,69 ± 2,34**
Deposited in the body, %:				
from the intake	33,23	34,05	34,39	36,75
from the digested	55,16	55,35	56,10	59,47

Примечание. Здесь и в табл. 3, 4: *$p < 0,05$; **$p < 0,01$; ***$p < 0,001$.

Табл. 3. Содержание фракций азота в рубцовой жидкости ремонтных телок, мг ($n = 3$)

Table 3. Content of nitrogen fractions in the rumen fluid of replacement heifers, mg ($n = 3$)

Indicator	Group			
	control	1st	2nd	3rd
1 h before feeding				
Total nitrogen	103,54 ± 2,41	103,65 ± 3,97	105,97 ± 2,17	107,37 ± 1,88
Including:				
protein	72,14 ± 2,76	72,13 ± 3,54	74,54 ± 3,96	75,69 ± 3,65
% of total nitrogen	69,67	69,59	70,34	70,49
non-protein	22,40 ± 0,99	22,54 ± 0,65	22,43 ± 1,15	22,68 ± 1,09
% of total nitrogen	30,33	30,41	29,66	29,51
Ammonia nitrogen	7,66 ± 0,45	7,49 ± 0,64	7,37 ± 0,61	6,95 ± 0,98
3 h after feeding				
Total nitrogen	145,99 ± 3,87	149,59 ± 2,75	163,36 ± 2,76*	177,22 ± 3,24**
Including:				
protein	103,30 ± 1,67	107,70 ± 2,03	123,87 ± 2,32***	138,95 ± 2,75***
% of total nitrogen	70,76	72,00	75,83	78,41
non-protein	42,69 ± 1,96	41,89 ± 1,87	40,49 ± 0,99	38,27 ± 1,63
% of total nitrogen	29,24	28,00	24,17	21,59
Ammonia nitrogen	18,45 ± 1,09	17,76 ± 1,06	15,38 ± 0,88	14,12 ± 0,94*

cally proved that improvement of carbohydrate nutrition of ruminants increases the intensity and regulates the orientation of metabolic processes in the sections of the complex stomach.

Feeding winter rye grain extrudate as part of the concentrate part of the diet improved some biochemical parameters of heifers' blood in the experimental groups relative to the control (see Table 4).

At the end of the experiment in the blood of heifers of the 3rd experimental group there was an increase in total protein in plasma by 6.51%, γ globulins – by 8.54% ($p< 0.01$), which indicates an increase in the intensity of protein metabolism compared to control animals. Protein sufficiency of the diet is determined by the concentration of albumin in blood serum, which characterizes the protein reserve of the organism.

The dynamics of increase of the albumin fraction of blood serum proteins was also observed at the end of the experiment. According to Table 4, the concentration of albumin in the animals of groups 2 and 3 at the end of the experiment was higher by 2.28 and 5.44% ($p < 0.05$) relative to the control and amounted to 45.49 and 47.01%, respectively (against 44.45% in the control group).

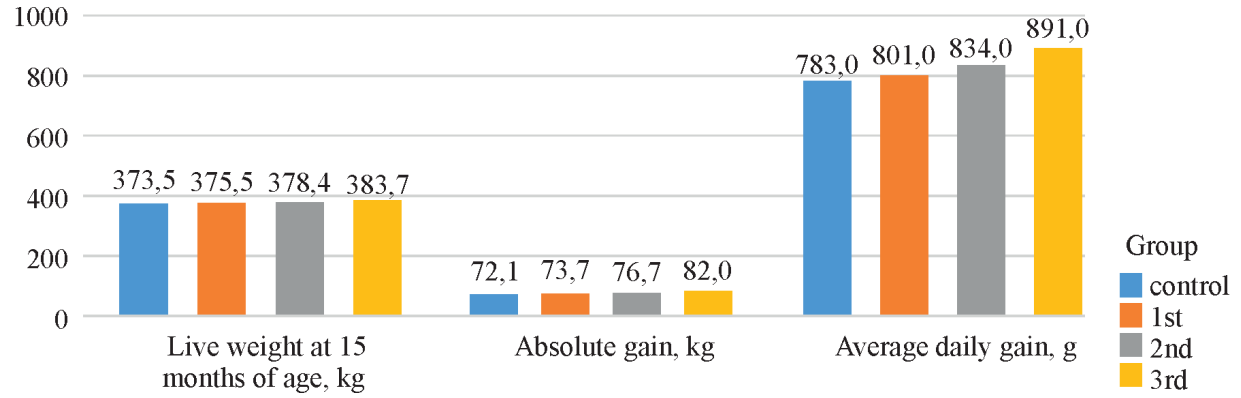
Albumin-globulin coefficient determines physicochemical properties of blood and protein synthesis in the liver. Animals of the 2nd and 3rd experimental groups, receiving 25.0 and 50.0% of winter rye grain extrudate as part of the concentrate part of the diet, at the end of the experiment exceeded the heifers of the control group by protein index. Such data indicate intensive metabolism and sufficient protein intake with fodder.

At the end of the experiment the amount of glucose in blood serum in the 2nd and 3rd experimental groups exceeded the control group by 8.89 and 15.78% and reached 2.81 ($p < 0.01$) and 3.04 mmol/l ($p < 0.001$). The established dynamics of glucose level in the blood of animals of experimental groups is due to the correction of metabolism in response to the introduction of winter rye grain extrudate into the diet, containing a greater volume of feed sugar.

Табл. 4. Показатели биохимического состава крови ремонтных телок ($X \pm S_x$)

Table 4. Biochemical composition indicators of replacement heifers' blood ($X \pm S_x$)

Group	Beginning of the experiment	End of the experiment
Total protein, g/l		
Control	73,13 ± 0,78	73,83 ± 0,53
1st	73,28 ± 0,54	74,63 ± 0,32**
2nd	72,93 ± 0,18	75,10 ± 0,75**
3rd	72,97 ± 1,17	78,97 ± 0,17
Albumins, %		
Control	44,72 ± 0,36	44,45 ± 0,71
1st	44,44 ± 0,75	44,44 ± 0,36
2nd	44,99 ± 0,92	45,49 ± 0,92
3rd	44,93 ± 0,98	47,01 ± 0,32*
α- globulins, %		
Control	18,42 ± 0,65	18,84 ± 0,28
1st	17,43 ± 0,63	17,43 ± 0,64
2nd	16,47 ± 0,14*	16,47 ± 0,14***
3rd	16,61 ± 1,02	14,03 ± 0,27***
β- globulins, %		
Control	17,97 ± 0,75	18,40 ± 0,52
1st	18,96 ± 0,90	18,96 ± 0,44
2nd	19,11 ± 0,33	18,16 ± 0,37
3rd	18,94 ± 0,88	18,94 ± 0,49
γ- globulins, %		
Control	18,89 ± 1,24	18,31 ± 0,56
1st	19,17 ± 0,57	19,17 ± 0,27
2nd	19,43 ± 0,64	19,88 ± 0,13
3rd	19,52 ± 0,83	20,02 ± 0,31
Albumin-globulin coefficient		
Control	0,81	0,80
1st	0,80	0,80
2nd	0,82	0,83
3rd	0,82	0,89
Glucose, mmol/l		
Control	2,44 ± 0,11	2,56 ± 0,41
1st	2,45 ± 0,09	2,75 ± 0,71
2nd	2,26 ± 0,06	2,81 ± 0,58
3rd	2,34 ± 0,12	3,04 ± 0,44
Cholesterol, mmol/l		
Control	3,24 ± 0,05	2,44 ± 0,55
1st	3,22 ± 0,11	2,62 ± 0,93
2nd	3,18 ± 0,14	3,02 ± 0,54
3rd	3,38 ± 0,31	3,10 ± 0,57
Urea, mmol/l		
Control	5,36 ± 0,19	5,45 ± 0,12
1st	5,39 ± 0,31	5,11 ± 0,34
2nd	5,25 ± 0,45	4,99 ± 0,21
3rd	5,33 ± 0,79	4,87 ± 0,09*



Интенсивность роста ремонтных телок (n = 11)
Growth rate of replacement heifers (n = 11)

In the experimental groups there was an increase in the concentration of cholesterol in blood compared to the control animals (average for the groups): in group 1 – by 7.37%, in group 2 – by 23.77, in group 3 – by 27.05%. The highest level of cholesterol in the blood of 15-month-old heifers was found in animals of the 3rd group.

Urea is a marker of the degree of utilization and biological value of the digested protein. By the end of the experiment, this indicator was within the physiological norm (4.87–5.45 mmol/l) in the blood of the representatives of all groups. At the same time in the heifers of the 2nd and 3rd groups the content of urea in blood was lower than in the control by 8.44 and 10.64% ($p< 0.05$), which allowed us to conclude that the heifers of these experimental groups better utilized the nitrogen supplied with feed.

The experiment also revealed the effect of feeding winter rye grain extrudate on the growth performance of the replacement heifers (see the figure). At 15 months of age heifers of 1-3 experimental groups exceeded the animals of the control group by 2.0; 4.90 and 10.2 kg, or 0.54; 1.31 and 2.73% ($p < 0.05$) in the live weight, respectively. During the experiment, the difference in absolute gain in favor of the heifers of 1-3 experimental groups was 2.22; 6.38 and 13.73%, respectively ($p < 0.001$). The average daily live weight gain of the control group was 18.0; 51.0 ($p< 0.05$) and 108.0 g ($p< 0.001$) inferior to the peers of the three experimental groups.

It can be assumed that feeding different volumes of winter rye grain extrudate influenced the increase in the absolute growth rate of experimental group replacement heifers.

CONCLUSIONS

1. More of the incoming with feed and from digested nitrogen was deposited in the body by the heifers of 1– 3 experimental groups: in comparison with the control the excess amounted to 0.82; 1.16 ($p < 0.05$) and 3.52% ($p < 0.01$) for the first indicator, 0.19; 0.94 ($p < 0.05$) and 4.31% ($p < 0.01$) for the second one.
2. The amount of ammonia in the contents of the rumen fluid 3 h after feeding in the heifers of all experimental groups decreased relative to the control by: 3,74% – in the 1st, 16,64% – in the 2nd, 23,47% – in the 3rd.
3. At the end of the experiment in the blood plasma of the 3rd experimental group heifers, the greatest increase in total protein (by 6.51%) and γ globulins (by 8.54%) was observed relative to the control animals ($p < 0.01$). In addition, the level of albumin in the 2nd and 3rd experimental groups was higher by 2.28 and 5.44% ($p < 0.05$) compared to the control, amounting to 45.49 and 47.01%, respectively (in the control group - 44.45%).
4. At 15 months of age, the heifers of the experimental groups exceeded the animals of the control group in live weight by 2.00; 4.90 and 10.20 kg, or 0.54; 1.31 and 2.73% ($p < 0.05$).
5. In order to increase the use of winter rye grain in cattle feeding it is necessary to include up to 50.0% of winter rye grain extrudate in the concentrate part of the ration of the replacement

heifers older than 12 months of age, which improves nitrogen metabolism in the body and, accordingly, increases growth rates.

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ИСТОРИЯ РАЗВИТИЯ СЕЛЕКЦИОННО-ПЛЕМЕННОЙ РАБОТЫ В СЕВЕРНОМ ОЛЕНЕВОДСТВЕ КРАЙНЕГО СЕВЕРА ДАЛЬНЕГО ВОСТОКА

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В ходе естественного и искусственного отбора в различных экологических зонах Крайнего Севера Дальнего Востока сформировались резко различающиеся между собой аборигенные типы оленей – чукотский и эвенский. В 1970–1972 гг., на начальном этапе племенной работы, проводили изучение хозяйственно полезных признаков оленей различных популяций тундровой, лесотундровой и таежной зон. Во время осенней корализации в тундровой зоне к улучшающей части стада были отнесены: телята 6,5 мес с живой массой 50,2 кг, бычки – 88,5 кг, третьяки – 99,2 кг, быки – 120,3 кг, важенки – 95,6 кг. Максимальных показателей по мясной продуктивности олени таежной и лесотундровой зон достигали в октябре, тундровой – к началу сентября. В 1971–1973 гг. в совхозе «Марковский» проводили сравнительную оценку мясной продуктивности северных оленей двух экстерьерно-конституциональных типов: высокорослый крупный и низкорослый компактный. На начало 1980-х годов основу племенной базы составили два племенных хозяйства: совхоз «Рассохинский» и «Возрождение», а также племенные стада в совхозах «Расцвет Севера», «Марковский», «Энмитагино», «Путь к коммунизму», «Дружба». В хозяйствах осуществлялось межпородное и межпопуляционное скрещивание: тофаларских оленей с местными эвенскими; эвенских важенок с быками аяно-майской популяции, завезенными из совхоза «Нельканский» Хабаровского края; местных оленематок (важенок) эвенского типа с производителями томпонского типа, завезенными из совхоза «Томпонский» в Якутии. Путем скрещивания неродственных групп оленей чукотской породы, отбора и разведения особей желательного типа в течение ряда поколений выведен высокопродуктивный тип северного оленя «Возрождение». Живая масса телочек данного типа в возрасте 5–6 мес превышает стандарт чукотской породы на 6,9%, бычков – на 12,6%, важенок 2,5 лет – на 14,2%, третьяков – на 22,2%. Генетический потенциал оленей внутрипородного типа «Возрождение» по живой массе полновозрастных важенок составил 120 кг, быков – 150 кг. Также олени этого типа отличаются от других пород ранними сроками гона и отела. В целях совершенствования селекционно-племенной работы в Магаданской области и Чукотском автономном округе с 2017 г. по настоящее время используются эффективные методы, основанные на достижениях молекулярной генетики. По результатам исследований отмечается высокая степень гетерозиготности у приохотской популяции эвенской породы (0,882) и у чукотской (0,865), что свидетельствует о преимуществе этих особей по адаптивным признакам и об устойчивости популяции.

Ключевые слова: чукотская порода, эвенская порода, бонитировка, внутрипородный тип «Возрождение», ISSR-анализ, гетерозиготность

HISTORY OF THE DEVELOPMENT OF BREEDING AND PEDIGREE WORK IN REINDEER HERDING IN THE FAR NORTH OF THE FAR EAST

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In the course of natural and artificial selection in different ecological zones of the Far North of the Far East, sharply different indigenous types of reindeer – Chukchi and Even – were formed. In 1970–1972, at the initial stage of the breeding work, the economically useful traits of reindeer of different populations of tundra, forest-tundra and taiga zones were studied. During the autumn inventory and sanitation events in the tundra zone, the improving part of the herd included: calves 6.5 months old with a live weight of 50.2 kg, bull calves – 88.5 kg, two-year olds – 99.2 kg, bulls – 120.3 kg, and rein-

deer does – 95.6 kg. Reindeer of taiga and forest-tundra zones reached their maximum meat productivity in October, and those of tundra zone – by the beginning of September. In 1971–1973 in the state farm "Markovsky" a comparative assessment of meat productivity of reindeer of two exterior-constitutional types: high-growing large and low-growing compact was carried out. At the beginning of the 1980s the basis of the breeding base was formed by two breeding farms: state farm "Rassokhinsky" and "Vozrozhdenie", as well as breeding herds in the state farms "Rastsvet Severa", "Markovsky", "Enmitagino", "Way to Communism", "Druzhba". Interbreed and interpopulation crossing was carried out in the farms: Tofalar reindeer with local Even reindeer; Even reindeer does with the bulls of the Ayano-Mai population imported from the state farm "Nelkansky" in the Khabarovsk Territory; local Even-type reindeer does with the Tomponsky-type producers imported from the state farm "Tomponsky" in Yakutia. By crossing unrelated groups of the Chukchi reindeer breed, selecting and breeding individuals of desirable type for a number of generations, a highly productive type of reindeer "Vozrozhdenie" was bred. Live weight of this type of heifers at the age of 5-6 months exceeds the standard of the Chukchi breed by 6.9%, bull calves – by 12.6%, reindeer does – by 14.2%, two-year olds – by 22.2%. The genetic potential of reindeer of the inbreed type "Vozrozhdenie" by the live weight of full-aged reindeer does amounted to 120 kg, bulls – 150 kg. Also deer of this type differ from other breeds by early dates of estrus and fawning. In order to improve breeding and pedigree work in the Magadan region and the Chukotka Autonomous District, effective methods based on the achievements of molecular genetics have been used since 2017 to date. According to the results of the study, a high degree of heterozygosity was observed in the Priokhotsk population of the Even breed (0.882) and in the Chukchi population (0.865), which indicates the advantage of these individuals in adaptive traits and population stability.

Keywords: Chukchi breed, Even breed, valuation, intrabreed type "Vozrozhdenie", ISSR-analysis, heterozygosity

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Northern reindeer herding is a rather complex and labor-intensive type of livestock breeding, as the reindeer (*Rangifer tarandus* L.) is the only domestic animal species whose habitat is the Arctic and sub-Arctic landscapes.

The purpose of the study is to analyze the dynamics of the development of selection and breeding work in domestic reindeer breeding during its existence in the Far North of the Far East. The main task is to identify the most effective methods of selection and breeding work for their subsequent introduction into practice at the present stage of development of northern reindeer breeding in the area of distribution of agricultural populations of the Chukchi and Even breeds.

Ethnographic and archaeological findings prove the comparative youth of reindeer husbandry. It is believed that reindeer husbandry emerged not earlier than the 1st millennium BC with the formation of two centers - Sayan and Tunguska, from which it extended to other territories. Reindeer husbandry of the Evenkis, Even, Koryaks, and Chukchi is connected with the Tungus center[1].

[1] *Vasilievsky R.A.* From the history of reindeer breeding // Magadansky Olenevod, 1962, N 2, pp. 47-48.

During the period of the Chukotka's discovery by the Russians (XVII century), pastoral Chukchi reindeer herding was only in its infancy, but since the beginning of the XIX century it began to progress strongly. In 1867 the Chukchi received permission from the Russian government to move their nomads to the left bank of the Kolyma River. Here Chukchi reindeer herding began to develop rapidly and soon occupied the entire tundra of the left bank of the Kolyma (see footnote 1).

In connection with the beginning of the development of the Far North in the Soviet era, reindeer breeding could not remain unattended, and since the 1950s, local periodicals began to publish the first information from the interested agencies about the problems of reindeer breeding farms with regard to the implementation of zootechnical and veterinary rules aimed at improving the economically useful qualities of reindeer. During this period, collective farms suffered major losses due to the slaughter of reindeer calves, low viability of the litter, and unsatisfactory rates of its development[2].

It is well known that the improvement of the breeding qualities of reindeer, as with livestock, depends entirely on external factors and involves the implementation of the following measures: rational nutritious feeding, proper selection and regular change of pastures, optimal herd size, proper grazing system, and obligatory division of herds into productive and non-productive parts (see footnote 2). This is not a complete list of the conditions necessary to obtain healthy and complete individuals.

The specifics of the natural and climatic zones of reindeer husbandry and their economic purpose have determined the direction of selection in reindeer husbandry, which has led to the differentiation of reindeer into various ecological populations, differing in productivity, body type, exterior, speed of maturity and ability to transmit their genetic features by inheritance[3].

In the 1970s, the breeds in northern reindeer husbandry had not yet been officially approved. However, in the course of natural and artificial selection in different ecological zones, sharply different aboriginal types - Chukchi and Even - were formed. Each type is characterized by certain economically useful features. The Chukchi type was created under the influence of natural and climatic conditions of the Arctic tundra on the basis of folk selection aimed at improving meat forms of animals. The Even type was formed by selection of animals with good riding qualities. Specific environmental conditions characteristic of the taiga zone – cold snowy winters, forested pastures, hot summers – made a peculiar imprint. Even reindeer (see Fig. 1) differ from the Chukchi reindeer (see Fig. 2) by their tall stature, massive bones, long legs with wide hooves, and somewhat compressed body[4].

Both types of reindeer required breeding for quality: the first one - to increase body size, the second one - to improve meat forms, to increase stature and slaughter yield. Since ancient times, in order to obtain strong, viable offspring, to reduce the number of mothers, and to have fast and hardy riding reindeer, the Chukchi of the East Tundrovsky, Anadyrsky and Markovsky districts have been trading reindeer from the Evenes.

In the 1970s, reindeer breeding farms studied phenotypic traits of reindeer from different zones and selected animals for meat productivity, reproductive traits (fertility, milk production, maternal qualities), calving dates, viability, etc.

At the initial stage of the breeding work economically useful traits of different populations available in the region were studied. The studies were conducted in 1970-1972 in tundra, forest-tundra and taiga zones. Identified standards of reindeer on a number of phenotypic traits were taken into account in the purposeful selection of animals for further reproduction. Thus, during autumn inventory and sanitation events in the

[2]*Skurlatov I.A.* Improving breeding qualities of reindeer // Magadansky Olenevod, 1958, N 1, pp. 30-33.

[3]*Soskin A.A., Glushnev S.V.* Development of live weight and exterior features of the first-generation littermates obtained from crossing the Even reindeer does with Ayan-Mai producers // Proceedings of the Magadan Zonal Research Institute of Agriculture of the North-East, Magadan, 1981, Issue 9, pp. 30-36.

[4]*Soskin A.A., Bryzgalov G.Ya.* Interpopulation crossbreeding of reindeer in the Magadan region // Magadansky Olenevod, 1982, N 34, pp. 26-28.

tundra zone, the following animals were classified as the improving part of the herd: calves at the age of 6.5 months with a live weight of 50.2 kg, bull calves with a live weight of 88.5 kg, two-year olds with a live weight of 99.2 kg, bulls with a live weight of 120.3 kg, and reindeer does with a live weight of 95.6 kg.

Reindeer of taiga and forest-tundra zones reached their maximum meat productivity in October, tundra zone – by the beginning of September[5].

In 1971-1973 in the state farm "Markovsky" of the Anadyr district a comparative assessment of meat productivity of reindeer of two exterior-constitutional types was carried out: high-grown large and low-grown compact. It was established that in the forest-tundra zone the optimal type of reindeer should combine high stature and high weight gain of the first type with good meat qualities of the second type[6].

For purposeful selection correlations between different productivity traits and their inheritance

Рис. 1. Эвенский тип оленей, распространенный в горно-таежной зоне Магаданской области
Fig. 1. The Even type of reindeer, widespread in the mountainous taiga zone of the Magadan region

Рис. 2. Чукотский тип оленей, характерный для тундровой зоны Чукотки
Fig. 2. The Chukchi type of reindeer, typical for the tundra zone of Chukotka

[5]*Kudela E.I., Deryazhentsev V.I.* Comparative characterization of some phenotypic traits of reindeer of different zones // Proceedings of the Magadan Zonal Research Institute of Agriculture of the North-East. Magadan, 1974, Issue 4, pp. 9-19.

[6]*Deryazhentsev V.I., Kudela E.I.* Comparative evaluation of meat productivity of reindeer of two exterior-constitutional types // Proceedings of the Magadan Zonal Research Institute of Agriculture of the North-East. Magadan, 1975, Issue 5, pp. 13-19.

were studied, finding out the possibilities of increasing meat productivity by selecting young animals by live weight at different ages. In this connection, in 1974 and 1975 on the basis of experimental-production farm "Yubileiny" and the state farm "Polarnik" a series of experiments were conducted, which determined the expediency of selection of calves for further breeding use according to their grading class at 6 months of age, i.e. after the suckling period[7].

In October 1977, in accordance with the approved plan of the breeding work in reindeer breeding of the Magadan region and Chukotka, the first mass appraisal of three herds of the state farm "Rassokhinsky" was carried out according to all the rules of the developed instructions. The reindeer were evaluated by live weight, body type and fatness with the subsequent determination of the quality class[8].

In the early 1980s, Magadan region became the largest reindeer herding region in the country. Over 700 thousand reindeer were grazing in all categories of farms, including 346 thousand breeding stock. Targeted breeding work provided a significant increase in productive qualities of reindeer. According to the results of the valuation, 86.3% of the animals were assigned to the 1st and 2nd classes. Consistent implementation of the measures to improve breeding allowed to form its own breeding base. Its basis was formed by the two breeding farms: state farm "Rassokhinsky" and "Vozrozhdenie", as well as breeding herds " Rastsvet Severa", "Markovsky", "Enmitagino", "Way to Communism", "Druzhba "[9].

The intensification of the reindeer breeding industry dictated the development of the breeding and pedigree work. As a result, the most effective methods were created, one of which was interbreeding and interpopulation crossing. This method is based on the combination and interaction of different genotypes. This is the fastest way to enrich and expand the hereditary basis of crossbreds, create new animal forms and increase their viability[10].

The farms "Omolon" and " Rastsvet Severa" successfully conducted experiments on crossbreeding Tofalar reindeer with local Even reindeer. 443 breeding sires were imported from Yakutia, Chita region and the Khabarovsk Territory. In the state farm "Omolon", the mixed youngsters obtained from mating of Even breeding females with Tofalar bulls-producers at the age of 6 months exceeded their Even peers in live weight by 12.7-13.8 kg[11].

The state farm "Yubileiny" conducted an experiment on industrial crossbreeding of Eveno-Ayan females with bulls of the Ayan-Mai population imported from the state farm "Nelkansky" of the Khabarovsk Territory. The Even-Ayan littermates surpassed their Even reindeer peers in live weight by 3.2 kg, in height at the withers by 4.7 cm, and in chest girth by 2.0 cm.

In the reindeer breeding farm "Rastsvet Severa" the effectiveness of crossbreeding the local Even-type reindeer breeders (reindeer does) with Tompon-type producers imported in the amount of 263 animals from the state farm "Tomponsky" (Yakutia) was studied. It should be noted that the producers involved in the breeding were obtained from crossing of Tofalars and local Yakut mothers of the Tomponsky population. As a result of the experiments, it was found that Even-Tompon litters differed significantly from the local ones in terms of growth and development of young animals. Absolute gain in the live weight from the beginning of birth in experimental males for 6 months amounted to 51.4 kg against 42.7 kg in the control ones, the difference was 10 kg in crossbred females. For 6 months, the live weight of the mixed males increased 7.7 times against 7.1 times in the local males; females – 7.4 times against 7.1 times, respectively. Thus, the advantage of the Even-Tompon reindeer of the first generation compared to the local

[7]*Deryazhentsev V.I., Shifner K.G.* Heritability and correlative relationships of some economically useful traits of reindeer // Proceedings of the Magadan Zonal Research Institute of Agriculture of the North-East. Magadan, 1978, Issue 7, pp. 4-11.

[8]The system of reindeer breeding in the Magadan region. Novosibirsk, 1986, p. 76.

[9]*Pivnev N.T.* Reindeer of the state farm "Rassokhinsky" // Magadansky Olenevod, 1978, N 2, pp. 30-31.

[10]*Pozhyzhiko E.G.* Improving local breed groups // Magadansky Olenevod, 1980, N 3, pp. 16-17.

[11]*Pivnev N.T.* Breeding base of reindeer breeding of the Magadan region // Magadansky Olenevod, 1982, N 2, pp. 21.

ones allowed us to recommend interpopulation crossbreeding[12].

It should be noted that breeding work in all farms of the Far North-East was carried out under the methodological guidance and direct participation of scientists of the Magadan Research Institute of Agriculture (Magadan NIISKh).

In view of the fact that by 1982 the main pastures were to be developed and the indicators of reindeer intensity in most farms were met, the main direction of increasing the production of reindeer herding products was in the intensification of the industry. In this regard, significant opportunities were opened for the improvement of breeding and pedigree work. It was possible to introduce into practice the "Methodology of reindeer valuation", which made it possible to establish the breeding value of animals with scientific accuracy. Two main breed groups of animals of aboriginal type were defined - Chukchi (Siberian tundra) and Even (Siberian forest).

In the 1980s, Chukotka's farms achieved high indicators of live weight of sexually mature reindeer-producers: in the "Vozrozhdenie" farm, the weight of reindeer does reached 100 kg and 129 kg, in the "Druzhba" state farm – 99 and 138 kg respectively, in the "Kommunist" state farm – 100 and 128 kg, and in the "Markovsky" state farm – 95 and 127 kg. The potential of highly productive Chukchi reindeer populations was effectively used to improve the performance of less productive herds[13].

Due to strict culling of animals, as well as under the influence of natural and climatic conditions, the Chukchi type of reindeer was significantly improved. The animals' precocity and their ability to fatten up quickly were accompanied by increased live weight. Thus, the young animals exceeded the indicators of the 1st class by 4-5 kg.

From 1983 to 2013, the Vozrozhdenie breeding farm in the Iultinsky District of Chukotka carried out the selection and pedigree work to breed a highly productive type of reindeer. The initial gene pool represented unrelated groups of reindeer of the Chukchi breed of the farms "Vpered" and "Vozrozhdenie", which united in 1950. Under the methodological guidance of the Magadan Research Institute of Agriculture, a breeding herd was formed, which became the basis of the intra-breed type of reindeer.

By crossing unrelated groups of the Chukchi breed reindeer, selecting and breeding individuals of the desired type over a number of generations, the highly productive type "Vozrozhdenie" was bred (see Fig. 3). The live weight of the heifers of this type at the age of 5-6 months exceeded the standard of the Chukchi breed by 6.9%, bull calves – by 12.6%, 2.5 - year-old reindeer does – by 14.2%, and two-year olds – by 22.2%.

Testing of the new type of reindeer for distinctiveness, uniformity and stability was carried out according to the methodology approved by the State Variety Commission on 24.11.2015.

The live weight indices of the inbreed type reindeer met the requirements of the highest valuation class for the Chukchi breed (see Fig. 4).

One of the most valuable economically useful traits for reindeer is the timing of calving of mothers. Early-born young calves have time to get stronger and achieve good development before the mass flight of bloodsucking insects and the onset of heat. In the autumn, such calves have a greater live weight, which is very important for wintering in the harsh natural conditions of the Arctic and Subarctic. Calving is earlier and more intense in the "Vozrozhdenie" intrabreed reindeer does compared to the Chukchi breed (see Fig. 5).

On the basis of zootechnical information on the creation of the intrabreed type the Magadan Research Institute of Agriculture received a patent for invention No. 1754033 "Method of breeding reindeer", a patent for breeding achievement No. 9099 "Reindeer (Rangifer taran-dus L.) "Vozrozhdenie".

[12]*Ustinov V.I.* Reindeer breeding of the Magadan region: Magadan: Book publishing house, 1977, 126 p.

[13]Chukotka aboriginal breed of reindeer: materials of the seminar-meeting "Breeding and pedigree work with reindeer of aboriginal breeds in the Chukotka Autonomous Okrug" (April 18-21, 2012). Moscow, 2012, pp. 22-30.

Puc. 3. Внутрипородный тип северных оленей чукотской породы «Возрождение»
Fig. 3. Intrabreed type of the Chukchi reindeer breed "Vozrozhdenie"

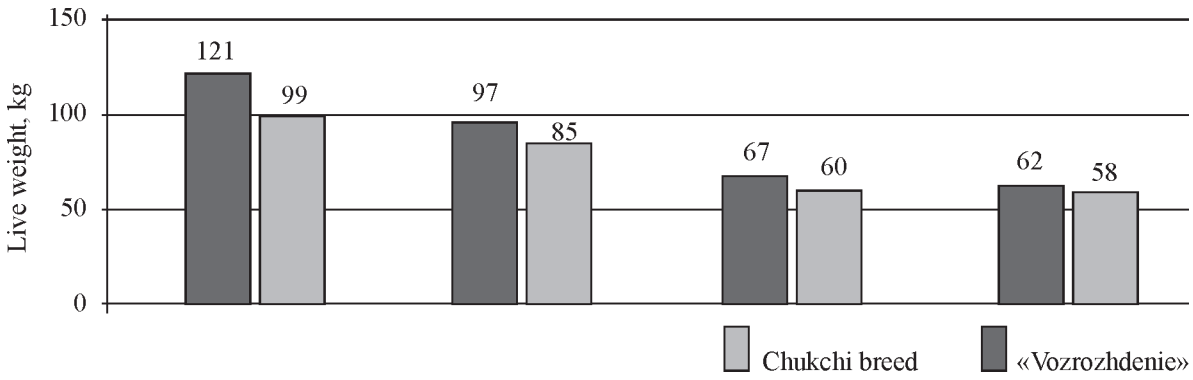
In order to improve the breeding and pedigree work in the Magadan region and the Chukotka Autonomous Area, more effective methods based on the achievements of molecular genetics have been used since 2013. DNA polymorphism makes it possible to study the genetic structure, differentiate breeds and populations of reindeer. Molecular multilocus analysis, or ISSR analysis, occupies a special place due to its high informativeness and speed of implementation[14-16] [1, 2].

In accordance with the "Plans of breeding and pedigree work" at a number of the breeding enterprises of the Chukotka Autonomous Area studies of the genetic structure of the Chukchi reindeer populations were conducted: gene pool farm "Vozrozhdenie", breeding reproducer "Khatyrskoye", breeding branches "Ayon", "Polarnik", "Zarya", "Kanchalansky", "Ozernoye", "Turvaurgin".

The studied populations of the Chukchi reindeer breed on all the above-mentioned farms are characterized by a rather high degree of heterozygosity. The level of intermicrosatellite DNA heterozygosity averages 0.865, which indicates the genetic diversity of the identified loci of the reindeer genome (see the table). The high level of heterozygosity gives animals an advantage in adaptive traits and provides stability of the population [3–9].

During the last 15 years, breeding organizations have bred and sold 35,000 reindeer of higher productivity classes to agricultural producers, 1225 reindeer of unrelated ecotypes of the Chukchi breed were purchased in the Kamchatka Territory and the Republic of Sakha (Yakutia) to enrich the gene pool [10].

In the Magadan region, due to the loss of the breeding base in the 1990s and a 15-fold



Puc. 4. Показатели живой массы оленей внутрипородного типа «Возрождение» и чукотской породы
Fig. 4. Live weight indices of the intrabreed reindeer type "Vozrozhdenie" and the Chukchi breed

[14]*Zinovieva N.A., Popov A.N., Ernst L.K., Marzanov N.S., Bochkarev V.V., Strekozov N.I., Brem G.* Methodical recommendations on the use of polymerase chain reaction method in animal breeding. Dubrovitsy, 1998, 47 p.

[15]*Zinovieva N.A., Gladyr E.A., Ernst L.K., Brem G.* Introduction to molecular gene diagnostics of farm animals. Dubrovitsy, 2002, 112 p.

[16]*Kalashnikova L.A., Dunin I.M., Glazko V.I.* Breeding of the XXI century: the use of DNA technologies. Moscow, 2000, 31 p.

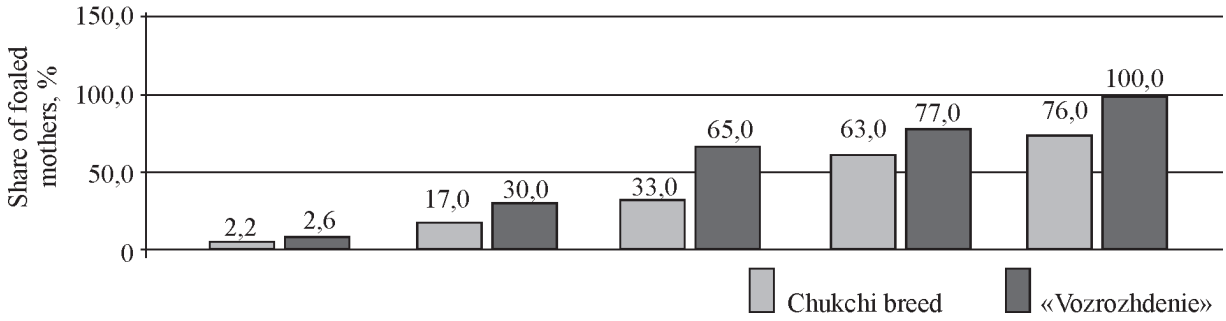


Рис. 5. Динамика отела оленей внутрипородного типа «Возрождение» и чукотской породы
Fig. 5. Calving dynamics of the intrabreed reindeer type of the "Vozrozhdenie" and the Chukchi breed

reduction in the number of reindeer, it became necessary to preserve the gene pool of the Even breed population and to study the genetic structure of the herds of the farm "Irbychan" and "Korkopsky" farm in the North-Even district. The high level of heterozygosity (0.882) of the Priokhota population of the Even breed (see the table), apparently, is associated with the peculiarities of formation of the gene pool of the farm "Irbychan", which occurred through the merger of three genetically different subpopulations of the Even breed: Parenskiy, Gizhiginsky and Garmandinsky, which indicates the advantage of these individuals in adaptive traits, ensuring the stability of the population. The high level of theoretical or expected heterozygosity confirms a high degree of genetic diversity in both the Chukchi and Even breeds.

The average number of alleles per microsatellite locus, reflecting intra-population diversity, in general for the Chukchi breed was 8.75, for the Even – 9.95. A decrease in the number of active effective alleles in the Chukchi breed (7.54) compared to the Even (8.49) is accompanied by a decrease in genetic and phenotypical diversity and leads to an increase in the population homogeneity.

For 2013-2023, the most effective methods based on the achievements of molecular genetics were identified and introduced into the practice of selection and breeding work with the Chukchi and Even breeds. The practical significance of the genetic research carried out is undeniable, since it can be recommended to solve important issues of selection and breeding work of reindeer herding enterprises. In addition, it is necessary to monitor the level of genetic diversity that ensures sustainable maintenance of populations.

Magadan NIISKh plans to conduct research to identify the genes and gene networks that control the development of economically significant signs of reindeer for the development of molecular markers for breeding purposes, as well as the genetic certification of the Chukchi and Even breeds of reindeer in the Far North of the Far East for targeted regulation of breeding processes.

Currently, for all breeding farms of the Chukotka Autonomous Area, 5 summer plans for selection and breeding work with the Chukotka breed of reindeer are being developed. Magadan NIISKh accompanies this work during the term of the plan.

In accordance with the state program of the Magadan region for the development of agriculture in the region, in close cooperation with the Ministry of Agriculture of the Magadan Region and the Department of Agriculture of the

Средние показатели генотипического разнообразия оленей чукотской и эвенской пород
Average indices of genotypic diversity of the Chukchi and Even breeds of reindeer

Indicator	Chukchi breed	Even breed
Average number of alleles per locus	8,75	9,95
Number of effective alleles	7,54	8,49
Homozygosity coefficient	0,135	0,118
Heterozygosity (by Robertson)	0,865	0,882

Chukotka Autonomous Area, the Magadan Research Institute of Agriculture is actively continuing to improve and strengthen the breeding work in domestic northern reindeer herding in the Far North of the Far East.

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ВЛИЯНИЕ РЕГУЛЯТОРА РОСТА И МИКРОУДОБРЕНИЯ НА УРОЖАЙНОСТЬ КАРТОФЕЛЯ В ЯКУТИИ

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Представлены результаты изучения влияния регулятора роста Новосил и микроудобрения Маг-Бор на показатели роста, фотосинтетической деятельности растений и урожайность картофеля сорта Якутянка в условиях Центральной Якутии. Почва опытного участка мерзлотно-пойменная супесчаная с недостаточным содержанием в пахотном слое гумуса (1,8–2,2%), подвижных соединений магния (1,25 мг/100 г), микроэлементов молибдена (0,03 мг/кг), марганца (29,0 мг/кг), бора (0,30 мг/кг). Установлено, что обработка посадок картофеля Новосилом массу растений увеличивала на 19–24%, площадь листьев и фотосинтетический потенциал – на 5–7%, магниево-борным удобрением (в дозе 5 г/л) – на 9 и 2% соответственно. Выявлена существенная прямая связь массы растений с их высотой и количеством в кусте (r = 0,71…0,81), площади листьев и значений фотосинтетического потенциала – с высотой, количеством и массой растений (r = 0,56…0,82). Вклад препаратов в изменчивость показателей составил 37–68%, погодных условий и взаимодействия факторов – 3–33%. Показано, что обработка растений Новосилом и совместно с Маг-Бор 5 г/л повышает урожайность клубней в сравнении с контролем на 6,4–6,6 т/га (34–35%), магниево-борным удобрением в дозе 5 г/л – на 2,5 т/га (14%). В вариантах Маг-Бор 10 г/л и Новосил + Маг-Бор 10 г/л урожайность была на уровне контроля или повышалась на 1,6 т/га (8,5%), в условиях засухи снижалась на 0,5–0,9 т/га. Доля влияния препаратов на изменчивость урожайности составила 68%, погодных условий – 26%, взаимодействия факторов – 4%. Рассчитаны уравнения регрессии, позволяющие оперативно и с высокой точностью прогнозировать площадь листьев и урожайность клубней по массе растений в фазе цветения. Разница между фактическими и рассчитанными значениями составляла 4,4–5,4%.

Ключевые слова: картофель, регулятор роста, микроудобрение, площадь листьев, фотосинтетический потенциал, урожайность

EFFECT OF GROWTH REGULATOR AND MICROFERTILIZER ON POTATO YIELD IN YAKUTIA

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The results of studying the effect of growth regulator Novosil and microfertilizer Mag-Bor on growth parameters, photosynthetic activity of plants and yield of potato variety Yakutyanka in condi-

tions of Central Yakutia are presented. The soil of the experimental plot is permafrost floodplain loamy with insufficient content of humus (1.8–2.2%), mobile compounds of magnesium (1.25 mg/100 g), molybdenum microelements (0.03 mg/kg), manganese (29.0 mg/kg), and boron (0.30 mg/kg) in the arable layer. It was found that treatment of potato plantings with Novosil increased plant mass by 19–24%, leaf area and photosynthetic potential by 5–7%, with magnesium-boron fertilizer (at a dose of 5 g/l) by 9 and 2%, respectively. Significant direct relationship of plant weight with its height and number in a bush (r = 0.71...0.81), leaf area and photosynthetic potential values – with height, number and weight of plants (r = 0.56...0.82) was revealed. The contribution of the preparations to the variability of indicators was 37–68%, weather conditions and factor interactions – 3–33%. It was demonstrated that treatment of plants with Novosil and together with Mag-Bor 5 g/l increases tuber yield in comparison with the control by 6.4–6.6 t/ha (34–35%), and with magnesium-boron fertilizer at a dose of 5 g/l – by 2.5 t/ha (14%). In the variants Mag-Bor 10 g/l and Novosil + Mag-Bor 10 g/l the yield was at the level of control or increased by 1.6 t/ha (8.5%), and under drought conditions it decreased by 0.5–0.9 t/ha. The share of the preparations' influence on the yield variability amounted to 68%, weather conditions – 26%, and factor interactions – 4%. Regression equations were calculated, allowing to forecast leaf area and tuber yield by plant weight in the flowering phase promptly and with high accuracy. The difference between the actual and the calculated values was 4.4–5.4%.

Keywords: potato, growth regulator, microfertilizer, leaf area, photosynthetic potential, yield

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INTRODUCTION

An important factor for further increase in yield and profitability of potato production is the development and introduction of agrotechnological methods of cultivation with the use of modern biological plant growth regulators[1, 2] [1-3]. The results of the studies conducted in different regions testify to the effectiveness of their use as environmentally friendly biostimulants of productivity and immunity of crop plants, including potato[3, 4]. They accelerated plant growth and development, increased resistance to biotic and abiotic environmental factors, yield and its quality, and reduced storage losses [4-6]. One of the effective natural plant growth regulators is Novosil[5].

At present, foliar application with macro- and microelements is widely used in potato cultivation technology to ensure rapid and more complete assimilation of nutrients by plants in

[1]*Vyshegurov S.H.* Biological features and integrated protection of potatoes from diseases and pests. Novosibirsk: Agro-Sibir, 2005, 81 p.

[2]*Galeev R.R.* Features of potato production in Western Siberia. Novosibirsk, 2017, 116 p.

[3]*Shapoval O.A., Mozharov I.P., Korshunov A.A.* Plant growth regulators in agrotechnology // Plant Protection and Quarantine, 2014, N 6, pp. 16-20.

[4]*Butov A.V., Mandrova A.A.* Yield, quality and safety of potatoes when using plant growth regulators // Food Processing: Techniques and Technology, 2017, N 2 (45), pp. 13-19.

[5]*Karpilenko G.P., Vitol I.S., Gavrilina O.V.* Preparation-phytoregulator "Novosil" and its effect on the protein-proteinase complex of malting barley // Butler Communications, 2013, vol.35, N 9, pp. 78-83.

critical periods, primarily at the beginning of tuber formation and tuber yield formation[6] [7]. At foliar feeding plants use up to 60-70% of trace elements, while at application in the soil - only a few percent [8]. Studies confirm the positive effect of foliar fertilization on the growth and development of potato plants, yield and its quality [9-13]. The content of macro- and microelements in the soils of Yakutia is significantly lower compared to the regions without perennially frozen soils[7]. Therefore, the study of the influence of growth regulators, macro- and microelements on the growth, development and yield of potatoes in the conditions of Central Yakutia has an important scientific and practical significance.

The purpose of the research was to study the effect of the growth regulator Novosil and magnesium-boron fertilizer on the growth, photosynthetic activity of plants and yield of potato tubers in the conditions of Central Yakutia.

MATERIAL AND METHODSD

The studies were conducted at the station of the Yakutsk Research Institute of Agriculture (YANIISKh) in the conditions of Central Yakutia. The soil of the experimental plot was permafrost floodplain loamy with insufficient content of humus (1.8-2.2%), mobile compounds of magnesium (1.25 mg/100 g), trace elements molybdenum (0.03 mg/kg), manganese (29.0 mg/kg), boron (0.30 mg/kg) in the arable layer. The object of the study was the plants and tubers of the regionalized potato variety Yakutyanka. The registration plot area – 24.5 m^2, the width of the protective strip – 5 m, placement of the variants is randomized, repetition is 4-fold. Potato growing technology is generally accepted for the region[8]. Vegetation irrigation was carried out in the 3rd ten-day period of June – 1st ten-day period of July at 350 m^3/ha.

The experiment scheme included six variants: 1) Control – water spraying, 2) Novosil, 3) Mag-Bor 5 g/l, 4) Mag-Bor 10 g/l, 5) Novosil + Mag-Bor 5 g/l, 6) Novosil + Mag-Bor 10 g/l. Spraying of the plants was carried out at the beginning of the flowering, during the period of mass flowering and 7 days after the second treatment with the rate of the working liquid consumption of 3 liters/100 m^2.

Phenological observations, records and analyses were carried out according to the methodology of the All-Russian Research Institute of Potato Farming named after A.G. Lorkh[9]. Agrochemical analyses of the soil were carried out in the analytical laboratory of YaNIISKh and the laboratory of the Farming Service of the Republic of Sakha (Yakutia). The leaf area and photosynthetic potential (PP) of the plants were calculated according to the method of A.A. Nichiporovich[10]. Moisture availability during the growing season was estimated by the Selyaninov hydrothermal coefficient (HTC)[11]. In the years of research, the sum of average daily air temperatures during the growing season (June-August) varied from 1451 to 1676° with the norm of 1443°, the sum of precipitation - from 60 to 187 mm with the norm of 127 mm, moisture conditions - from optimal (HTC = 1.29) to severe drought (HTC = 0.37). The experimental material was processed statistically according to the method of B.A. Dospekhov[12] using a package of applied programs[13].

[6]*Mineev V.G., Sychev V.G., Gamzikov G.P., Sheujen A.H., Agafonov E.V., Belousov N.M., Egorov V.S., Podkolzin A.I., Romanenkov V.A., Torshin S.P., Lapa V.V., Tsyganov A.R., Persikova T.F., Eleshev R.E., Saparov A.S.* Agrochemistry: textbook. Moscow: Publishing house VNIIA named after D.N. Pryanishnikov, 2017, 854 p.

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[12]*Dospekhov B.A.* Methodology of field experiment (with the basics of statistical processing of research results). Moscow: Alliance, 2014, 386 p.

[13]*Sorokin O.D.* Applied statistics on the computer. Krasnoobsk: GUE "EBCA SB RAAS", 2009, 222 p.

RESULTS AND DISCUSSION

Treatment of potato plantings with the growth regulator Novosil separately and in complex with magnesium-boron fertilizer at a dose of 5 g/l increased the plant mass by 91–113 g/bush (19–24%), leaf area by 1.6-2.2 thousand m^2/ha (5-6%), PP for vegetation by 67–79 thousand m^2 - day/ha (6-7%) in comparison with the control (see the table). In the variant Mag-Bor 5 g/l, the indicators of growth and photosynthetic activity of the plants increased less significantly (by 2–9%). In the variants Mag-Bor 10 g/l and Novosil + Mag-Bor 10 g/l the plant weight increased only by 2– 8%, the leaf area and PP were at the level or less than the control. The greatest contribution to the variability of indicators was made by preparations (37– 68%), less significant – by weather conditions (7–26%) and the interaction of factors (3–33%).

A strong direct correlation ($p < 0.01$) of the plant mass with its height and number in the bush ($r = 0.71...0.81$), leaf area with height, number and mass of the plants ($r = 0.66...0.82$), PP values for vegetation with height, number and mass of plants ($r = 0.56...0.77$), leaf area ($r = 0.90$) was revealed.

The regression coefficient shows that with the increase in the bush weight in the flowering phase by 100 g (x), the leaf area of plants (y_1) increased by 1.9 thousand m^2/ha (1). The difference between the actual and the calculated leaf area was not more than ±4.4%, which allows for prompt and accurate prediction of leaf area by plant weight:

$$y_1 = 0{,}0190\,x + 26{,}017, \quad R^2 = 0{,}6919. \qquad (1)$$

Yield of potato tubers of the Yakutyanka variety varied from 16.9 to 27.6 t/ha (V = 16%). In the variants Novosil and Novosil + Mag-Bor 5 g/l it was higher than the control on average by 6.4-6.6 t/ha (34-35%) (see the table). Application of magnesium-boron fertilizer at a dose of 5 g/l increased the yield by 2.5 t/ha (14%), in the variants Mag-Bor 10 g/l and Novosil + Mag-Bor 10 g/l it was at the level of the control (-0.1 t/ha) or increased by 1.6 t/ha (8.5%). Under drought conditions, the yield in these variants was lower than the control by 0.5-0.9 t/ha. The share of the effect of preparations on yield variability amounted to 68%, weather conditions - 26%, interaction of factors - 4%.

Correlation analysis revealed a direct relationship ($p < 0.01$) of tuber yield with height ($r = 0.68$), number ($r = 0.73$) and weight ($r = 0.93$) of the plants in the bush, leaf area ($r = 0.86...0.93$) and PP for interphase periods ($r = 0.77...0.94$). Regression analysis showed that an increase in the plant crude weight by 100 g/bush (x) in the flowering phase caused an increase in tuber yield (y_2) by 6.5 t/ha:

$$y_2 = 0{,}0647\,x - 12{,}28, \quad R^2 = 0{,}8681. \qquad (2)$$

The difference between actual and calculated yields averaged 5.4%, or 1.2 t/ha, which makes it

Влияние регулятора роста Новосил и микроудобрения Маг-Бор на массу, площадь листьев растений, ФП и урожайность картофеля (среднее за 3 года)
Effect of Novosil growth regulator and Mag-Bor microfertilizer on potato weight, leaf area, FP and yield (3-year average)

Option	Weight of plants in the flowering phase, g/shrub	Leaf area in the flowering phase, thousand m^2/ha	FP per vegetation, thousand m^2 - day/ha	Yield, t/ha
Control	476	35,3	1129	18,9
Novosil	589	37,3	1208	25,3
Mag-Bor 5 g/l	519	36,0	1155	21,4
Mag-Bor 10 g/l	485	34,9	1122	18,8
Novosil + Mag-Bor 5 g/l	567	36,9	1196	25,5
Novosil + Mag-Bor 10 g/l	513	35,6	1125	20,5

possible to forecast yields in the flowering phase by plant mass promptly and with high accuracy.

CONCLUSION

In the conditions of Central Yakutia the treatment of potato plantings with growth regulator Novosil increases plant mass by 19–24%, leaf area and photosynthetic potential – by 5–7%, magnesium-boron fertilizer (at a dose of 5 g/l) – by 9 and 2% respectively. A significant direct relationship of the plant weight with their height and number in the bush (r = 0.71...0.81), as well as the leaf area and PP values with height, number and weight of plants (r = 0.56...0.82) was revealed. The greatest contribution to the variability of indicators is made by preparations (37–68%), less significant - by weather conditions and interaction of factors (3–33%). Treatment of potato plants with Novosil growth regulator and in combination with Mag-Bor 5 g/l increases tuber yield in comparison with the control by 6.4-6.6 t/ha (34–35%), magnesium-boron fertilizer at a dose of 5 g/l – by 2.5 t/ha (14%). In the variants Mag-Bor 10 g/l and Novosil + Mag-Bor 10 g/l, the yield was at the level of control (-0.1 t/ha) or increased by 1.6 t/ha (8.5%). In drought conditions, the yield in the above variants was less than the control by 0.5–0.9 t/ha. The share of the effect of the preparations on the variability of the yield amounted to 68%, weather conditions – 26%, interaction of factors – 4%. Regression equations were calculated, which allow to forecast leaf area and tuber yield by plant weight in the flowering phase promptly and with high accuracy. The difference between the actual and calculated values was 4.4–5.4%.

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АНАТОЛИЙ НИКОЛАЕВИЧ ВЛАСЕНКО

Российская академия наук, Сибирский федеральный научный центр агробиотехнологий Российской академии наук понесли тяжелую утрату: 5 августа 2023 г. безвременно ушел из жизни Анатолий Николаевич Власенко, академик Россельхозакадемии, Российской академии наук, доктор сельскохозяйственных наук, профессор, заслуженный агроном Российской Федерации, лауреат Государственной премии Российской Федерации в области науки и техники, академик Национальной академии Республики Монголия, член Европейского общества гербологов.

Анатолий Николаевич родился 25 августа 1946 г. в с. Ирбизино Карасукского района Новосибирской области. Окончив среднюю школу, трудился рабочим на железнодорожном транспорте, учителем в начальной школе. В 1965 г. произошло событие, во многом определившее его дальнейшую жизнь: Анатолий Николаевич поступил в Новосибирский сельскохозяйственный институт. По окончании института в 1970 г. его направили на работу в Сибирский научно-исследовательский институт земледелия и химизации сельского хозяйства Сибирского отделения Всесоюзной академии сельскохозяйственных наук. Здесь он начал трудиться лаборантом, прошел все ступени карьерного роста и с 1990 г. возглавлял этот институт. С 2016 г. – руководитель научного направления института, главный научный сотрудник.

Научные труды Анатолия Николаевича Власенко посвящены разработке актуальных проблем экологизации земледелия на современном этапе. Важное место в них занимают следующие направления: экологизация почвообработки, современные технологии возделывания сельскохозяйственных культур, ориентированные на заданные величины урожая и заданный уровень его качества, оптимальную себестоимость и поддержание нормального состояния окружающей среды. Исследования выполнены с учетом системного взаимодействия факторов в многофакторных экспериментах, их результаты адаптированы к определенным агроландшафтам, хозяйственным укладам, уровням интенсификации производства.

Значительное место в научных трудах А.Н. Власенко занимают разработка и совершенствование интегрированных систем защиты растений от вредных организмов, моделирова-

ние систем земледелия. Под руководством академиков Россельхозакадемии В.И. Кирюшина и А.Н. Власенко учеными института были сформулированы основные принципы земледелия на ландшафтной основе. Созданы адаптивно-ландшафтные системы земледелия Новосибирской области. Работа Анатолия Николаевича «Адаптивно-ландшафтная система земледелия Новосибирской области» рекомендована Россельхозакадемией в качестве эталона для разработки программ землепользования для всех субъектов Российской Федерации.

Научная новизна трудов А.Н. Власенко также заключается в разработке теоретических и методологических основ совершенствования систем земледелия и технологий возделывания сельскохозяйственных культур. В них раскрыто содержание научно-технического прогресса в земледелии Сибири, определены основные направления его развития.

За цикл научных работ по проблеме получения высококачественного агросырья и методам контроля его качества Анатолию Николаевичу в составе авторского коллектива была присуждена Государственная премия Российской Федерации и присвоено звание лауреата Государственной премии РФ в области науки и техники.

В 2020 г. за серию работ по совершенствованию теоретических основ почвозащитных технологий в земледелии Сибири А.Н. Власенко первым в Российской Федерации награжден Золотой медалью РАН им. Т.С. Мальцева.

Анатолием Николаевичем опубликовано более 360 научных работ, в том числе 24 книги и монографии, подготовлено более 50 рекомендаций и методических пособий по возделыванию и технологиям различных сельскохозяйственных культур, он автор 12 патентов на изобретения, им подготовлены пять докторов и три кандидата наук.

Работы академика А.Н. Власенко нашли широкое практическое применение в хозяйствах Новосибирской области и других субъектов Российской Федерации.

Анатолий Николаевич активно участвовал в общественной жизни ВАСХНИЛ, РАСХН, СО РАСХН, администрации Сибирского федерального округа РФ. Он был членом бюро секции земледелия, мелиорации, водного и лесного хозяйства отделения сельскохозяйственных наук РАН, бюро отделения сельскохозяйственных наук СО РАН, совета по развитию АПК при губернаторе Новосибирской области, экспертно-консультационного совета по вопросам социально-экономического развития регионов Сибирского федерального округа при полномочном представителе президента в СФО, редколлегий журналов «Вестник защиты растений», «Сибирский вестник сельскохозяйственной науки», «Земледелие».

За заслуги в развитии научных исследований и внедрения разработок в производство Анатолий Николаевич награжден медалями «За труды по сельскому хозяйству», «За трудовое отличие» и «Ветеран труда», золотой медалью им. В.Р. Вильямса. Он отмечен почетными грамотами Министерства науки и технологий РФ, президиумов РАСХН и СО РАСХН, администрации Новосибирской области, в 1999 г. удостоен премии Новосибирска «Успех года».

Научно-практическая сельскохозяйственная общественность Сибири и Российской Федерации, хорошо знавшая заслуги Анатолия Николаевича Власенко в области развития АПК, навсегда сохранит о нем светлую память.

Г.А. Романенко, В.Н. Пармон, Ю.Ф. Лачуга, А.Л. Иванов, В.И. Кирюшин, К.С. Голохваст

В.В. Альт, Г.П. Гамзиков, А.В. Гончарова, А.С. Донченко,
Н.А. Донченко, Н.М. Иванов, Н.И. Кашеваров, К.Я. Мотовилов,
Ю.А. Новоселов, В.А. Солошенко, Н.А. Сурин, Н.В. Цуглинок, А.А. Шпедт

ПАМЯТИ АКАДЕМИКА ИВАНА ФЕДОРОВИЧА ХРАМЦОВА

Российская академия наук, Омский аграрный научный центр с прискорбием извещает, что 9 августа на 74-м году жизни скончался Иван Федорович Храмцов, доктор сельскохозяйственных наук, профессор, академик Российской академии наук, директор Сибирского научно-исследовательского института сельского хозяйства с 1998 по 2018 г.

И.Ф. Храмцов – специалист в области земледелия и агрохимии, автор более 300 научных работ, в том числе семи книг (пяти монографий), четырех патентов на изобретения; руководитель девяти специалистов высшей квалификации, в том числе одного доктора наук.

Научные исследования Ивана Федоровича посвящены совершенствованию теоретических основ и практических приемов регулирования почвенного плодородия и продуктивности сельскохозяйственных культур за счет экологически сбалансированных систем применения удобрений в севооборотах лесостепи Западной Сибири.

Ученым установлены основные закономерности и направленность действия различных систем удобрений в севообороте на агрохимические и биологические показатели плодородия черноземных почв и условия их регулирования. Определены нормативы действия и последействия возрастающих норм минеральных и органических удобрений при длительном систематическом их применении на продуктивность севооборотов и качество продукции. Выявлены количественные параметры выноса, расхода коэффициентов использования питательных веществ из почвы и удобрений, определена структура баланса элементов питания в агроценозах, разработаны приемы повышения эффективности минеральных удобрений в севооборотах, обеспечивающие существенный ресурсосберегающий, экологический и экономический эффект.

Разработанные и рекомендованные системы применения удобрений внедрены в полевых севооборотах ОПХ СибНИИСХоза («Омское», 1982–2007 гг., «Боевое»,1983–2007 гг.), а также в других хозяйствах лесостепной зоны Омской области. Освоение систем удобрений в этих хозяйствах в комплексе с зональной технологией обеспечивало стабильность зернового производства по годам, а также повышение продуктивности одного гектара пашни на 0,5–0,9 т зерна по сравнению с соответствующими средними районными показателями за аналогичные годы.

Иван Федорович лично разрабатывал и возглавлял крупное научное направление – совершенствование теоретических основ и практических приемов регулирования почвенного плодородия и продуктивности сельскохозяйственных культур за счет экологически сбалансированных систем применения удобрений в севооборотах лесостепи Западной Сибири.

Как директор СибНИИСХоза особое внимание И.Ф. Храмцов уделял молодым специалистам, непосредственно курируя работу аспирантуры. В институте ежегодно проводили конференции молодых ученых, где научные сотрудники, только начинающие свой путь в науке, и аспиранты демонстрировали свои научные достижения.

Иван Федорович принимал участие в коллегии Министерства сельского хозяйства и продовольствия Омской области. Под его руководством велась работа Центра научного обеспечения АПК области, где решали текущие и перспективные вопросы совершенствования функционирования отраслей агропромышленного комплекса.

И.Ф. Храмцов вел большую общественно-научную работу: был членом президиума Сибирского отделения Россельхозакадемии, заместителем председателя координационного совета по земледелию президиума СО РАСХН, входил в состав Научного координационного совета Омской области, диссертационных советов при Омском государственном аграрном университете и Тюменской сельскохозяйственной академии, председателем совета Омского аграрного университетского комплекса, членом редакционной коллегии журналов «Российская сельскохозяйственная наука», «Сибирский вестник сельскохозяйственной науки», «Земледелие», «Зерновое хозяйство».

Кроме научно-исследовательской работы Иван Федорович вел активную педагогическую деятельность, читая лекции в Омском государственном аграрном университете на кафедре агрохимии, занимался подготовкой аспирантов в СибНИИСХозе.

За достижения в развитии сельскохозяйственной науки Иван Федорович награжден памятной медалью «50 лет начала освоения целинных земель», Почетной медалью академика А.Н. Бараева, юбилейной медалью «40 лет Сибирского отделения Россельхозакадемии 1969–2009 гг.», медалью И.И. Синягина «За содействие в развитии аграрной науки Сибири», Золотой медалью им. Т.С. Мальцева, Памятной медалью Сергея Иосифовича Манякина, памятной юбилейной медалью «60 лет Сибирского отделения Российской академии наук». Ему присвоены звания «Почетный работник АПК России», кавалера Золотого почетного знака «Достояние Сибири». Иван Федорович также награжден почетными грамотами Министерства сельского хозяйства Российской Федерации, Почетной грамотой Россельхозакадемии, президиума Сибирского отделения Россельхозакадемии, министерства сельского хозяйства и продовольствия Омской области, государственной наградой Омской области – медалью «За высокие достижения».

Особенно тяжела безвременная утрата для ученых Омского аграрного научного центра, поскольку работа Ивана Федоровича была примером, достойным подражания.

Выражаем искренние соболезнования родным и близким покойного по поводу кончины самого дорогого, близкого человека.

Светлая память об Иване Федоровиче, видном ученом, талантливом организаторе, общественном деятеле и просто порядочном человеке навсегда сохранится в сердцах сотрудников ученых-агариев Сибири и Российской Федерации.

Г.А. Романенко, В.Н. Пармон, Ю.Ф. Лачуга, А.Л. Иванов, В.И. Кирюшин, М.С. Чекусов, В.С. Бойко

В.В. Альт, Л.В. Будажапов, Н.Г. Власенко, К.С. Голохваст, Г.П. Гамзиков, А.В. Гончарова, А.С. Донченко, Н.А. Донченко, Н.М. Иванов, Н.И. Кашеваров, К.Я. Мотовилов, Ю.А. Новоселов, В.А. Солошенко, Н.А. Сурин, Н.В. Цуглинок, А.А. Шпедт

ПАМЯТИ АЛЕКСЕЯ ПЕТРОВИЧА КАЛАШНИКОВА

В 2023 г. академику Алексею Петровичу Калашникову исполнилось бы 105 лет со дня рождения.

Научная деятельность молодого ученого, выпускника аспирантуры Тимирязевской сельскохозяйственной академии, начиналась на Урале. В то время по всей стране формировались отродья черно-пестрого скота (уральское, сибирское, прибалтийское и др.). Задача ставилась трудновыполнимая: получить массив отечественного скота с продуктивностью, не уступающей лучшим зарубежным породам, т.е. около 5 тыс. кг молока в год на одну корову. Мнения ученых и руководителей страны о методологии выполнения поставленной задачи разделились: метизация отечественного скота или создание стабильной качественной кормовой базы, соответствующей продуктивности улучшенных животных. Алексей Петрович, возглавив Свердловский научно-исследовательский институт сельского хозяйства, начал успешно развивать оба направления. Так появилось уральское отродье черно-пестрого скота, а также силосный тип кормления из высокоурожайных сортов кукурузы. Новое назначение А.П. Калашникова руководителем Сибирского научно-исследовательского института животноводства послужило началом формирования комплексного института нового типа, объединившего ученых семи специальностей. Первый промышленный молочный комплекс в Советском Союзе на 1200 коров с полной механизацией производственных процессов авторского исполнения стал прекрасным проектом нового института и его конструкторского бюро. Молочная продуктивность стада в 1976 г. достигла 4,9 тыс. кг молока в год, что в то время было выдающимся результатом. За реконструкцию ферм на промышленную технологию институт награжден Премией Совета Министров СССР, Алексей Петрович, его руководитель, переведен в Москву на должность академика-секретаря ВАСХНИЛ и директора ВИЖ.

Апофеозом научной деятельности А.П. Калашникова стали детализированные нормы кормления сельскохозяйственных животных, авторы которых до сих пор не оценены по достоинству. Справочное пособие «Нормы и рационы кормления сельскохозяйственных животных» имело три переиздания и стало настольной книгой специалистов-практиков в животноводстве, а также учебным пособием для студентов и аспирантов.

Координация научной деятельности ведущих ученых по кормлению из 30 научно-исследовательских институтов и вузов в течение двух пятилеток (1980–1990 гг.) – подтверждение

выдающихся организаторских способностей академика-секретаря ВАСХНИЛ и пример эффективности комплексных исследований.

В достижении 6-тысячного удоя по всему молочному стаду России есть доля заслуг большого коллектива ученых-экспериментаторов от Калининграда до Камчатки. Научная школа последователей академика А.П. Калашникова, занимающихся совершенствованием теории кормления, подтвердила правильность выбранного направления – увеличение численности стад с высокой реализацией продуктивного потенциала (10–12 тыс. кг молока на одну корову) даже в далеко не идеальных климатических условиях России.

Объединение усилий ученых фундаментального и прикладного профиля будет способствовать росту эффективности животноводства, особенно его качественной составляющей, что связано с продолжительностью жизни человека.

Коллектив СибНИПТИЖ СФНЦА РАН

AUTHOR GUIDELINES

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

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

- general agriculture and crop production;
- plant breeding, seed production and biotechnology;
- agrochemistry, soil science, plant protection and quarantine;
- fodder production;
- infectious diseases and animal immunology;
- private zootechnics, feeding, technology of feed preparation and production of livestock products;
- breeding, selection, genetics, and animal biotechnology;
- technologies, machinery and equipment for the agro-industrial complex;
- food systems.

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

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

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- an article is not subject to review in any other journal;
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Before submitting an article, it is necessary to make sure that the file (files) contains all the information required in Russian and English, tables and figures provide the source of the information presented, all references are written correctly.

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

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Transliteration of the source = English name of the source

Monograph

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

Part of a book

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

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

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