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SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

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СОДЕРЖАНИЕ

CONTENTS

ЗЕМЛЕДЕЛИЕ И ХИМИЗАЦИЯ

AGRICULTURE AND CHEMICALIZATION

РАСТЕНИЕВОДСТВО И СЕЛЕКЦИЯ

PLANT GROWING AND BREEDING

СОДЕРЖАНИЕ

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ВЛИЯНИЕ ОРГАНИЧЕСКИХ УДОБРЕНИЙ НА ОСНОВЕ КУРИНОГО ПОМЕТА НА ПРОДУКТИВНОСТЬ ОВСА И МИКРОБИОЛОГИЧЕСКИЕ ПОКАЗАТЕЛИ ПОЧВЫ

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Представлены результаты изучения влияния препаратов на основе куриного помета на рост и развитие овса. Куриный помет содержит в своем составе ценные вещества, которые легко используются растениями, но из-за содержания большого количества патогенных микроорганизмов его применение может приводить к загрязнению окружающей среды. В настоящее время перспективным направлением является использование птичьего помета после дополнительной обработки. В исследованиях применяли переработанный куриный помет с использованием кавитационно-вихревого теплогенератора методом перегонки сухого помета в виде 10%-го раствора в воде и получения различных проб удобрений. Обработку помета проводили при разных тепловых режимах – 60 и 75 °С, с использованием озона или без него. Изучено влияние органических удобрений на основе куриного помета на биологическую активность почвы и продуктивность овса. Численность основных групп микроорганизмов устанавливали общепринятым методом высева на плотные питательные среды. Фитотоксичность почвы определяли в соответствии с рекомендациями по тест-объекту. Рост и развитие овса изучали в течение вегетации, оценивая наступление фенологических фаз, биометрические показатели и элементы структуры урожайности. Выявлено негативное влияние куриного помета на микрофлору (появление условно фитопатогенных грибов) и фитотоксичность почвы, а также на состояние культурных растений. Помет, переработанный методом перегонки в органические удобрения, улучшает экологическую обстановку. Установлено положительное влияние органических удобрений на основе птичьего помета на фитосанитарное состояние и азотфиксирующую активность почвы. На фоне применения органических удобрений отмечено увеличение продуктивности овса. Получена достоверная прибавка зеленой массы и сухого вещества в фазу цветения овса на 6,0–6,2 и 1,1–1,7 т/га соответственно. Урожайность зерна овса была выше на 0,7–0,8 т/га, или 20%, по сравнению с контролем.

Ключевые слова: микрофлора почвы, помет, органическое удобрение, овес

EFFECT OF ORGANIC FERTILIZERS BASED ON CHICKEN MANURE ON OAT PRODUCTIVITY AND MICROBIOLOGICAL INDICATORS OF THE SOIL

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The results of studying the effect of preparations based on chicken manure on the growth and development of oats are presented. Chicken manure contains valuable substances that are easily used by

plants, but because of the large number of pathogens, its use can lead to pollution of the environment. Currently, a promising direction is the use of poultry manure after additional treatment. Recycled chicken manure was used in the research using a cavitation-vortex heat generator by distilling dry manure as a 10% solution in water and obtaining various fertilizer samples. The manure was treated at different thermal regimes - 60 and 75 °C, with or without ozone. The effect of organic fertilizers based on chicken manure on soil biological activity and productivity of oats was studied. Numbers of the main groups of microorganisms were established by the conventional method of seeding on nutrient dense media. Soil phytotoxicity was determined according to the test-object recommendations. Oat growth and development were studied during the vegetation period, evaluating the onset of phenological phases, biometric indicators and elements of yield structure. A negative effect of chicken manure on the microflora (the appearance of conditionally phytopathogenic fungi) and phytotoxicity of soil, as well as on the condition of cultivated plants was revealed. The manure processed by distillation into organic fertilizer improves the environmental situation. A positive effect of organic fertilizers based on poultry manure on the phytosanitary state of the soil and nitrogen-fixing activity of the soil was found. An increase in productivity of oats was noted on the background of the application of organic fertilizers. There was a significant increase in green mass and dry matter in the flowering phase of oats by 6.0-6.2 and 1.1-1.7 tons/ha, respectively. Oat grain yield was higher by 0.7-0.8 t/ha, or 20%, compared to the control.

Keywords: soil microflora, manure, organic fertilizer, oats

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INTRODUCTION

Poultry farming is one of the most rapidly developing agro-industrial industries in the world due to the growing demand for eggs and meat products [1]. Chicken manure, a waste product generated in large quantities during poultry breeding, is a mixture of chicken feces, feathers, bedding and spilled feed, drugs and water[1][2].

Such by-products are potentially important to be applied to the soil as an organic fertilizer because of their relatively high content of nutrients, especially nitrogen, which is associated with an initially high content of protein and amino acids[2] [3]. The application of chicken manure into the soil as an organic fertilizer is the cheapest and most environmentally friendly method of its utilization [1]. The main problem is how to maximize the benefits of chicken manure as an organic fertilizer while mitigating the potential negative impact on the environment, as there occurs its contamination by pathogens, including bacteria, fungi, viruses [4, 5]. Currently, one of the environmentally safe and promising directions of use as an organic fertilizer poultry manure is its preliminary processing, which allows you to bring the quality of fertilizer to the necessary technological, hygienic and fertilizer indicators [6].

It has been established that the interaction between soil microbes and recycled organic fertilizer can establish homeostasis of soil mi-

[1]Aires A.M. Biodigestão Anaeróbica da Cama de Frangos de Corte com ou sem Separação das Frações Sólida e Líquida. Master's Thesis, Faculdade de Ciências Agrárias e Veterinárias- UNESP, Jaboticabal, Brazil. 2009.

[2]Griffiths N. Best practice guidelines for using poultry litter on pastures. In Agnote DPI-212. Sydney, Australia: State of New South Wales (NSW) Department of Primary Industries 2007. P. 1–33.

crobial communities, promote plant growth, and suppress soil-borne pathogens [7]. Complex biological and ecological processes take place in the rhizosphere, in particular the interaction between plants and microbes, and there are beneficial microbes as well as soil pathogens that compete with each other [8-12].

The rhizosphere community includes many species with beneficial effects on plant growth and health, such as nitrogen-fixing bacteria, mycorrhizal fungi, rhizomicrobes that stimulate plant growth, biocontrol microbes and protozoa, while soil-borne pathogens that colonize the rhizosphere cause plant diseases by breaking the protective microbial shield and overcoming innate plant defense mechanisms [13]. The complexity and diversity of microbes in the rhizosphere are necessary to maintain homeostasis in the soil ecosystem [14].

Given the severity of the problem of utilization of poultry manure in the agricultural complex of the Siberian region, preventing degradation and increasing soil fertility, as well as the lack of information about the effect of the new organic fertilizer on the microbiological parameters of the soil, there is reason to talk about the relevance of the research presented.

The purpose of the study is to give a comparative assessment of organic fertilizers based on chicken manure and establish their impact on the biological activity of the soil; determine the effectiveness of the use of poultry manure as an organic fertilizer to preserve soil bioresources and oat productivity.

MATERIAL AND METHODS

The studies were carried out in 2020, 2021 in field experiments at the Siberian Research Institute of Fodder Crops, SFSCA RAS, located in the northern forest-steppe of the Priob'ye region of Novosibirsk. The soil type was medium-loamy leached chernozem, the content of organic carbon in the soil was 3.48%, pH 5.3. The sum of the absorbed bases is 58-61 mg/eq. per 100 g of soil. Forecrop - fallow.

In terms of climatic resources, it is a moderately warm, insufficiently humid agroclimatic region. Average annual precipitation is 350-450 mm, of which 254 mm falls in the warm period of the year (April - September), in June - August - 113-130 mm. Hydrothermal coefficient (according to Selyaninov) is 1.0-1.2 in the period with air temperature above 10 °C. The sum of positive temperatures above 10 °C averages 1880° with deviations by years from 1500 to 2250°.

According to the amount of precipitation the growing season 2020 is possible to characterize (according to the generalized indicator HTC for May - September 1.29) as close to the climatic norm for the place of research, but with variable amount of precipitation by months and lack of moisture in June (HTC 0.4) and in the second decade of July (HTC 0.6). During the vegetation period 2021, the sum of precipitation was 202 mm (GTC 0.9). From May to August, the sum of temperatures above 10 °C was 2090°. During the summer months of vegetation air temperature was at the level of mean annual value, and only in May higher by 1.7-3.5 °C. Precipitation was distributed unevenly.

Experiment scheme: control, chicken manure (without processing), preparation 1, preparation 2, nitrogen fertilizer N_{60}. Two variants of organic fertilizers based on chicken manure were studied that were obtained using cavitation-vortex heat generator by distillation of semi-dry manure as a 10% solution in water and obtaining different samples of fertilizers, further used in the experiment. Treatment of manure was carried out at thermal regimes from 60 to 75 ° C with or without ozone. The batches of obtained organic fertilizer differed in processing modes of chicken manure. Under laboratory conditions the chemical composition of the processed chicken manure was determined, the control was the original samples of manure. It was found that the mass fraction of dry matter of unprocessed chicken manure is 76.7%, processed - 3.6%. The share of organic matter in terms of dry matter was 77.2% in the original sample and 81.6% in the processed sample; the pH of the original samples was 8.6, the processed samples was 7.0. The content of total nitrogen, phosphorus and potassium in terms of dry matter in the initial samples of chicken manure was 4.04; 2.48 and 1.56%. Under treatment, their content in the final product

slightly increased (with the exception of phosphorus): 5.56; 2.78 and 12.78%, respectively. Thus, laboratory studies of the chemical composition of poultry manure revealed an increase in the content of the main nutrients in processed chicken manure compared to the unprocessed.

Variants without fertilization, with the application of chicken manure without treatment and with the application of nitrogen mineral fertilizers at a rate of N_{60}, equivalent to organic fertilizers were taken as control. Sowing was carried out in the III ten-day period of May. Repetition of the experiments was threefold, the arrangement of the variants was systematic. Planting and accounting area of plots 4 × 15 m = 60 m^2. Fertilizer application was carried out in two terms: in spring - in the soil under pre-sowing cultivation (manually in the form of a solution) and in the growing season during the period of grain formation.

Oat plants developed differently in the years of research. In 2021 the growing season was prolonged, the phases of plant development lagged by a week behind similar phases in 2020. Plant growth was evaluated during the growing season. In addition, the characteristics of the oat crop were analyzed. After sowing on days 12, 26, 41, 59, and 79, the characteristics of plant growth and development were evaluated. To determine the main parameters of plant growth in the field, 10 plants were randomly selected from each repetition (n = 30 in each variant). Plants were dug up and records and observations were made. Yield parameters were evaluated after harvesting. Several main phases were distinguished during the crop vegetation. The duration of the interphase periods was determined according to the following oat development phases: full sprouting, tillering, tubing, ear formation, flowering, milky ripeness, waxy ripeness, and full ripeness. Yield components were analyzed by evaluating ten random plants in each previously delimited plot at harvest time. Weight of 1000 grains was estimated by threshing, counting grains, and weighing.

The number of major groups of microorganisms was determined by the conventional method of seeding on nutrient dense media. Microorganisms were counted on the following media: recording of ammonificators - on MPA (meat-and-peptone agar); biochemical activity of microorganisms assimilating mineral forms of nitrogen - on SAA (starch-and-ammonia agar); recording of aerobic nitrogen fixers - on Ashby medium by clump fouling in percentage; recording of cellulose-destroying microorganisms - on Getchinson's medium by clump fouling in percentage; biochemical activity of fungi - on Czapek's medium. Microorganisms were seeded by the method of limiting dilutions, incubated at 28 °C for 3-7 days. The number of growing colonies taking into account soil moisture content, drop volume, and dilution was recalculated to the number of microorganisms in 1 g of absolutely dry soil. Soil phytotoxicity was determined in accordance with the biotest recommendations. Radish seeds of Zhara variety were used as a biotest. Total phytotoxicity was measured by seed germination, sprout length, and root length of the plant material. To determine the toxicity of water-soluble substances, radish seeds were soaked in a soil extract.

RESULTS AND DISCUSSION

It has been proved that crops are responsive to the introduction of organic fertilizers and their preparations. Rational use of soil fertility in combination with the use of preparations based on chicken manure with reasonable doses of timing and methods of application makes it possible to optimize plant nutrition in order to obtain a high-quality yield. The advantage of organic fertilizers consists in versatile influence on plants and soil. They are a significant source of nutrients for crops and microorganisms involved in soil formation.

The application of chicken manure affected the number of the main groups of microorganisms. When applying chicken manure, the number of ammonifiers at the beginning of the growing season tended to decrease by 2 times in the variants of chicken manure and preparation 1. Insignificant differences were revealed in the variant with the application of nitrogen fertilizers and preparation 2. At the end of the growing period the activity of ammonificators decreased in all variants compared with the beginning of the period. In the variant with nitro-

gen fertilizers the number of microorganisms decomposing organic nitrogen decreased by 4 times.

Preparations and organic fertilizers had no effect on the group of bacteria assimilating mineral nitrogen. The depressing effect was noted only in the variants with the preparation 2 and with nitrogen fertilizers in June. The greatest inhibitory effect was detected with the use of nitrogen fertilizers, where the number of bacteria assimilating mineral nitrogen decreased by 5.4 times compared with the control. In September, the number of microorganisms decreased on the background of using preparation 1, preparation 2 and nitrogen fertilizers. Mineralization processes prevailed in the autumn period (see Table 1).

Thus, the application of chicken manure and nitrogen fertilizers reduced the number of microorganisms assimilating organic forms of nitrogen at the beginning of the growing season. The number of microorganisms assimilating mineral forms of nitrogen decreased in the variants with preparation 2 and nitrogen fertilizers.

The least fungi were observed in the variants of chicken manure, preparation 2 with additives, nitrogen fertilizers, which is less than the control from 1.1 and up to 1.8 thousand. In the variant of chicken manure fungi of the genus *Fusarium* dominated, which can lead to fusariosis plants. Application of preparation 1 stimulated the development of fungi of the genus *Trichoderma*, which improved phytosanitary condition of the soil. At the end of the growing season the number of micromycetes increased compared with the beginning. When chicken manure was applied there was a tendency to increase the number of micromycetes, preparation 1 and nitrogen fertilizers slightly reduced the number of fungi, preparation 2 with additives significantly reduced the number of fungi by 3.9 times (see Table 2).

The application of chicken manure as a fertilizer reduced the number of micromycetes, but led to the dominance of conditionally phytopathogenic fungi at the beginning of the growing season. Preparations 1 and 2 promoted the development of fungi of the genus *Trichoderma*. Application of nitrogen fertilizers did not affect the number of micromycetes in the soil.

Табл. 1. Микрофлора почвы под овсом при внесении удобрений, млн КОЕ в 1 г абсолютно сухой почвы (среднее за 2020, 2021 гг.)

Table 1. Microflora of the soil under oats when applying fertilizers, mln. CFU in 1 g of absolutely dry soil, (average for 2020-2021)

Option	Bacteria that assimilate organic nitrogen (MPA)		Bacteria that assimilate mineral nitrogen (SAA)	
	June	September	June	September
Control	301,10	44,50	129,30	124,80
Chicken manure	154,90	59,15	172,65	106,15
Preparation 1	149,90	58,65	129,65	60,65
Supplemented preparation 2	347,90	32,30	89,30	78,80
Nitrogen fertilizers N_{60}	204,90	11,80*	23,65	84,15
LSD_{05}	157,59	15,27	140,42	83,94

* Reliable at the 95% level.

Under the conditions of leached chernozem, an increase in nitrogen-fixing capacity of the soil was observed in all variants, except the variant with nitrogen fertilizers (see Table 3).

Periodic application of organic fertilizers promotes the development of free-living microorganisms assimilating atmospheric nitrogen. Application of nitrogen fertilizers reduces nitrogen fixation activity.

The most sensitive and easy-to-determine indicator of soil contamination is its total phytotoxicity. Phytotoxicity is a property of soil due to the presence of pollutants and toxins that inhibit the growth and development of higher plants. The main advantages of the method of phytotoxicity determination are its efficiency, simplicity and sufficiently good reproducibility.

Soils are considered phytotoxic if the aqueous extract from which inhibits seed germination of the test crop or development of seedlings and roots by 20% or more compared with the control, or has a stimulating effect (less than 30%), which also often indicates the presence of highly toxic substances in this soil. In June,

Табл. 2. Численность микромицетов почвы под овсом при внесении удобрений, тыс. в 1 г абсолютно сухой почвы (среднее за 2020, 2021 гг.)

Table 2. The number of micromycetes of the soil under oats when fertilizing, thousand per 1 g of absolutely dry soil (average for 2020, 2021)

Option	June	September
Control	4,65	11,80
Chicken manure	3,30	18,48
Preparation 1	5,30	10,81
Supplemented preparation 2	2,45	3,01*
Nitrogen fertilizers N_{60}	3,95	9,35
LSD_{05}	4,29	7,16

* Reliable at the 95% level.

Табл. 3. Учет *Azotobacter* на среде Эшби, % (среднее за 2020, 2021 гг.)

Table 3. *Azotobacter* registration on Ashby medium, % (average for 2020, 2021)

Option	June	September
Control	55,95	35,30
Chicken manure	84,45*	88,50*
Preparation 1	92,65*	96,00*
Supplemented preparation 2	91,00*	77,50*
Nitrogen fertilizers N_{60}	26,65	20,50
LSD_{05}	22,55	17,30

* Reliable at the 95% level.

no phytotoxic action was observed when considering the total phytotoxicity of the soil (see Fig. 1).

Stimulation of root and seedling growth against the background of the preparations 1 and 2 was detected. Root length of test-crop on these variants increased by 0,63-0,65 cm compared to the control. With regard to nitrogen fertilizers, a slight inhibition of root length of test-cultures was noted (see Fig. 2).

When considering the phytotoxicity of water-soluble substances against the background of manure application, inhibition of radish root and sprout growth was observed (see Fig. 2). This can be explained by the content of toxic substances that are soluble in water and have an inhibitory effect on the test-culture. Roots of the test-culture developed best when using the preparation 1.

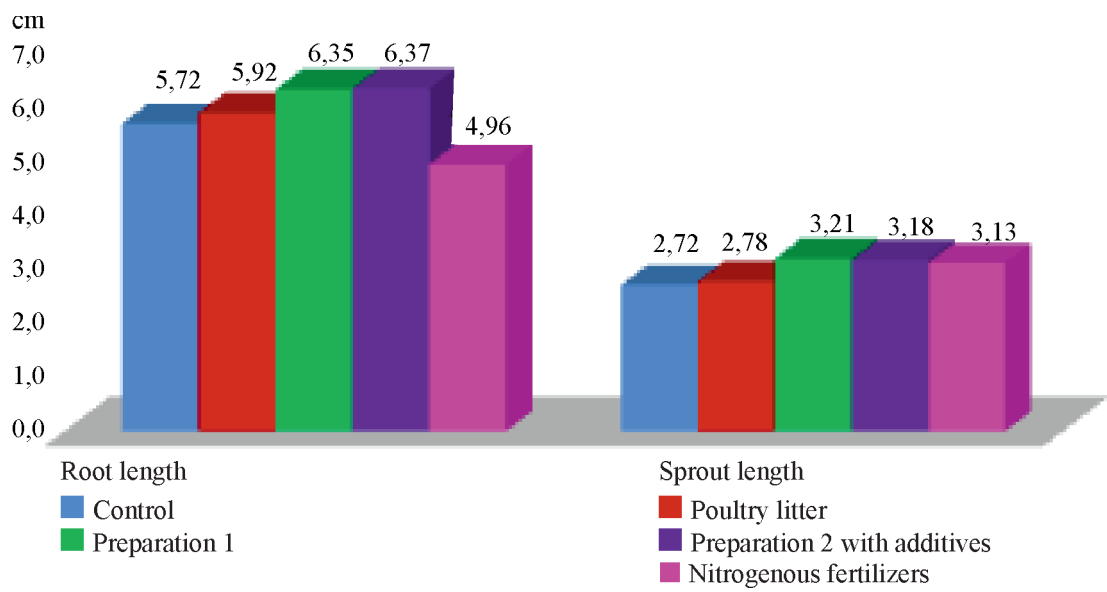

Рис. 1. Общая фитотоксичность почвы после внесения препаратов под овес в начале вегетации (среднее за 2020, 2021 гг.)

Fig. 1. Total phytotoxicity of the soil after the introduction of preparations for oat culture at the beginning of the growing season (average for 2020, 2021)

The presence of toxic water-soluble substances in the soil had a negative effect on the development of radish seedlings. This was expressed in the reduction of sprout length when using all the preparations.

The study of soil phytotoxicity was carried out in dynamics. By the end of the growing season on the background of applying manure and nitrogen fertilizers, a slight inhibition of root growth and sprouts of the test crop was noted, indicating a slight overall toxic effect (see Fig. 3).

When using preparations 1 and 2, no inhibitory effect on the roots was detected, on the contrary, there was a stimulation of root growth of the test crop. In the soil sampled at the end of the growing season, phytotoxicity of water-soluble substances was observed, as evidenced by the retardation of root and seedling growth (see Fig. 4). Significant decrease in root length compared to distilled water was observed in the control soil (1.3 times) and in the variant with manure application (1.7 times).

The use of preparations 1 and 2 insignificantly inhibited the growth of test-culture roots compared to distilled water, but stimulated them relative to the control.

The length of the seedlings decreased in relation to distilled water in all variants, but when using the preparation 2, the differences were not significant. The length of the test-culture seedlings was depressed most of all against the background of manure application (by 1.9 times).

Thus, when pure chicken manure is used as a fertilizer for crops, the ecological condition of the soil deteriorates, as evidenced by the phytotoxic effects on the test objects.

In our research the effect of preparations was monitored not only on the soil, but also on the growth and development of oats. Based on the results obtained in the field experiment in 2021, 2022, a positive effect of organic fertilizers based on chicken manure on the formation of the main elements of the oat crop structure: the number and weight of shoots, plant height, weight of 1000 grains and seeds per plant was established.

Positive effect of preparations 1 and 2 on the height of oat plants was noted, which differed depending on the phenological phase. In the tillering phase, the height of the control plants was 30.0 cm; in variants with the use of preparations 1 and 2, it was 1.2-4.6 cm higher

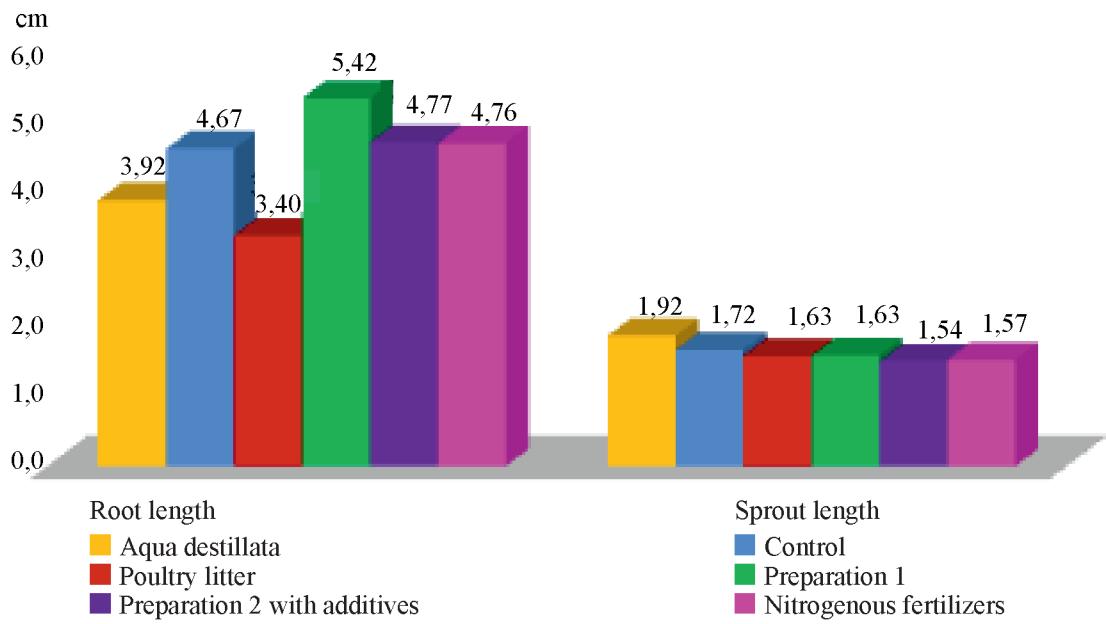

Рис. 2. Фитотоксичность водорастворимых веществ почвы после внесения препаратов под овес в начале вегетации (среднее за 2020, 2021 гг.)

Fig. 2. Phytotoxicity of water-soluble soil substances after the introduction of preparations for oat culture at the beginning of the growing season (average for 2020, 2021)

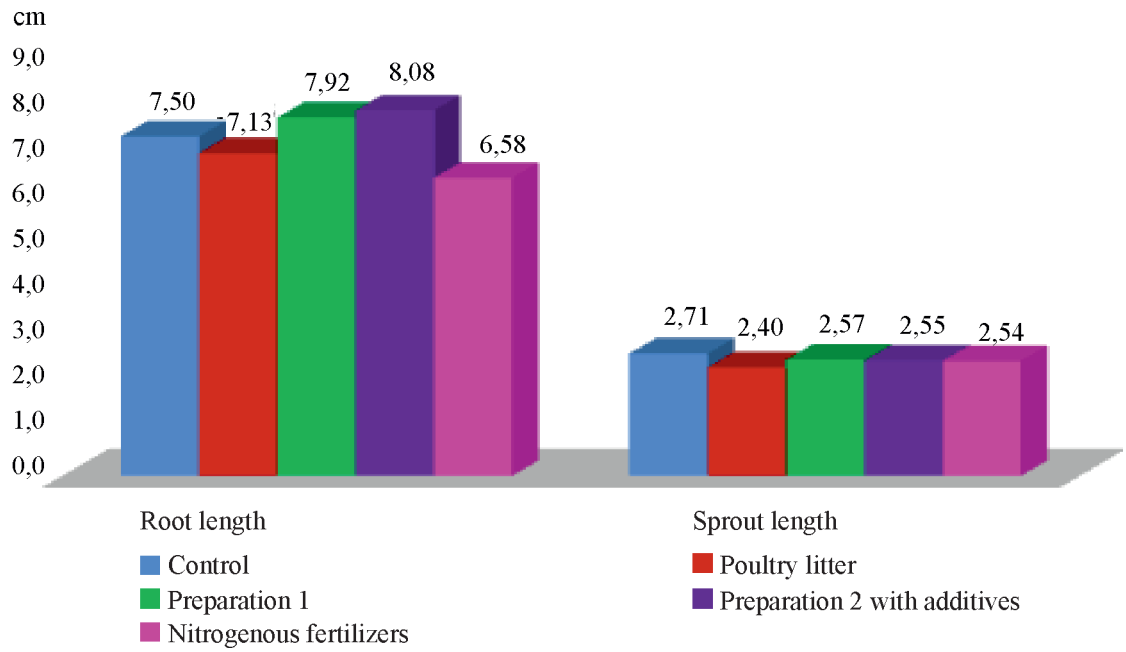

Рис. 3. Общая фитотоксичность почвы после внесения препаратов под овес в конце вегетации (среднее за 2020, 2021 гг.)

Fig. 3. Total phytotoxicity of the soil after the introduction of preparations for oat culture at the end of the growing season (average for 2020, 2021)

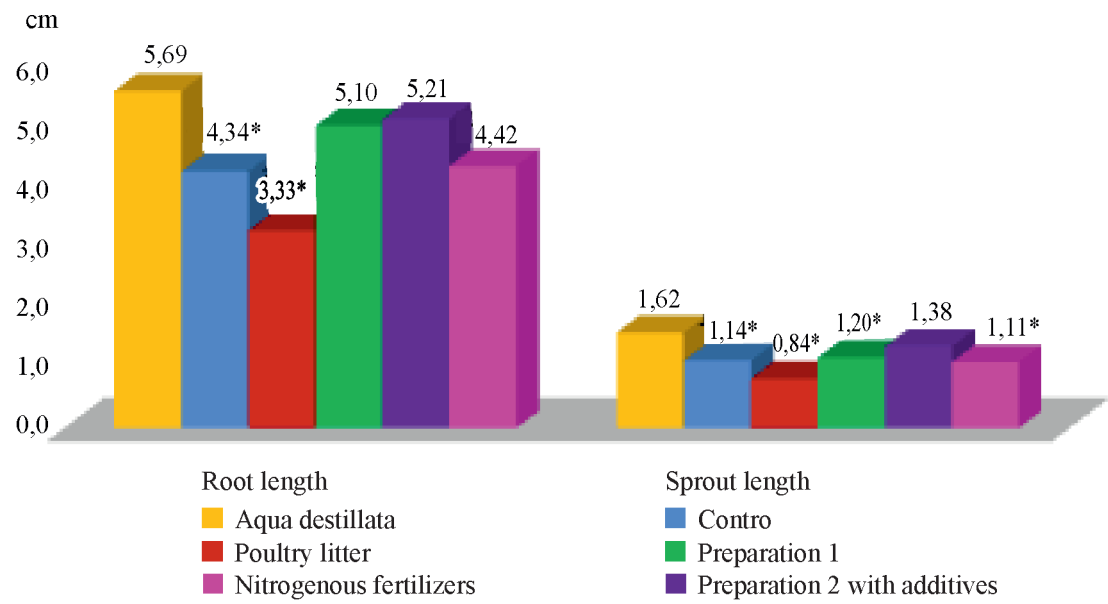

Рис. 4. Фитотоксичность водорастворимых веществ почвы после внесения препаратов под овес в конце вегетации (среднее за 2020, 2021 гг.)

Fig. 4. Phytotoxicity of water-soluble soil substances after the introduction of preparations for oat culture at the end of the growing season (average for 2020, 2021)

* Reliable at the 5% level

(by 4-15%). A similar trend was observed in the flowering phase. At the phase of maturity, the height of the control variant was 88.0 cm, the use of preparations 1 and 2 had a growth-stimulating effect - an increase in plant height by 4.5-7.0%.

Application of preparations 1 and 2 on the basis of chicken manure contributed to more active accumulation of green mass and dry matter in the phase of oat flowering, which significantly increased by 6,0-6,2 and 1,16-1,7 t/ha respectively compared to the control (see table 4).

Application of preparations 1 and 2 had positive effect on oat yield, the gain was 0.7-0.82 t/ha, which is 20% higher than the control and 10% more effective than the application of mineral fertilizers. The weight of grains in a panicle increased by 16-25%, the number of grains in a panicle by 17 and the weight of 1000 grains by 3.6% (see Table 5).

Analysis of productivity elements of the yield structure showed that the increase in the yield is associated primarily with an increase in grain weight in the panicle (r = 0.74) and the number of grains in the panicle (r = 0.68).

Observations of oat crops (with the use of preparations) conducted in 2021 in conditions of a fairly favorable phytosanitary situation did not reveal a tendency to increase the level of plant infection with disease-causing agents in organic fertilizers. Evaluation of the phytosanitary status of the crops revealed the presence of plant root blotches. On the control variant the index of disease development was 9.5%, which is lower than the ETH (economic threshold of harmfulness), with a prevalence of 100%. On the experimental variants the index of disease development was significantly lower - up to 2.7% and prevalence up to 70%.

Табл. 4. Влияние органических и минеральных удобрений на урожайность зеленой массы овса, т/га (среднее за 2020, 2021 гг.)

Table 4. The effect of organic and mineral fertilizers on the yield of green mass of oats, t/ha (average for 2020, 2021)

Option	Green mass, t/ha	Dry matter content, %	Dry matter yield, t/ha
Control	25,1	18,5	4,6
Chicken manure	28,3	18,1	5,0
Preparation 1	31,6*	18,5	5,8
Supplemented preparation 2	31,1*	20,2	6,3
Nitrogen fertilizers N_{60}	28,8	18,0	5,0
LSD_{05}	2,81		

* Reliable at the 95% level.

Табл. 5. Влияние препаратов на основе куриного помета на формирование элементов структуры урожая овса (среднее за 2020, 2021 гг.)

Table 5. The effect of preparations based on chicken manure on the formation of elements of the structure of the oat harvest (average for 2020, 2021)

Option	Number of plants before harvesting, pcs. / m^2	Grain weight in a panicle, g	Number of grains in a panicle, pcs.	Thousand-kernel weight, g	Biological yield, t/ha	Yield, t/ha
Control	338	1,12	27	36,4	4,1	3,9
Chicken manure	345	1,23	30	38,5	4,5	4,3
Preparation 1	350	1,4	32	37,8	4,9*	4,7*
Supplemented preparation 2	356	1,35	31	37,4	4,8*	4,6*
Nitrogen fertilizers N_{60}	345	1,22	30	38,7	4,4	4,3
LSD_{05}					0,49	0,46

CONCLUSIONS

1. In the forest-steppe zone of Western Siberia the positive effect of application of preparations 1 and 2 (based on chicken manure) to the soil before sowing and during the growing season in the phase of fruit formation in oats was achieved. Reliable increase of green mass and dry matter in the phase of oat flowering by 6,0-6,2 and 1,16-1,7 t/ha, respectively, in comparison with the control was obtained. Oat grain yield was higher by 0,71-0,82 t/ha or 20% compared to the control. Treatment with preparations 1 and 2 improved structural indices of oat plants: the grain weight increased by 16-25% and the number of grains in the panicle by 17%.

2. The analysis of data on the microbiological composition of soils when applying different forms of organic and mineral fertilizers showed that the use of chicken manure has no positive effect on the number of useful soil microflora under oats. Application of preparations 1 and 2 improves the phytosanitary state of the soil, the development of free-living microorganisms assimilating atmospheric nitrogen, which increases the availability of nutrients for plants.

3. The use of pure chicken manure as fertilizer for crops worsens the ecological condition of the soil, as evidenced by the phytotoxic effects on the test objects. The application of preparations obtained with the use of cavitation-vortex equipment contributes to the reduction of phytotoxic effects compared with the control.

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УРОЖАЙ И ОКУПАЕМОСТЬ УДОБРЕНИЙ ПРИ КОРНЕВОМ И НЕКОРНЕВОМ ПИТАНИИ РАСТЕНИЙ КУКУРУЗЫ

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Представлены результаты исследования влияния корневого и некорневого питания на урожай зерна гибридов кукурузы. Полевые опыты проведены в 2018–2020 гг. в зоне достаточного увлажнения Ставропольского края. Корневое питание растений проводили под предпосевную культивацию (весной) аммиачной селитрой и нитроаммофоской дозе 30 кг д.в. Некорневое питание вносили по листу в фазе 8 листьев удобрением Вуксал Макромикс в дозе 2,5 л/га. Удобрения изучали на среднераннем гибриде Машук 220 МВ и среднеспелом Машук 355 МВ. Наибольший урожай зерна гибридов в 2018 г. получен от внесения по листу удобрения Вуксал Макромикс в дозе 2,5 л/га, прибавка относительно контроля гибрида Машук 220 МВ составила 0,89 т/га, гибрида Машук 355 МВ – 1,44 т/га. В 2019 г. наибольший урожай зерна гибридов получен от внесения под предпосевную культивацию нитроаммофоски в дозе $N_{30}P_{30}K_{30}$. Прибавка урожая зерна гибрида Машук 220 МВ составила 0,78 т/га (11,2%), гибрида Машук 355 МВ – 0,90 т/га (11,7%). В 2020 г. наибольший урожай зерна гибрида Машук 220 МВ получен при подкормке растений через листья удобрением Вуксал Макромикс в дозе 2,5 л/га, гибрида Машук 355 МВ при внесении под предпосевную культивацию аммиачной селитры в дозе N_{30}, прибавки составили соответственно 0,37 т/га (8,1%) и 0,29 т/га (6,6%). В среднем за 2018–2020 гг. наибольший урожай гибридов отмечен при внесении удобрения Вуксал Макромикс 2,5 л/га по листу. Прибавка урожая зерна гибрида Машук 220 МВ составила 0,60 т/га (11,0%), гибрида Машук 355 МВ – 0,63 т/га (10,5%). Окупаемость удобрений зерном при выращивании гибрида Машук 220 МВ была выше в варианте корневого питания растений удобрением Вуксал Макромикс 2,5 л/га, на 1 р. затрат получено 0,90 р. дохода. При выращивании гибрида Машук 355 МВ при внесении под предпосевную культивацию аммиачной селитры в дозе N_{30} на 1 р. затрат получено 1,69 р. дохода.

Ключевые слова: кукуруза, удобрения, корневая и некорневая подкормка, урожайность, зерно

YIELD AND RETURN ON FERTILIZER WITH ROOT AND FOLIAR FEEDING OF CORN PLANTS

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The results of the study of the effect of root and foliar nutrition on grain yield of maize hybrids are presented. Field experiments were conducted in 2018-2020 in the zone of sufficient moisture of the Stavropol Territory. Root nutrition of plants was carried out under presowing cultivation (in spring) with ammonium nitrate and nitroammonium phosphate at a dose of 30 kg of active agent. Foliar feeding was applied in the 8-leaf phase with Vuxal Macromix fertilizer at a dose of 2.5 l/ha. Fertilizers were studied on the middle-early hybrid Mashuk 220 MV and the mid-season-ripening Mashuk 355 MV. The highest hybrid grain yield in 2018 was obtained from the leaf application of the Vuxal Makromiks fertilizer at a dose of 2.5 l/ha, the increase relative to the control of the hybrid Mashuk 220 MV was 0.89 t/ha, the hybrid Mashuk 355 MV - 1.44 t/ha. In 2019, the highest hybrid grain yield was obtained from the application of ammonium nitrate phosphate fertilizer at a dose of $N_{30}P_{30}K_{30}$ under pre-sowing cultivation. The grain yield increase of Mashuk 220 MV hybrid was 0.78 t/ha (11.2%), of Mashuk 355 MV hybrid - 0.90 t/ha (11.7%). In 2020, the highest yield of the grain hybrid Mashuk 220 MV was obtained when feeding the plants through the leaves with

the Vuxal Macromix fertilizer at a dose of 2.5 l / ha, the hybrid Mashuk 355 MV when applying ammonium nitrate phosphate fertilizer at a dose of N_{30} under pre-sowing cultivation, the increase amounted to respectively 0.37 t / ha (8.1%) and 0.29 t / ha (6.6%). On average for 2018-2020, the highest hybrid yields were seen with a 2.5 L/ha application of Vuxal Macromix foliar fertilizer. Increase in grain yield of the hybrid Mashuk 220 MV was 0.60 t / ha (11,0%), the hybrid Mashuk 355 MV - 0.63 t / ha (10,5%). Payback of fertilizers by grain when growing hybrid Mashuk 220 MV was higher in the variant of root feeding of plants by fertilizer Vuxal Macromix 2,5 l/ha, for 1 ruble of costs 0,90 ruble of income was received. When growing the hybrid Mashuk 355 MV with the introduction of ammonium nitrate under pre-sowing cultivation at a dose of N_{30}, 1 ruble of costs received 1.69 rubles of income.

Keywords: corn, fertilizers, root and foliar feeding, productivity, grain

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INTRODUCTION

The assimilation of chemical elements in the process of mineral nutrition is the most important physiological need of plants [1]. Corn needs fertile soil, which is created by an appropriate system of fertilizers. The means to increase corn yield is the proper use of fertilizers [2, 3]. For these purposes various ways of improving the provision of plants with elements of nutrition are used: the application of mineral fertilizers: broadcast sowing under the main tillage, under pre-sowing cultivation, at sowing, as well as the use of agrochemicals in the form of foliar fertilizers [4, 5]. Root nutrition of corn is an important factor. The peculiarities of corn root system give it the opportunity for rapid and significant consumption of nutrients from the soil [6].

A leaf is the plant's main laboratory where the organic matter of the crop is created. Through the leaves, plants are also able to absorb macro- and micronutrients from fertilizers. As a result of biochemical reactions, photosynthesis is accelerated in the leaves, chlorophyll content increases, which contributes to carbohydrate and protein metabolism. In connection with this peculiarity of leaves, foliar plant nutrition for corn is also of great importance [7]. Studies of many authors have noted a positive effect on corn yield of nitrogen and complex fertilizers applied under pre-sowing cultivation[1] [8-10]. Top dressing corn fertilizers, including the metabolism of the plant organism and increasing its potential, also have a positive effect on the yield.

The production and application of fertilizers in Russia are increasing every year, and their range is expanding. In recent years, there has been increased interest in various mineral and organomineral fertilizers to improve the feeding conditions of plants with nutrients through the leaf [11-13]. In addition to macro and microelements, many of them contain amino acids, vitamins, natural hormones, growth-stimulating and other substances. Modern most effective agrochemicals for foliar plant nutrition are

[1]Sychev V.G. Prospects of using new agrochemicals in modern agricultural technologies. Prospects of using innovative forms of fertilizers, protection means and plant growth regulators in agricultural technologies of crops: Proceedings of participants of the 10th Scientific-Practical Conference "Anapa-2018". Edited by Academician of the Russian Academy of Sciences V.G. Sychev. Moscow: LLC "Plodorodie", 2018, pp 3-6, 244 p.

complex multicomponent and multifunctional products with innovative solutions. Fertilizers for foliar plant nutrition, quickly incorporated into the metabolism, are transported to the plant organs and provide an increase in corn grain yield.

The purpose of fertilizer application is to eliminate the lack of the necessary amount of a particular nutrient required by corn and to obtain cost recovery. Therefore, the question of science-based, rational use of mineral fertilizers and agrochemicals with the highest cost recovery is relevant.

The purpose of the research is to compare the effectiveness and payback of ammonium nitrate and nitroammophoska applied under presowing cultivation and foliar feeding of corn plants in the phase of 7-8 leaves with fertilizer Vuxal Macromix.

MATERIAL AND METHODS

Field experiments were conducted in 2018-2020 in the experimental field of the All-Russian Research Institute of Corn in the zone of sufficient moisture in the Stavropol region. The soil of the experimental plot was ordinary carbonate thick heavy-loam chernozem. Volumetric weight of one-meter layer of soil averaged 1.25 g/m3. There is about 4.7% of humus in the 0-20 cm layer. The reaction of the humus horizon soil solution is alkaline (pH of the water extract is 7.5). The content of mobile phosphorus in the soil is low, exchangeable potassium is medium.

The studies were conducted on a medium-early hybrid Mashuk 220 MV (FAO 220) and a medium-early hybrid Mashuk 355 MV (FAO 350). The plot area occupied by one corn hybrid was 19.6 m^2 (7.0 × 2.8 m), the recording area was 9.8 m^2 (7.0 × 1.4 m). Repetition of variants in the experiment was four times. Corn was preceded by winter wheat. The main tillage of the soil was mouldboard. After harvesting the forecrop, stubble cleaning was done twice and plowing was done in the fall. In the spring before sowing two cultivations were carried out.

In 2018 corn was sown on April 28, in 2019 on April 29, and in 2020 on April 30 with a UPS-8 drill. Corn sprouted in 2018 on May 6, in 2019 on May 10, and in 2020 on May 11. After the emergence of seedlings in the phase of 2-3 leaves the optimal density of plants was formed - 70 thousand pcs/ha. To control weeds, corn was treated with herbicide Adengo (0.5 l/ha) in the phase of 3 leaves. In order to loosen the soil in the phase of 7-8 leaves inter-row cultivation was conducted.

Ammonium nitrate and nitroammonium phosphate were applied in the spring under the first spring cultivation. Fertilization of corn plants with Vuxal Macromix was carried out after inter-row cultivation in the phase of 7-8 leaves using OP-2500 sprayer of ARGO series at a working fluid consumption of 250 l/ha.

Yields were counted in the phase of full grain ripeness. The cobs were picked by hand and threshed on a threshing machine. Grain moisture content was determined during threshing and converted to standard 14% moisture content. Mathematical processing of the yield data was carried out according to the method of B.A. Dospekhov[2].

Ammonium saltpeter (ammonium nitrate, German saltpeter) NH_4NO_3 - contains (N) 34-35%. Nitroammophoska (ammonium dihydroorthophosphate, ammonium nitrate, potassium chloride) $NH_4H_2PO_4$ + NH_4NO_3 + KCl contains (NPK) 16 : 16 : 16. Vuxal Macromix is a mineral fertilizer for foliar feeding of corn with macronutrients (N - 241,0 g/l, P_2O_5 - 241,0; K_2O - 181,0 g/l) and trace elements (B - 0,3 g/l, Cu - 0,76, Fe - 1,51, Mn - 0,76, Mo - 0,015, Zn - 0,76 g/l). Preparative form is a suspension with additional effects of pH-corrector and a sticking agent.

Soil samples for nutrient analysis in the 0-20 cm layer were taken in the phase of 5 leaves in corn. Soil chemical analysis for nitrate nitrogen content was carried out according to Grandval-Lajoux method, mobile phosphorus and exchangeable potassium according to Machighin method.

[2]Dospekhov B.A. Methodology of field experience. Moscow: Kolos, 1979, 416 p.

The average multiyear amount of precipitation during the corn growing season is 343.6 mm. In 2018-2020 precipitation during May - September (corn growing season) was less than the long-term average: in 2018 by 47.1 mm (13.7%), in 2019 by 41.5 mm (12.1%), and in 2020 by 71.3 mm (20.8%). The average daily air temperature during the growing season of corn in the years of research was higher than the long-term average (17.9 °C), in 2018 - by 3.1 °C, in 2019 - by 1.8 °C, in 2020 - by 2.3 °C.

RESULTS AND DISCUSSION

Fertilization had an impact on the increase of nutrition elements in the soil. In 2018, the control without fertilizers, the content of nitrate nitrogen was 17.4 mg/kg, mobile phosphorus 15 mg/kg, exchangeable potassium 312 mg/kg, in 2019 respectively 17.6; 12.0; 270 mg/kg, in 2020 - 17.6; 9.0; 235 mg/kg. In 2018, the application of ammonium nitrate under pre-sowing cultivation at a dose of N30 increased the content of nitrate nitrogen by 8.9 mg/kg, mobile phosphorus by 1.3 mg/kg, exchangeable potassium by 18 mg/kg, in 2019 by 6.4; 2.0; 21.0 mg/kg, in 2020 by 5.2; 1.0; 31.0 mg/kg respectively. The application of nitroammophoska at a dose of $N_{30}P_{30}K_{30}$ under pre-sowing cultivation in 2018 increased the content of nitrate nitrogen by 6.9 mg/kg, mobile phosphorus by 2.0 mg/kg. In 2019, nitrogen increased by 16.3 mg/kg, mobile phosphorus by 14 mg/kg, and exchangeable potassium by 25 mg/kg; in 2020, 12.4; 6.0; 56 mg/kg, respectively. On average over three years nitrate nitrogen content increased from the use of fertilizers by 11.9 mg/kg, mobile phosphorus - by 7.3 mg/kg, exchangeable potassium - 27 mg/kg.

The data obtained indicate a positive response of plants to the application of fertilizers both under pre-sowing cultivation and by leaf. Feeding plants with different fertilizers compared with unfertilized control increased corn grain yield (see Table 1).

In 2018, foliar application of Vuxal Macromix fertilizer at the 7-8 leaf phase proved to be the most effective fertilizer application.

When feeding plants through the leaves fertilizer Vuxal Macromix yield of grain hybrid Mashuk 220 MV significantly increased by 18.6%, hybrid Mashuk 355 MV - by 24.4%. Absorption of nutrients through the roots when applying under cultivation full mineral fertilizer $N_{30}P_{30}K_{30}$ did not significantly increase the grain yield of hybrids Mashuk 220 MV by 14.2% and Mashuk 355 MV by 5.3%.

Excluding phosphorus and potassium from the root nutrition and applying only ammonium nitrate at a dose of N_{30} was also not significant, the yield of grain hybrid Mashuk 220 MV increased by 1.3%, Mashuk 355 MV - by 12.8%.

In 2019, the greatest increase in grain yield of hybrid Mashuk 220 MV by 11.2%, Mashuk 355 MV by 11.7% was observed with root feeding of plants with nitroammophoska at a dose of $N_{30}P_{30}K_{30}$. Root feeding of plants by fertilizer Vuxal Macromix on the leaf gave an increase

Табл. 1. Влияние удобрений на урожай зерна, т/га (2018–2020 гг.)
Table 1. Effect of fertilizers on grain yield, t/ha (2018–2020)

Hybrid	Year	Without fertilizers	Cultivation fertilizer application		Vuxal Macromix 2.5 l/ha treatment at the 7-8 leaf phase	$LSD_{0,05}$, t/ha
			N_{30}	$N_{30}P_{30}K_{30}$		
Mashuk 220 MV	2018	4,79	4,85	5,47	5,68	0,71
	2019	6,98	7,53	7,76	7,60	0,30
	2020	4,55	4,64	4,38	4,92	0,36
On average		5,44	5,67	5,87	6,04	
Mashuk 355 MV	2018	5,90	6,42	6,21	7,34	0,73
	2019	7,71	8,40	8,61	8,10	0,43
	2020	4,39	4,68	4,50	4,64	0,42
On average		6,00	6,50	6,44	6,63	

in grain yield hybrid Mashuk 220 MV 8,9%, but its advantage was not significantly different from the addition of ammonium nitrate under preplanting cultivation in a dose of N_{30}, which gave a 7.9% gain. Root nutrition of plants hybrid Mashuk 355 MV ammonium nitrate at a dose of N_{30} significantly increased grain yield by 8.9%. From the application of fertilizer Vuxal Macromix on the leaf increase in grain yield was insignificant (5.1%).

In 2020, the efficiency of root nutrition fertilizer application was lower than that of foliar feeding of plants by leaf. The best use of nutrients through the leaves when applying fertilizer Vuxal Macromix in the phase of 7-8 leaves significantly increased the grain yield of hybrid Mashuk 220 MV (8.1%). Marked insignificant increase in grain yield of the hybrid (2%), when applying under the preplanting cultivation ammonium nitrate N_{30}, and when applying under cultivation $N_{30}P_{30}K_{30}$ a negative effect and a reduction of grain yield by 3.7% was observed. On hybrid Mashuk 355 MV no advantages of fertilizing with Vuxal Macromix on the leaf compared to the addition of ammonium nitrate to the preplanting cultivation in the dose of N_{30}, received an insignificant increase in grain yield (5,7 and 6,6% respectively) was noted.

On average for 2018-2020 foliar feeding with fertilizer Vuxal Macromix in the phase of 7-8 leaves provided the maximum increase in grain yield of hybrids (by 11.0 and 10.5%). Applying nitroammophoska $N_{30}P_{30}K_{30}$ for root nutrition under preplanting cultivation increased the yield of hybrids by 7,9 and 7,3%. For the corn hybrid Mashuk 355 MV root nutrition of plants with ammonium nitrate at a dose of N30 applied under pre-sowing cultivation was more effective than for the hybrid Mashuk 220 MV, the increase in yield was respectively 8.3 and 4.2%.

The data obtained on the cost recovery of fertilizer application showed the expediency of using both ammonium nitrate under cultivation and foliar feeding of plants with the fertilizer Vuxal Macromix (see Table 2).

The cost of fertilizer application on the leaf, including their cost, at foliar fertilization with the fertilizer Vuxal Macromix were higher than when applying mineral fertilizers under cultivation. However, the cost of the yield increase in foliar feeding by the fertilizer Vuxal Macromix at the phase of 7-8 leaves was 1,9 times higher than the cost of fertilizer on the

Табл. 2. Окупаемость удобрений в среднем за 2018–2020 гг.
Table 2. Payback on fertilizers on average for 2018–2020

Indicator	Hybrid	Cultivation fertilizer application		Vuxal Macromix 2.5 l/ha treatment at the 7-8 leaf phase
		N_{30}	$N_{30}P_{30}K_{30}$	
Yield gain, t/ha	Mashuk 220 MV	0,23	0,43	0,60
	Mashuk 355 MV	0,50	0,44	0,63
Cost of additional production, rbl./ha	Mashuk 220 MV	2300	4300	6000
	Mashuk 355 MV	5000	4400	6300
Fertilizer application costs, rbl./ha	Mashuk 220 MV	1857	3008	3153
	Mashuk 355 MV	1857	3008	3153
Including the cost of fertilizers, rbl./ha	Mashuk 220 MV	1004	2150	2500
	Mashuk 355 MV	1004	2150	2500
Additional net income, rbl./ha	Mashuk 220 MV	443	1292	2847
	Mashuk 355 MV	3143	1392	3147
Received income per 1 ruble of costs, rbl.	Mashuk 220 MV	0,24	0,43	0,90
	Mashuk 355 MV	1,69	0,46	1,00

hybrid Mashuk 220 MV, Mashuk 355 MV 2,0 times higher, when applying nitroammophoska $N_{30}P_{30}K_{30}$ under cultivation respectively 1,4 and 1,5 times higher, ammonium nitrate N_{30} - 1,2 and 2,7 times higher.

The use of fertilizer Vuxal Macromix for foliar feeding of the hybrids Mashuk 220 MV and Mashuk 355 MV gave the greatest additional net income, which was due to a higher increase in grain yield. Less increase in grain yield obtained in the variants of the application under cultivation of nitroammophoska $N_{30}P_{30}K_{30}$ and nitrate N_{30} was accompanied by a decrease in profits.

0,90 rubles of additional production was spent for one ruble of additional costs at foliar feeding of plants of the hybrid Mashuk 220 MV by the fertilizer Vuxal Macromix in the phase of 7-8 leaves, when applying under cultivation of nitroammophoska $N_{30}P_{30}K_{30}$ - 0,43 rubles, ammonium nitrate N_{30} - 0,24 rubles, the hybrid Mashuk 355 MV respectively 1,00; 0,46 and 1,69 rubles.

CONCLUSIONS

1. Analysis of the data on the effect of root and foliar feeding of plants showed that the application of the fertilizer Vuxal Macromix at a dose of 2.5 l/ha by leaf has an advantage compared to the application of fertilizer N_{30} and $N_{30}P_{30}K_{30}$ under pre-sowing cultivation. Root feeding of plants with ammonium nitrate at a dose of N_{30}, applied under pre-sowing cultivation, increases the yield of corn hybrid Mashuk 220 MV by 4.2%, Mashuk 355 MV - by 8.3%, and with nitroammophoska $N_{30}P_{30}K_{30}$ - by 7.9 and 7.3%. Fertilizing plants with Vuxal Macromix in the phase of 7-8 leaves at a dose of 2.5 l/ha gave a yield increase of 11.0 and 10.5%.

2. From an economic point of view, when growing hybrid Mashuk 220 MV the fertilizer application payback by an increase in the grain yield is higher at foliar feeding of plants with the fertilizer Vuxal Macromix 2.5 l / ha in the phase of 7-8 leaves, hybrid Mashuk 355 MV - with root feeding of plants with ammonium nitrate at a dose of N_{30}, applied under preplant cultivation.

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ОСОБЕННОСТИ ФОРМИРОВАНИЯ УРОЖАЯ И КАЧЕСТВА ЗЕРНА ОЗИМОЙ ПШЕНИЦЫ В ЦЕНТРАЛЬНОМ ЧЕРНОЗЕМЬЕ

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Представлены результаты многолетних исследований (2017–2021) озимой пшеницы на юго-востоке Центрального Черноземья. Цель работы – изучение особенностей формирования урожайности и качества зерна культуры в местных природно-климатических условиях. Материал исследований – сорта Базальт, Крастал, Черноземка 130, Черноземка 115 и Базальт 2. Определены урожайность вместе с параметрами адаптивности, экологической пластичности и стабильности, а также содержание белка и клейковины в зерне. По каждому сорту установлена корреляционная зависимость урожайности, содержания белка и клейковины в зерне с температурой воздуха и количеством осадков, которые сложились в период весенне-летней вегетации. Показана возможность получения в регионе высоких урожаев культуры с содержанием белка и клейковины в зерне не ниже 3-го класса, а также варьирования изучаемых показателей по годам. Фактором среды, лимитирующим урожайность и качество зерна в регионе, в весенне-летний и осенний периоды вегетации является засуха. Установлены ключевые декады месяцев весенне-летней вегетации (апрель – июль), гидротермические условия которых оказывают существенное влияние на формирование урожайности, количество белка и клейковины в зерне. Среди них: II декада апреля, II декада мая, II и III декады июня и I декада июля. Температура воздуха и выпадающие осадки в эти декады имеют сильную корреляционную зависимость разной направленности с урожайностью и качеством зерна. При этом количественные выражения коэффициентов корреляции по сортам отличаются, но их значения близки и находятся в пределах одной группы зависимости.

Ключевые слова: озимая пшеница, урожайность, белок, клейковина, температура воздуха, осадки, корреляция

SPECIFICS OF YIELD FORMATION AND GRAIN QUALITY OF WINTER WHEAT IN THE CENTRAL CHERNOZEM REGION

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The results of multiannual studies (2017-2021) of winter wheat in the southeast of the Central Chernozem region are presented. The purpose of the work is to study the peculiarities of yield formation and grain quality of the crop in the local natural and climatic conditions. The research material included the varieties Bazalt, Krastal, Chernozemka 130, Chernozemka 115, and Bazalt 2. Yield along with parameters of adaptability, ecological plasticity and stability, as well as protein and gluten content in grain were determined. The correlation dependence of yield, protein and gluten content in grain with air temperature and precipitation during the spring-summer vegetation period

was established for each variety. The possibility of obtaining high crop yields in the region with protein and gluten content in the grain not lower than the 3rd class, as well as the variation of the studied indicators by year was shown. The environmental factor limiting the yield and quality of grain in the region, in the spring-summer and autumn periods of the growing season is drought. The key ten-days of the months of spring-summer vegetation (April-July), the hydrothermal conditions of which have a significant impact on the formation of yield, the amount of protein and gluten in the grain, were determined. These include the second ten-day period of April, the second ten-day period of May, the second and third ten-day periods of June, and the first ten-day period of July. Air temperature and precipitation during these ten-day periods have a strong correlation of different directions with grain yield and quality. The quantitative expressions of the correlation coefficients differ by varieties, but their values are close and are within the same dependence group.

Keywords: winter wheat, yield, protein, gluten, air temperature, precipitation, correlation

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INTRODUCTION

Winter wheat has been the leading food grain crop in the Central Black Earth Region since the mid-20th century, replacing spring wheat and winter rye in the crops. Its wide distribution was facilitated by the creation of varieties suitable for cultivation in the region [1]. However, as the practice of winter wheat cultivation has shown, the sown areas and grain yield in the region vary significantly from year to year [2]. The quality of the manufactured products is also unstable, since most of the harvested food grain belongs to the 4th and 5th classes [3].

The main causes of instability are unfavorable climatic factors of the region (drought, winter stress, etc.), as well as agronomic violations in the cultivation of the crop. At the same time, different cultivation technologies, despite their significant influence, only contribute to a greater or lesser extent to the realization of the genetic potential of the variety's productivity. It follows that the basis for counteracting the negative weather factors should be continuous breeding work, since the genotype of a new variety is the main factor in the formation of yield in specific ecological and geographical conditions. It is possible to counteract the climatic limits of the environment, especially their frequent changes, by using varieties with different economic and biological characteristics and properties (different levels of productivity, resistance to abiotic and biotic stresses, protein and gluten content, resistance to lodging, the duration of the growing season, etc.). [4-6]. Differences in genomic composition allow to differentiate cultivated varieties by their adaptability, and this is an important aspect of increasing the yield, since there is evidence that sowing in each farm 3-4 varieties of contrasting adaptability can increase the gross yield of grain by 30-40% [7].

High genetic potential of modern varieties often remains untapped. Therefore, the task of creating varieties with higher ecological plasticity and a broad norm of response to changing environmental conditions, which increase the possibility of obtaining stable harvests with good technological qualities, is of particular relevance [8]. Variety policy based on the principle of mosaic placement of varieties allows to maximize the positive effect of genotype-media interaction and better use the genetic diversity of varieties, increasing the stability of yields,

grain quality and adaptability of the crop as a whole [9, 10].

The purpose of the research is to study the peculiarities of yield formation and grain quality in the conditions of the southeast of the Central Black Earth Region.

MATERIAL AND METHODS

The studies were conducted in 2017-2021. Five varieties of winter soft wheat created at the Voronezh Federal Agricultural Scientific Centre named after V.V. Dokuchaev were used as source material for the studies. These include Bazalt (in the State Register of Breeding Achievements since 1993), Krastal (2009), Chernozemka 115 (2011), Chernozemka 130 (2018) and Bazalt 2 (2019).

Field experiments were laid in a specialized crop rotation. Black fallow was the forecrop, the cultivation technology was the one established in the zone[1]. Control plot area was 20-25 m^2, seeding rate - 5 million germinated grains/ha, repetition 4-6 times. Harvesting was carried out by Sampo-130 combine.

The soil of the experimental plots was ordinary medium-humic medium heavy loamy chernozem.

The statistical processing of the research results was performed using Microsoft Office Excel and Statistica programs. Environmental plasticity and stability were evaluated by the method of S.A. Eberhart, W.A. Rassell in the methodical version of V.Z. Pakudin and L.M. Lopatina [11], where the plasticity of varieties is estimated by regression coefficient (bi), characterizing the average response of variety to changing environmental conditions, and stability - by variant trait (Si2). The parameters of homeostability of varieties quality indices were evaluated according to V.V. Hangildin [12]. Gluten in the grain was determined by GOST R 54478-2011, protein - by Kjeldahl method (CIASA - Central Institute of Agrochemical Service of Agriculture).

Hydrothermal conditions of spring-summer vegetation (April-July) during the years of studies were diverse. Average air temperatures of most months were higher than multiyear values. The exceptions were May and June 2017, April and May 2020, when average monthly temperatures were slightly lower than normal. Precipitation was uneven and varied greatly both by year and by month of the growing season (from 6% versus multi-year in June 2018 to 289% in April 2020). The weather conditions of the growing season 2020, 2021 were very unfavorable. Sowing (I ten-day period of September) and autumn vegetation of plants took place in conditions of strong soil and air drought. Practically significant precipitation (> 5 mm) was absent for more than 2 months (from the second ten-day period of August to the second ten-day period of October inclusive). In general, during the autumn vegetation period (September-November) the amount of precipitation was only 33% of the norm. As a result, sprouts were incomplete (on average, up to 30-40% of the number of sown grains, their period extended for 2 weeks or more), and their growth and development were weak due to the total absence of moisture in the root zone and low relative air humidity. Full sprouts were received neither by the beginning of the cessation of autumn vegetation (November 10), nor by the beginning of the resumption of vegetation (April 12). As a result, by the beginning of harvesting the varieties had a very sparse stem, which was the reason for low yields in 2021.

Based on the amount of precipitation for April - June (the period of growth and development of plants from spring till ripening), we can conclude that conditions in 2018 and 2019 were dry for winter wheat (60 and 69% of the norm, respectively). The growing season of 2020, 2021 was also dry, but only the drought that significantly impacted yields was observed in the fall growing season. Conditions in 2017 and 2020 can be classified as normal and favorable years.

[1]Turusov V.I., Garmashov V.M., Novichikhin A.M., Dorokhov B.A., Nuzhnaya N.A., Bocharnikova E.G., Abanina O.A., Kharkovsky A.A., Gorbacheva A.V. Recommendations for growing winter wheat in the Voronezh region. Kamennaya Steppe, 2019. 37 p.

RESULTS AND DISCUSSION

Based on the calculated indices of environmental conditions, 2017, 2018 and 2020 were favorable for yields with positive Ij = 2.39; 0.13 and 0.68 indices, respectively, and 2019 and 2021 were unfavorable with negative Ij = -0.94 and -2.25 indices (see Table 1).

Yield variation was significant, ranging from 6.85 t/ha in the favorable 2017 to 2.21 t/ha in the unfavorable 2021. The corresponding coefficients of variation are shown in Table 2. The main reason that negatively affected the formation of yields was drought conditions. In the present experiment three out of five years were with drought, and its manifestation was noted in different periods of vegetation.

To determine the variety that showed the best adaptability in cultivation under the prevailing local conditions during the years of research, we analyzed the resulting yield on the parameters of ecological plasticity, stability and homeostability.

The plasticity of the varieties studied can be judged by the value of the regression coefficient (bj), which in our experiment was close to unity (0.91-1.05). This suggests a high ecological plasticity of the varieties under study in local conditions. At the same time, changes in their yields by year correspond to changes in environmental conditions.

The root mean square deviation from the regression line (S2dj) indicates the stability of varieties. The smaller this deviation (→0), the more stable the variety. In our experiment, the smaller values of the index (high stability) were characterized by Bazalt, Chernozemka 115 and Chernozemka 130.

The concepts of plasticity and stability are associated with homeostasis (Hom), which characterizes the ability of a genotype to minimize the effects of adverse environmental influences. The criterion of homeostability is the low variability of traits (V). The relationship between these indicators characterizes the resistance of the trait (yield) to changing environmental conditions. The best on these indicators were varieties Krastal (Hom = 3,3; V = 35,0%) and Chernozemka 130 (Hom = 2,5; V = 37,9%).

According to the results, the variety Chernozemka 130, which genome most effectively used the local climatic conditions to realize the productivity potential, was identified.

In order to determine the degree and nature of the influence of meteorological conditions on the yield, the correlation analysis of the relationship of yield with the average monthly and ten-day temperatures and precipitation during the spring-summer growing season was carried out (see Table 3). During this period the plants go through phases of development

Табл. 1. Урожайность и индекс условий среды
Table 1. Yield and environmental conditions index

Variety	Yield, t/ha					
	2017	2018	2019	2020	2021	$\bar{X}$
Basalt	6,04	4,04	2,65	4,85	1,74	3,86
Krastal	6,72	4,18	3,37	5,97	2,83	4,61
Chernozemka 115	6,83	4,32	3,74	5,15	1,91	4,39
Chernozemka 130	7,23	5,11	3,90	5,06	2,31	4,72
Basalt 2	7,41	5,30	3,93	4,65	2,25	4,71
$\bar{X}j$*	6,85	4,59	3,52	5,14	2,21	4,46
*Ij***	2,39	0,13	–0,94	0,68	–2,25	

Here and in Table 4.
* Average yield for the year.
** Environmental conditions index.

Табл. 2. Урожайность и параметры пластичности, стабильности и гомеостатичности
Table 2. Yield and parameters of plasticity, stability and homeostaticity

Variety	Yield, t/ha		*V*, %	*Hom*	b_j	S^2d_j
	max	min				
Basalt	6,04	1,74	44,0	2,0	0,97	0,07
Krastal	6,72	2,83	35,0	3,3	0,91	0,36
Chernozemka 115	6,83	1,91	41,4	2,2	1,03	0,06
Chernozemka 130	7,23	2,31	37,9	2,5	1,03	0,08
Basalt 2	7,41	2,25	39,2	2,3	1,05	0,30

Note. *V* – variation coefficient; *Hom* – homeostaticity; b_j – environmental plasticity; S^2d_j – environmental stability.

from spring till full ripeness. The following gradation was used to estimate the degree of correlation between the indicators: r < 0.3 - weak correlation, r = 0.3-0.7 - medium, r > 0.7 - strong[2].

With the average monthly temperatures in April, May and June yield capacity have a medium to strong (depending on the variety) inverse (negative) relationship (r = -0.53...-0.84; r = -0.51...-0.85 and r = -0.66...-0.85 respectively). Also, negative, but less weak correlation (r = -0.15...-0.41) is observed with July temperatures. It follows from this that higher temperatures in these months compared with long-term

Табл. 3. Коэффициенты корреляции урожайности с температурой и осадками
Table 3. Coefficients of correlation of yield with temperature and precipitation

Variety	April		May		June		July	
	˚C	mm	˚C	mm	˚C	mm	˚C	mm
Monthly average								
Basalt	–0,79	0,46	–0,71	0,19	–0,76	–0,22	–0,21	–0,26
Krastal	–0,84	0,37	–0,85	0,37	–0,66	–0,01	–0,15	–0,47
Chernozemka 115	–0,66	0,30	–0,69	0,26	–0,72	–0,24	–0,41	–0,21
Chernozemka 130	–0,61	0,35	–0,59	0,14	–0,81	–0,34	–0,38	–0,10
Basalt 2	–0,53	0,32	–0,51	0,09	–0,85	–0,39	–0,40	–0,02
I ten-day period								
Basalt	0,18	–0,24	0,30	–0,51	–0,26	0,46	–0,01	–0,68
Krastal	0,28	–0,45	0,10	–0,44	–0,18	0,61	0,08	–0,52
Chernozemka 115	0,21	–0,21	0,26	–0,35	–0,11	0,40	–0,18	–0,59
Chernozemka 130	0,26	–0,09	0,36	–0,40	–0,25	0,34	–0,24	–0,71
Basalt 2	0,27	–0,02	0,40	–0,37	–0,29	0,29	–0,34	–0,75
II ten-day period								
Basalt	–0,92	0,86	–0,92	0,81	–0,46	–0,71	–	–
Krastal	–0,94	0,93	–0,97	0,80	–0,35	–0,66	–	–
Chernozemka 115	–0,91	0,76	–0,92	0,85	–0,48	–0,55	–	–
Chernozemka 130	–0,84	0,73	–0,86	0,78	–0,60	–0,61	–	–
Basalt 2	–0,76	0,66	–0,80	0,72	–0,68	–0,59	–	–
III ten-day period								
Basalt	–0,12	0,12	–0,81	–0,44	–0,82	–0,50	–	–
Krastal	–0,24	0,13	–0,87	–0,29	–0,83	–0,31	–	–
Chernozemka 115	0,06	–0,07	–0,70	–0,52	–0,89	–0,58	–	–
Chernozemka 130	0,07	–0,07	–0,64	–0,54	–0,82	–0,65	–	–
Basalt 2	0,12	–0,14	–0,54	–0,54	–0,76	–0,69	–	–

[2]Dospekhov B.A. Methodology of field experience. Moscow: Kolos, 1979, 416 p.

values have a negative impact on the formation of yield.

The dependence of yield on the amount of monthly precipitation is multidirectional. With precipitation in April and May, it is direct (positive), and in June and July - inverse. Dependence with precipitation in April is of average strength (r = 0,30...0,46), and with precipitation in May, June and July - from weak to strong with appropriate signs for correlation coefficients (CC).

However, monthly indicators of temperature and precipitation do not reveal the completeness of their influence on the yield. Firstly, temperature conditions during the growing season are not always smoothly transitioned from one regime to another, and precipitation is not evenly distributed during the calendar month. Secondly, a plant may go through several developmental phases during one month. Depending on the duration of this or that phase, the influence of meteorological factors on the growth and development of plants, the formation of productivity elements, resistance to lodging, etc., may be strong or weak.

The analysis showed that in April, the key is the II ten-day period (from the 10th to the 20th). At this time, winter wheat vegetation resumes most often in the region, and a sharp increase in heat in this ten-day period has a strong negative effect on future yields (r = -0.76...-0.94). Abundant precipitation in this ten-day period, on the contrary, promotes growth of the yield capacity (r = 0.66...0.93). Influence of temperatures and precipitation of the I ten-day period on the yield capacity is weak, and of the III ten-day period - weak and multidirectional depending on the variety.

May conditions have ambiguous influence on vegetating plants. Higher temperatures in the first ten-day period compared to the long-term average have a weak positive correlation with the yield capacity (r = 0.10 ... 0.40), and in the second and third ten-day periods a strong negative correlation (r = -0.80 ... -0.97 and r = -0.54 ... -0.87, respectively). During the second and third ten-day periods of May, winter wheat plants undergo the phases of booting, ear formation and the beginning of flowering. Probably, high temperatures at this time negatively affect creation of productivity elements (the number of spikelets in a spike, grain size, etc.), and suppressed because of the heat growth leads to insufficient accumulation of organic biomass. Precipitation also has a different effect on the yield at this time. Negative correlation with average precipitation during I and III ten-day periods of May (r = -0,35 ... -0,51 and r = -0,29 ... -0,54, respectively), and positive and strong correlation (r = 0,75 ... 0,86) with precipitation during II ten-day period is observed. Positive influence of precipitation in the second ten-day period may be due to improved conditions of productivity elements formation during booting, and negative may be due to an increase because of heavy precipitation of vegetative biomass, which may result in early (before earing) lodging with negative consequences for the crop capacity.

Elevated temperatures of all three ten-days of June have a negative impact on yield formation, and from the first ten-day period to the third increasing - r = -0.11 ... -0.29, r = -0.35 ... -0.68 and r = -0.76 ... -0.89, respectively. In this month, winter wheat plants in the region, as a rule, sequentially pass phases of flowering, formation and grain filling. It is believed that drought during these phases leads to a significant decrease in plant productivity [13]. By the third ten-day period of June, plants reach milky ripeness, that is why higher temperatures in this ten-day period have a strong negative correlation with yield due to the possible formation of small and puny grain. Precipitation during ten-day periods in June, like in May, influences yield in different directions - positively in the first ten-day period (r = 0,29 ... 0,61) and negatively in the second and third ten-day periods (r = -0,55 ... -0,71 and r = -0,31 ... -0,69, respectively). The negative relationship between increased precipitation and yield in the second and third ten-day periods of June can also be explained by lodging of plants in these ten-day periods.

In the first ten-day period of July, plants go through the phases of milk-wax ripeness and

wax ripeness. Increased temperatures at this time affect already formed grain, so they have little effect on the yield (weak correlation). High precipitation can significantly and negatively affect the yield (r = -0.52...-0.75). Full ripening and harvesting occur, as a rule, in II - beginning of III ten-day period of July.

Not only the yield of winter wheat depends on the growing conditions, but also its quality [14]. Nutritive value of harvested wheat grain determines its protein content. In this regard, the corresponding analysis to determine the content of protein and gluten in the grain was carried out (see Table 4).

The best conditions for protein and gluten formation in the grain were in 2021, when the indicators were 16.2 and 43.9%, respectively. In 2018, the protein and gluten content was the lowest - 11.8 and 26.9%. Compared to 2021, other years' conditions are unfavorable, as seen in the corresponding indices of environmental conditions. But it should be noted that in 2017, 2019 and 2020, the average values of gluten content in the grain of the varieties in these years exceeded 28%, and this corresponds to the requirements of not less than the 2nd class in grain gathering. In general, soil and climatic conditions in the studied years allowed to obtain the 3rd class grain.

In our opinion, the formation of high protein content in the varieties in 2021 was influenced not only by weather conditions, but also by the low yield of this year. The relationship between the yield and the content of protein and gluten in the grain in our experiment can be judged by the corresponding CC. They indicate a negative correlation between the indicators and amounted to r = -0,59 ... -0,88 with protein and r = -0,56 ... -0,83 with gluten.

Correlation coefficients of protein and gluten in the grain with hydrothermal conditions are presented in Table 5. For convenience of analysis of the table data, the obtained CC for each month or ten-day period are summarized in a general group and presented as extreme values (min-max) in total for all the varieties with their values of protein and gluten.

Positive relation for these indicators is noted with an increase in monthly temperatures in April (r = 0,21...0,63) and negative - with precipitation (r = -0,24...-0,67). Dependence on weather conditions in May is weak, and in

Табл. 4. Содержание белка и клейковины в зерне
Table 4. Protein and gluten content in grain

Variety	2017	2018	2019	2020	2021	$\bar{x}$
Protein content, %						
Basalt	12,8	10,5	14,0	14,0	16,8	13,6
Krastal	12,5	12,0	15,1	14,0	16,5	14,0
Chernozemka 115	11,8	12,3	13,2	13,1	16,2	13,3
Chernozemka 130	11,8	12,1	12,9	13,2	15,1	13,0
Basalt 2	12,1	12,3	12,6	13,7	16,2	13,4
$\bar{x}j$*	12,2	11,8	13,6	13,6	16,2	13,5
*Ij***	–1,27	–1,63	0,09	0,13	2,69	
Gluten content, %						
Basalt	30,6	22,2	31,7	32,7	45,0	32,4
Krastal	26,8	25,9	30,3	28,2	41,8	30,6
Chernozemka 115	26,5	27,6	28,3	25,8	40,6	29,8
Chernozemka 130	26,6	27,7	31,2	25,2	45,8	31,3
Basalt 2	30,2	30,9	28,8	29,2	46,2	33,1
$\bar{x}j$*	28,1	26,9	30,1	28,2	43,9	31,4
*Ij***	–3,29	–4,57	–1,37	–3,21	12,45	

Табл. 5. Коэффициенты корреляции белка и клейковины с температурой и осадками
Table 5. Correlation coefficients of protein and gluten with temperature and precipitation

Variety	April				May				June				July			
	Temperature, °C		Precipitation, mm		Temperature, °C		Precipitation, мм		Temperature, °C		Precipitation, мм		Temperature, °C		Precipitation, мм	
	Protein	Gluten	Protein	Gluten	Protein	Gluten	Protein	Gluten	Protein	Gluten	Protein	Gluten a	Protein	Gluten	Protein	Gluten
Monthly average																
Basalt	0,31	0,29	–0,65	–0,60	–0,14	–0,14	0,61	0,58	0,57	0,44	0,91	0,93	0,32	0,42	–0,61	–0,63
Krastal	0,53	0,51	–0,67	–0,52	0,16	0,23	0,39	0,25	0,78	0,49	0,71	0,72	0,21	0,52	–0,32	–0,32
Chernozemka 115	0,28	0,54	–0,24	–0,41	0,20	0,36	0,12	0,07	0,46	0,35	0,69	0,59	0,74	0,59	–0,35	–0,13
Chernozemka 130	0,34	0,63	–0,36	–0,50	0,19	0,40	0,20	0,10	0,66	0,41	0,71	0,58	0,59	0,49	–0,36	–0,13
Basalt 2	0,21	0,39	–0,25	–0,28	0,10	0,26	0,20	0,08	0,50	0,22	0,75	0,60	0,73	0,72	–0,45	–0,27
I ten-day period																
Basalt	0,39	0,39	–0,64	0,65	–0,92	–0,90	0,63	0,58	0,25	0,08	0,40	0,47	0,15	0,14	0,83	0,72
Krastal	0,21	0,15	–0,36	–0,32	–0,78	–0,70	0,69	0,53	0,42	–0,04	0,06	0,18	0,11	0,09	0,92	0,65
Chernozemka 115	–0,08	0,06	–0,31	–0,16	–0,57	–0,64	0,25	0,43	–0,18	–0,24	0,21	0,11	0,37	0,03	0,52	0,46
Chernozemka 130	–0,04	0,11	–0,34	–0,13	–0,65	–0,57	0,38	0,53	0,09	0,14	0,14	0,05	0,37	–0,04	0,71	0,54
Basalt 2	–0,05	0,03	–0,41	–0,23	–0,63	–0,51	0,25	0,29	–0,10	–0,39	0,27	0,24	0,43	0,12	0,57	0,34
II ten-day period																
Basalt	0,45	0,48	–0,22	–0,16	0,24	0,23	–0,57	–0,64	0,41	0,29	0,49	0,38	0,47	0,59	–0,72	–0,73
Krastal	0,67	0,77	–0,52	–0,42	0,51	0,56	–0,64	–0,88	0,56	0,26	0,71	0,42	0,40	0,76	–0,86	–0,92
Chernozemka 115	0,68	0,85	–0,26	–0,24	0,53	0,63	–0,84	–0,96	0,34	0,10	0,19	0,30	0,85	0,87	–0,86	–0,92
Chernozemka 130	0,66	0,88	–0,37	–0,53	0,55	0,66	–0,76	–0,96	0,53	0,12	0,39	0,41	0,69	0,80	–0,89	–0,95
Basalt 2	0,60	0,76	–0,20	–0,27	0,46	0,52	–0,77	–0,93	0,42	0,03	0,20	0,11	0,79	0,94	–0,82	–0,84
III ten-day period																
Basalt	–0,42	–0,53	–0,13	–0,14	0,30	0,29	0,85	0,93	0,47	0,54	0,92	0,95	–	–	–	–
Krastal	–0,16	–0,42	–0,20	–0,09	0,52	0,54	0,70	0,90	0,57	0,81	0,81	0,88	–	–	–	–
Chernozemka 115	–0,62	–0,43	0,22	–0,06	0,34	0,60	0,90	0,87	0,83	0,91	0,92	0,79	–	–	–	–
Chernozemka 130	–0,48	–0,33	0,15	–0,15	0,37	0,68	0,84	0,84	0,75	0,90	0,93	0,76	–	–	–	–
Basalt 2	–0,64	–0,59	0,24	0,06	0,25	0,40	0,91	0,92	0,75	0,89	0,96	0,82	–	–	–	–

June and July - stronger. This dependence is positive with June (r = 0,22 ... 0,78) and July (r = 0,21 ... 0,74) temperatures and contributes to protein content growth. Precipitation at this time has an ambiguous effect: June precipitation is positive (r = 0,58...0,93), while July precipitation is negative (r = -0,13...-0,72).

Correlation of protein complex formation with ten-day indicators of temperature and precipitation specifies this dependence.

There is a direct correlation between an increase in grain protein content and rising temperatures during the resumption of the spring vegetation (II ten-day period of April, r = 0.45... 0,88), and also during booting and earing (II and III ten-day periods of May, r = 0,23-0,66 and r = 0,25-0,68 correspondingly), grain ripening (III ten-day period of June, r = 0,47-0,90) and full ripeness (II ten-day period of July, r = 0,40-0,94). Reduction of protein content in grain occurs with increasing temperature in the III ten-day period of April (r = -0,16 ... -0,64) and the I ten-day period of May (r = -0,51 ... -0,92) during spring tillering and the beginning of booting.

Higher contents of protein and gluten are formed on the background of higher amount of precipitation during the beginning of booting (the first ten-days of May, r = 0,25 ... 0,69), earing (the third decade of May, r = 0,70 ... 0,93), grain ripening (the third decade of June, r = 0,76 ... 0,96) and milk ripening (the first decade of July, r = 0,34 ... 0,92). A decrease of protein and gluten in grains is noted with an increase of precipitation during the renewal of the spring vegetation (II ten-day period of April, r = -0,16 ... -0,53), during booting (II ten-day period of May, r = -0,57 ... -0,96) and during full ripeness and harvest (II ten-day period of July, r = -0,72 ... -0,95). The influence of other ten-day temperatures and precipitation on the formation of high protein and gluten content in grain is small.

CONCLUSION

The limiting environmental factor for the cultivation of winter wheat in the Central Black Earth Region is drought, the manifestation of which in our experiment was observed in three years out of five. At the same time, drought conditions can occur both in the fall and spring and summer periods of the growing season. Genome of the variety Chernozemka 130 most effectively used the prevailing weather conditions to realize the productivity potential.

The temperature conditions of the II ten-day period of April (renewal of the spring vegetation), II and III ten-day periods of May (phases of booting and earing), as well as III ten-day period of June (grain filling) are key for yield formation in local conditions. Higher temperatures in these ten-day periods compared to the long-term average lead to lower yields.

Yield increases as compared to the long-term average due to more precipitation in the second ten-day period of April, the second ten-day period of May and the first ten-day period of June (grain formation), and decreases due to abundant precipitation in the first and third ten-day periods of May, II and III ten-day periods of June and I ten-day period of July (milk-ripening and waxing ripeness).

Higher temperatures of II ten-day periods of April, II and III ten-day periods of May, III ten-day period of June and II ten-day period of July (full ripeness) contribute to an increase in grain protein and gluten content. At the same time, a negative correlation with higher temperatures of III ten-day period of April and I ten-day period of May is observed. An increase in protein and gluten content in grains is observed with an increase in precipitation in the I and III ten-day periods of May, III ten-day period of June and I ten-day period of July, and a decrease - with an increase in precipitation in the II ten-day period of May and II ten-day period of July.

Quantitative values of correlation coefficients in varieties within the same month or ten-day period have differences in magnitude, but, as a rule, they are not large and are within one group of dependence - strong, medium or weak.

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СЕЛЕКЦИОННАЯ ОЦЕНКА ЧЕРНОЙ СМОРОДИНЫ ПО ПРИЗНАКУ ГАБИТУС КУСТА

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Представлены результаты фенотипической оценки генетической коллекции черной смородины, отборных форм, инбредного и гибридного потомства по признаку габитус куста. Изучена возможность использования перспективных генотипов для получения потомства с оптимальным типом кроны. Исследования проведены в 2017–2021 гг. в условиях Брянской области на участках генетической коллекции, конкурсного изучения отборных форм, гибридного фонда черной смородины. Возделывание смородины черной в коллекционных посадках и на гибридном участке проводили в соответствии с общепринятой в Нечерноземной зоне России агротехникой. Погодные условия Брянской области типичны для Центрального региона России, климат умеренно континентальный. Проведена дифференциация сортов и отборных форм по форме кроны растений. Выполнен гибридологический анализ наследования признака габитус куста на примере девяти семей от контролируемых скрещиваний, трех популяций от самоопыления различных по форме куста генотипов и трех – от свободного опыления перспективных генотипов черной смородины. Установлены сорта, соответствующие отдельным параметрам комбайновой технологии уборки ягод по признакам габитус куста, ширина основания, высота растений. К ним относятся сорта Литвиновская, Миф, Рита, Кудесник, Кудмиг, Ben Hope, Нежданчик, Подарок Астахова, Тамерлан, Tiben, Этюд, Чернавка и другие, а также ряд перспективных гибридов – 4-94-1, 3-80-01, 4-5-2, 4-19-04, 62-03-7 и др. Фенотипическая оценка потомства черной смородины показала, что проявление признака габитус куста имеет существенную зависимость от типа кроны генотипов, задействованных в селекционной работе.

Ключевые слова: черная смородина, машинная уборка, технология возделывания, селекция, габитус куста, гибриды

BREEDING EVALUATION OF BLACK CURRANT ON THE BASIS OF SHRUB HABITUS

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Results of phenotypic evaluation of black currant genetic collection, selected forms, inbred and hybrid progeny by shrub habitus are presented. The possibility of using promising genotypes to produce the progeny with an optimal type of crowns was studied. Studies were conducted in 2017-2021 in the conditions of the Bryansk region in the plots of the genetic collection, competitive study of selected forms, and hybrid black currant stock. The cultivation of black currants in the collection plantations and on the hybrid plot was carried out in accordance with the common in the Non-Black Earth Zone of Russia agro-technique. The weather conditions of the Bryansk region are typical for the Central region of Russia, the climate is moderately continental. Differentiation of varieties and selected forms by crown shape of plants was carried out. Hybridological analysis of inheritance of shrub habitus trait on the example of nine families from controlled crosses, three populations from self-pollination of genotypes different in shrub shape and three - from free pollination of promising black currant genotypes was performed. Varieties corresponding to the individual parameters of combine berry harvesting technology in terms of shrub habitus, base width, plant height were identified. These include the varieties Litvinovskaya, Myth, Rita, Kudesnik, Kudmig, Ben Hope,

Nezhdanchik, Podarok Astakhova, Tamerlan, Tiben, Etyud, Chernavka and others, as well as a number of promising hybrids - 4-94-1, 3-80-01, 4-5-2, 4-19-04, 62-03-7, etc. The phenotypic evaluation of black currant progeny showed that the manifestation of the shrub habitus trait has a significant dependence on the crown type of the genotypes involved in the breeding work.

Keywords: black currant, machine harvesting, cultivation technology, selection, shrub habitus, hybrids

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Conflict of interest

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INTRODUCTION

Among berry shrubs black currant is a recognized success and has wide prospects in homestead and industrial gardening. Its obvious advantages are associated with unpretentiousness to the growing conditions, winter hardiness, rapid onset of fruiting and high yield, the possibility of full mechanization of most technological operations and harvesting [1-3]. The special value of black currant is due to the high level of accumulation of biologically active substances in berries and processed products, the combination of vitamin C and P-active substances, macro- and microelements contained in them, dessert taste of some varieties and availability to the consumer [4, 5].

To date, significant progress has been made in improving the assortment of the crop. Most modern black currant varieties are derivatives - recombinants of wild species in the 3rd-5th generation, which allows selecting large-fruited and productive genotypes in the progeny. Due to the painstaking work of researchers, new high-yield varieties with valuable qualities, suitable for intensive technology of cultivation, such as Kipiana, Myth, Kudesnik, Litvinovskaya, Yadrenaya 2, Tamerlan, Shaman, Ceres, Black Magic Karbon, Ben Sarek, etc. were created. [6-8].

In connection with the creation of technological varieties, N.I. Vavilov pointed out back in 1932 that whatever crop to be taken, for each of them the coming mechanization puts its own specific requirements for the creation of plant types corresponding to mechanized harvesting. Fulfillment of these requirements is the actual task of breeders and geneticists. The creation of berry crop varieties suitable for machine harvesting is one of the priority areas of modern breeding programs [9, 10]. For currants, the possibility of mechanized cultivation is associated with such indicators as an upright and compact bush type with moderate height shoots, short internodes, with strong branches that do not droop under the weight of the harvest, a small number of skeletal branches, dense bush base, concentration of the main yield in the upper part of the crown, etc. [11].

Studies on the improvement of bush habitus were carried out in different institutions and achieved certain success. Thus, according to the breeding program of East Malling Experimental Station, a tall and erect North American species Californian black currant (*Ribes bracteosum* Douge.) and a hybrid form between representatives of the black currant subgenus *R. nigrum* Douge. and *R. bracteosum* L. Brownish currant *R. fuscescens* Jancz were used in the selection for uprightness [12]. In crosses of brownish currant with a representative of Scandinavian subspecies of black currant (spp. *scandinavicum*) Brödtorp variety, a relatively upright variety Jet was obtained [13]. An outstanding donor of upright and compact bush habit is the Western European variety Goliath, in the progeny of which there is a large proportion of seedlings with the same parameters when crossed with the Baldwin, Seabrooks Black, French Black, Boskopian giant varieties [14]. In Germany (Max Planck Institute), X-ray irradiation of cuttings of Westwick Choise variety resulted in Westra variety with very compact type of bush, upright stiff branches, which transmits similar architectonics to its hybrids[1].

Attempts to create new forms of currant with a given structure and bush structure were also made by domestic researchers. According to A.S. Ravkin [15], erectness and compactness are the features peculiar to different subspecies of black currant species. They can be found with a sufficient degree of expression united in one plant in the forms of European subspecies and Californian black currant, as well as in crossing the forms of European and Siberian subspecies.

Crossing between *R. fuscescens* and the relatively low-growing varieties Goliath and Kent (Baldwin) proved to be successful. This is how the variety Vysokaya[2] was created. Among the progeny of the variety Memory of Michurin, obtained by pollination with its pollen harvested from the plants irradiated in the gamma field, the variety Compact dwarf, characterized by compactness and erectness, was isolated [15]. In the Moscow area, a very compact seedling named Vertical, forming a compressed bush with upright shoots without branching and good yield, was selected in the offspring of the Westra variety [16].

The pioneering research of Michurin Federal Research Center scientists, which began in the late 80's of the last century, formed the basis of modern industrial technology of black currant cultivation using a specialized set of machines, including combine harvester method of harvesting. The requirements for the varieties corresponding to the parameters of machinery operation during harvesting were studied and presented [17]. It was found that the variety corresponding to the working conditions of berry-harvesting machinery determines its performance and the proportion of yield losses [18].

The use of berry harvesters in view of the scarcity of human resources for manual harvesting is a fundamental principle in expanding the marketable area of black currant. However, an upright bush with a good crop load often acquires a semi-spreading, spreading and even creeping habitus. In genotypes with a spreading type of bush, the branches are almost creeping position, in which case mechanized harvesting is difficult. It has been found that the most suitable bush shape for industrial use is from erect to semi-spreading [11]. Varieties with a height of 1.2-1.8 m are suitable for mechanized harvesting, since weakly grown and excessively tall plants interfere with the effective work of machines. Plants with a wide bush base are also unacceptable: the working bodies of berry harvesting equipment, especially in the presence of lodged branches of more than 5%, significantly traumatize the shoots. It is established that the width of plant base should not exceed 0.3 m [19]. The purpose of the study is to study the collection of black currant varieties of the the Kokino base station of the Federal Horticultural Center for

[1]Knyazev S.D., Pikunova A.V., Bakhotskaya A.Y., Shavyrkina M.A., Chekalin E.I. Innovative directions of breeding research of black currant. Breeding and varietal development of garden crops: collection of scientific works: ed. by E.N. Sedov. Orel: VNIISPK, 2014. pp. 192-211.

[2]Semenchenko P.P. Introduction of berry bushes in Moldova. Kishinev, 1979. 112 p.

Breeding, Agrotechnology and Nursery on the basis of bush habitus to analyze the character of inheritance in the progeny of crown shape and selection of promising initial forms for breeding on the technology of cultivation and harvesting.

MATERIAL AND METHODS

The study of black currant bush habitus was carried out in the collection and breeding garden of the Kokino base station (the Bryansk region) from 2017 to 2021 on plants 4-5 years old. The object of research was 90 varieties of black currant, 21 selected forms, progeny of nine combinations of crosses, three inbred populations and three - from free pollination. Linear characteristics of bushes in collection plantings were studied in triplicate, with at least five plants of each variety in each replication. Plants in hybrid families were studied by every bush, i.e. each individually. The degree of dominance of the crown compactness trait in the F1 population and the frequency of heterosis seedlings pulling out in the families according to the generally accepted method of breeding[3] were studied during the hybridological analysis with respect to quantitative traits.

Black currant bush shape was evaluated on a five-point scale according to the method of Michurin Federal Research Center (see Fig. 1)[4]. Cultivation of black currant in the collection plantations and on the hybrid plot was carried out in accordance with the generally accepted agrotechnics in the Non-Black Earth Zone of Russia. Weather conditions of the Bryansk region are typical for the Central region of Russia, the climate is moderately continental, characterized by moderately cold winter, warm summer and uneven distribution of precipitation.

RESULTS AND DISCUSSION

An important direction in black currant breeding is to increase the manufacturability of new varieties, namely, the possibility of mechanization of agrotechnical operations of cultivation and harvesting. This is achieved due to a certain architectonics of plants, a small bush base (0,3-0,4 m in diameter) due to 6-8 branches of zero order, thin and medium-

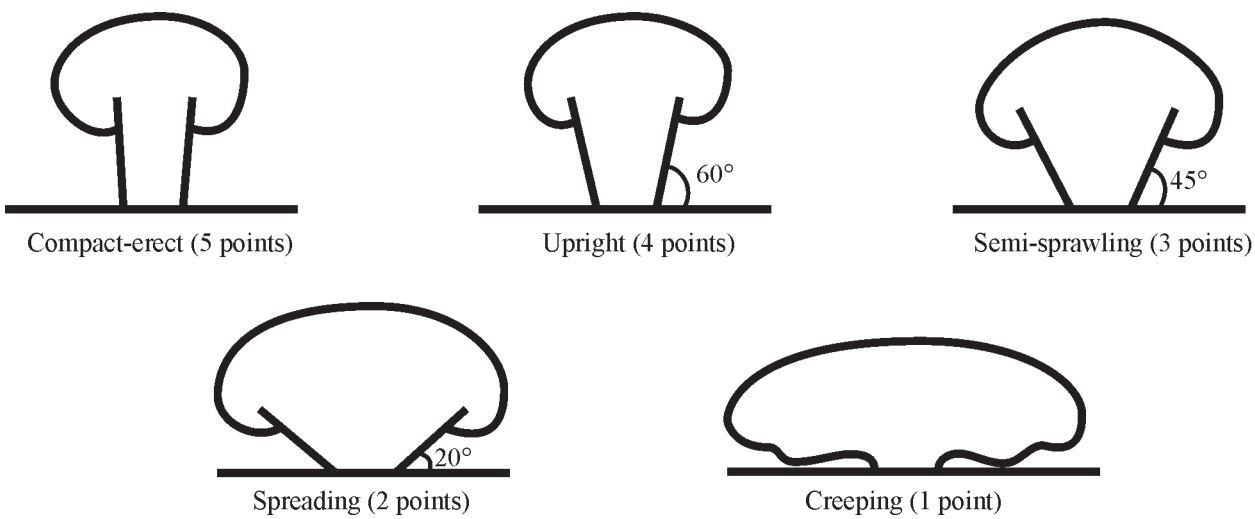

Рис. 1. Шкала для оценки формы кроны смородины черной

Fig. 1. Scale for assessing the shape of black currant crowns

[3] Kichina V.V., Ogoltsova T.P., Saveliev N.I., Zubov A.A. Genetic basis of breeding. Program and methods of breeding of fruit, berry and nut crops, ed. by E.N. Sedov. Orel: VNIISPK Publishing House, 1995. pp. 5-25.

[4] Yakimenko O.F., Novopokrovsky V.S. Evaluation and selection of black currant varieties for machine harvesting: methodical recommendations. Michurinsk, 1988. 17 p.

growing plants, concentration of harvest in the upper part and peripheral zone of the crown, simultaneous ripening of fruits with a strong peel at dry detachment, etc.

Part of the difficulty in cultivating high-yield varieties is that most of them are not able to withstand the load during the harvest seasons. Often the branches droop to such an extent that machine harvesting is virtually impossible. The best habitus of black currant plants will be an upright and compactly upright bush structure. With such an architectonics, the plants acquire a semi-sprawling habit under high crop load. This facilitates manual and mechanized harvesting of fruits and allows the plants to be placed quite densely.

For blackcurrant in machine harvesting, it is considered optimal to have a bush habit from a spreading to an upright shape. The creeping type of bush and the presence of lodged branches inevitably leads to the ingress of soil and associated debris into the berry pile, and also increases the injury of the branches. However, there is no final opinion on the habitus of the bush and the question remains open, which is due to the wide choice of berry harvesters and their design features.

Evaluation of varieties and selections of black currant on the basis of bush habitus made it possible to differentiate them into groups. The most creeping shape of the crown (1 point) at full harvest load is characteristic of dikusha currant derivatives - varieties Degtyarevskaya, Memory of Potapenko, Globus and Annadi. Varieties Klussonovskaya and Dar Smolyaninovoj are referred to the same group. The next group of plants with sprawling bush habit (2 points) is the most numerous. It includes the varieties Belorusochka, Bagira, Iskushenie, Minusinskaya sladkaya, Dachnitsa, Kupalinka, Glarioza, Dobry Jin, Galaxy, Shalunya, Orlovia, Zelenaya dymka, Black Pearl, Chereshneva, Nympha, Kazkova, Orlovsky waltz, Lentyaj, Sharovidnaya, Partizanka Bryanskaya, Slavyanka, Memory of Vavilov, Chudnoe mgnovenie, Svyatyazanka, Little Prince, Mriya, Monisto, Mriya-3, Krynichka, Yadrenaya, Pygmey, Mriya-5, Chelyabinskaya, Trilena, Uslada, Ben Alder. Moreover, many of these varieties in the first years of growth, the bush habit is more often medium spreading, and with the increasing load on the fruit-bearing shoots the bush acquires a spreading shape.

One of the best types of crowns is semi-spreading (3 points on the shape of the bush). Plants of this habit form varieties Debryansk, Kaskad, Kudesnik, Dobrynya, Sudarushka, Strelets, Amethyst, Gift of Kalinin, Gulliver, Selechenskaya 2, Memory of Bredova, Sevchanka, Myth, Memory of Ravkin, Charodey, Nezhdanchik, Kudmig, Orlovskaya serenada, Sanyuta, Chernavka, Zaglyadenie, Tamerlan, Etude, Black Magic, Ben Sarek and selections 42-5-1/05 (Grazia × Monisto), 13-51-1 (Shalunya, free pollination), 62-03-7 (Venus × Barmaley), 33-27-1 (Sagittarius × Celechenskaya 2). Straight-growing habit of plants with a bush shape of 4 points is formed by the varieties Golubichka, Nightingale Night, Litvinovskaya, Lama, Delicates, Izjumnaya, Vera, Selechenskaya, Barmaley, Zusha, Astakhov Gift, Bryansk agate, Triton, Tisel, Gift to Veterans, Nadina, Ben Tirran, Rita, Ben Hope, Big Ben, Tiben and selected forms 3-80-01 (7-49-3 I1), 5-57-01 (Sagittarius × Mriya), 10-141-2, 4-63-4 (Strelets × Golubichka), 3-37-26/02 (Dobrynia × Venus), 4-5-2 (SK-7 × Exotica), 4-16-09 4-94-1 (10-141-2 × Partizanka Bryanskaya), 11-115-02 (Tamerlan × Bryansk agate), 9-5-01, 43-39-12/05 (Orlovskaya serenada, free pollination), 36-27-4/05 (Debryansk, free pollination).

Compact- erect habit is much less common in fruit-bearing black currant plants, and such habit is observed only in the variety Vertical. From the hybrid stock quite productive forms (2.2-2.5 kg / bush) with compact- erect crown shape (5 points) were selected: 4-19-04 (Mriya × Litvinovskaya), 12-117-01 (Ben Tirran I1), 11-141-01 (Ben Tirran, open pollination), 2-28-01 (Tisel, open pollination), 3-30-4 (Gift of Kalinin, open pollination). There is a high probability that their use in further breeding work will make it possible to select high-yielding forms with semi-spreading and upright bush habit, which will reduce the proportion of lodged branches at the maximum yield load.

In the studies conducted earlier by V.S.

Novopokrovsky[5] and O.V. Danshina[6] when studying the trait of bush habitus, it was found that in hybrid progeny of black currant the spreading form of plants is dominant and the segregation of erect seedlings is possible only if the original forms with erect bush habitus participate in hybridization. Our phenotypic evaluation of hybrid and inbred progeny showed that crown type of most seedlings corresponded to the trait level of the original forms. Thus, in the family Dar Smolyaninovoj × Sharovidnaya, where the original forms are characterized by the creeping and spreading crown forms, the prevailing part of the progeny did not differ from their parents in the architectonics of the bush. Or, for example, in the Kudesnik × Litvinovskaya family with semi-spreading and erect bush habitus of the parents, the crown shape of the studied progeny did not exceed their parameters. Such correspondence between the crown structure of parents and the progeny is not always observed. In spite of the fact that specimens with compact erect habitus were not used as parents, in some populations a small proportion of seedlings with crown shape of the bush of 5 points were identified. For example, in families Strelets × Golubichka, Strelets × Litvinovskaya, Myth × Litvinovskaya and in the progeny from free pollination of upright varieties Ben Tirran and Tisel, from 1.6 to 7.9% of compact upright hybrids were selected (see Fig. 2). This is due to the fact that a form with erect crown type was involved as one of the parents. Thus, the study of black currant progeny by plant architectonics indicates a direct dependence of the manifestation of this trait on the original genotypes involved in the breeding.

Assessment of the degree of dominance of the bush habitus trait in the progenies of Tamerlan × Kudesnik, Dar Smolyaninovoj × Sharovidnaya, Strelets × Selechenskaya 2 families revealed the same bush structure of parents and hybrids (Hp = 0) (see the table). In families Tamerlan × Kudesnik and Strelets × Selechenskaya 2 the highest yield of transgressive seedlings was observed: Tch = 8.5 and 10.8%, respectively, while none of the parents was characterized by compact crowns. This only confirms the polygenic character of inheritance of the bush habitus trait and explains its significant variation within hybrid and inbred populations.

In the combinations Strelets × Mriya, Strelets × Litvinovskaya, Kudesnik × Litvinovskaya there is a deviation of progeny towards the better crown shape of the original form (Hp = +0.2...+0.8). In the family Debryansk × Litvinovskaya a depression in inheritance of the optimal crown shape (Hp = -1.4) was established. Transgressive seedlings were identified among the studied progeny from self-pollination. In the inbred progeny of the variety Chereshneva with a spreading crown of the bush, 8.2% of semi-spreading seedlings were observed.

Lodged branches are lifted by the berry harvesters, oriented along the row, or broken out. The number of lodged branches in mechanized harvesting should not exceed 5%. In the varieties Bagheera, Slavyanka, Kupalinka, Dar Smolyaninovoj, Kazkova, Klussonovskaya, Dyagterevskaya the amount of peripheral lodged branches at maturity of the crop was more than 5% and ranged from 5.9-12.5%. Such varieties need additional pruning of bushes when preparing them for combine harvesting.

The model of industrial variety developed for black currant provides for the optimal parameters of bush height in the range of 1.2-1.8 m [20]. As a result of collection evaluation of phenotypic manifestation of the trait "plant height", it was found that the group of low-growing (bush height up to 1.2 m) are the varieties Bagira, Svyatyazanka, Degtyarevskaya, Slavyanka, Mriya, Dobrynya, Shalunya, Nympha, Dachnitsa, Izium, Kazkova, Pygmy, Kupalinka, Mriya-3, Sanyuta, Chereshneva. Quite a high

[5]Novopokrovsky V.S. Analysis of black currant hybrids in terms of bush habitus and berry strength in connection with mechanized harvesting. Selection and variety study of berry crops: Collection of scientific works of Michurin All-Russian Institute of Gardening. Michurinsk, 1987. pp. 75-78.

[6] Danshina O.V. Breeding evaluation of black currant forms for suitability for machine harvesting: Ph. D. in Agricultural Sciences thesis: Kokino, 2017. 167 p.

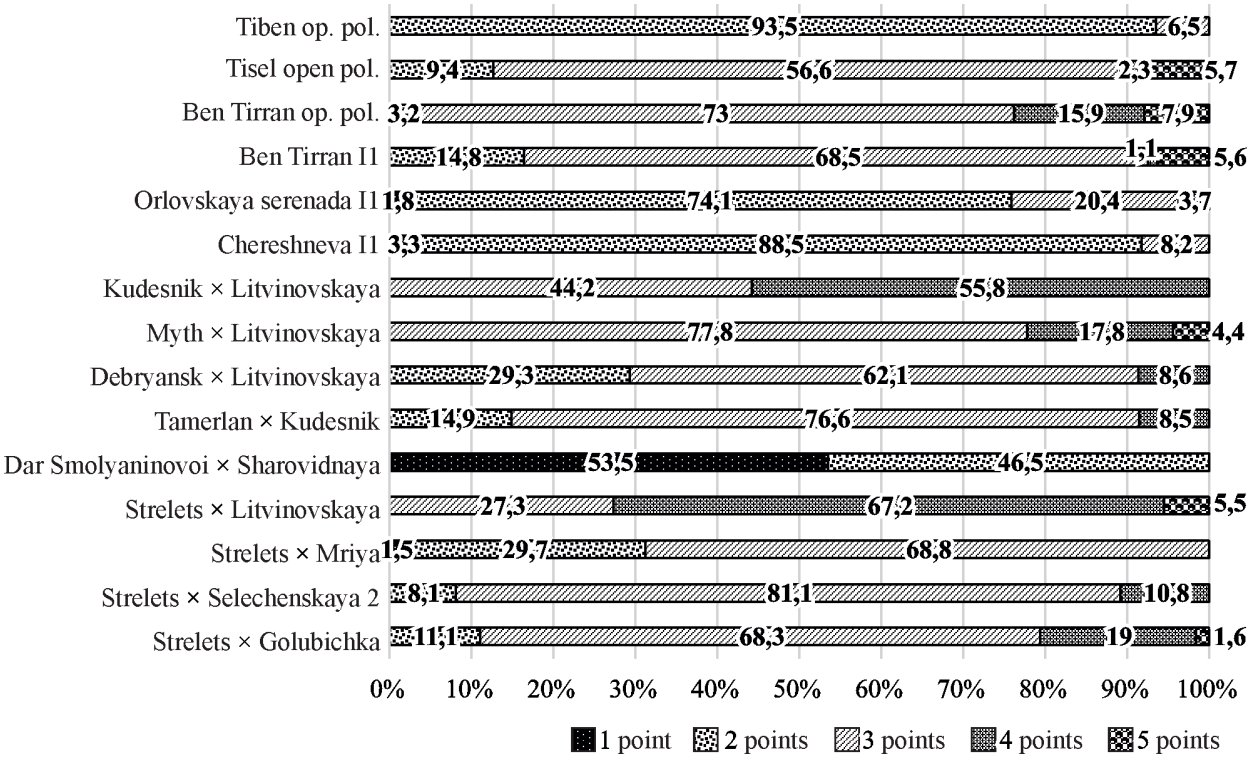

Рис. 2. Расщепление потомства смородины черной по типу компактности куста

Fig. 2. Black currant progeny splitting by type of shrub compactness

Оценка потомства смородины черной по выходу трансгрессивных сеянцев (Тч, %) и степени доминирования (Нр) в гибридных и инбредных популяциях по признаку габитус куста
Evaluation of black currant progeny by the yield of transgressive seedlings (Frequency of transgressions Ft, %) and the degree of dominance (Hp) in hybrid and inbred populations according to shrub habitus

Initial varieties		Seedlings studied, pcs.	Crown shape, grade			Tch, %	Hp
♀	♂		♀	♂	F_1		
Strelets	Golubichka	63	3,0	4,0	3,1	1,6	-0,8
	Selechenskaya 2	37	3,0	3,0	3,0	10,8	0
	Mriya	64	3,0	2,0	2,7	0	+0,4
	Litvinovskaya	55	3,0	4,0	3,9	5,5	+0,8
Dar Smolyaninovoi	Sharovidnaya	43	1,0	2,0	1,5	0	0
Tamerlan	Kudesnik	47	3,0	3,0	2,9	8,5	0
Debryansk	Litvinovskaya	58	3,0	4,0	2,8	0	-1,4
Myth		45	3,0	4,0	3,3	4,4	-0,4
Kudesnik		43	3,0	4,0	3,6	0	+0,2
Chereshneva	Chereshneva	61	2,0	2,0	2,1	8,2	0
Orlovskaya serenada	Orlovskaya serenada	54	3,0	3,0	2,3	3,7	0
Ben Tirran	Ben Tirran	54	4,0	4,0	3,1	5,6	0
Ben Tirran, open pollination		63	4,0	–	3,3	7,9	–
Tisel, open pollination		53	4,0	–	3,3	–	–
Tiben, open pollination		77	4,0	–	2,1	–	–

bush, about 1.9 m, form the varieties Delicates, Chudnoe mgnovenie, Amethyst, Monisto, Trilena, Minusinskaya sladkaya, Memory of Bredova, Gulliver, Memory of Vavilov, Sofievskaya, Selechenskaya, Chelyabinskaya, Triton, which exceeds the optimal threshold on this feature for the use of berry harvester and requires additional costs for plantation pruning. The height of plants of other varieties and selected forms, which we studied in this study (a total of 110 genotypes), is in the range of 1.2-1.8 m, which corresponds to the parameters of the work of mechanisms during harvesting.

To reduce losses of blackcurrant berries, it is necessary to estimate the width of the plant base, which should not exceed 0.3 m. Such a requirement is dictated by the design features of modern berry-harvesting equipment, because the wide base of bushes in conjunction with lodged shoots reduce the working area of picking devices and increase crop losses.

A wide bush base (0.35 to 0.50 m) is typical for such varieties as Amethyst, Izjumnaya, Gulliver, Slavyanka, Klussonovskaya, Kazkova, Krynichka, Trilena, Degtyarevskaya, Dar Smolyaninovoj, Chudnoe mgnovenie, Minusinskaya sladkaya. Their use in the technology with machine harvesting is possible only with additional operations on the preparation of plantations (forming pruning). Otherwise, harvesting is accompanied by significant damage to the plants.

The base of the bush in the varieties Kupalinka, Litvinovskaya, Tamerlan, Zusha, Podarok Astakhova, Dobrynya, Orlovskaya Serenada, Nezhdanchik, Ben Hope, Triton, Podarok to Veterans, Tisel, Lama, Partizanka Bryanskaya, Kudesnik, Myth, Tiben, Tyazanka, Etude, Bagira, Charodei, Chernavka, Pygmey, Little Prince, Shalunya, Selechenskaya 2, Rita, Green Haze, Sharovidnaya, Glarioza, Kudmig, Chereshneva and forms 42-5-1/05, 4-94-1, 3-80-01, 4-19-04, 62-03-7, 9-5-01, 43-39-12/05, 36-27-4/05, 4-5-2, 5-57-01, 21-25-1/05, 33-27-1, 7-49-3, 4-63-4, 3-37-26/02 averaged from 0.2 to 0.3 m, which corresponds to the requirements for currant plants in combine harvesting. Narrow bush base (up to 0.15 m) was noted in the varieties Sudarushka, Dachnitsa, Mriya.

CONCLUSION

Manifestation of the trait of bush habitus in the studied populations of black currant is largely due to genotypic differences in the original forms. The varieties Myth, Litvinovskaya, Tamerlan, Zusha, Gift of Astakhov, Nezhdanchik, Orlovskaya serenada, Ben Hope, Gift to veterans, Tisel, Kudesnik, Tiben, Etude, Charodey, Chernavka, Selechenskaya 2, Rita, Kudmig and selections 42-5-1/05, 4-94-1, 3-80-01, 4-19-04, 62-03-7, 9-5-01, 36-27-4/05, 4-5-2, 5-57-01, 21-25-1/05, 33-27-1, 7-49-3, 4-63-4, 43-39-12/05, 3-37-26/02 are promising for breeding as sources of the studied trait, taking into account the shape of the crown, plant height, base width. The presented genotypes meet the requirements of suitability for combine harvesting. Using them in further crosses will allow us to conduct breeding work on the technology of varieties at a qualitatively new level.

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ИНФОРМАЦИЯ ОБ АВТОРЕ

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УСТОЙЧИВОСТЬ СОРТОВ ОЗИМОЙ ПШЕНИЦЫ К ВОЗБУДИТЕЛЯМ БОЛЕЗНЕЙ В УСЛОВИЯХ СТЕПНОЙ ЗОНЫ КАБАРДИНО-БАЛКАРСКОЙ РЕСПУБЛИКИ

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Представлены результаты исследований (2019–2021 гг.) видового состава комплекса болезней в условиях степной засушливой зоны Кабардино-Балкарии, которые имеют научную и практическую значимость для определения степени устойчивости изучаемых сортов озимой пшеницы к фитопатогенам. Проведен фитосанитарный мониторинг на 10 районированных сортах озимой пшеницы. Выделены болезни и их возбудители: пиренофороз (*Pyrenophora tritici-repentis (Died.)*), септориоз (*Septoria tritici Rob. et Desm.*), мучнистая роса (*Erysiphe graminis DC. f. sp. tritici Em. Marchal*), бурая и желтая ржавчины (*Puccinia recondite Rob. et Desm. f. sp. tritici; P. striiformis West*), твердая головня (*Tilletia tritici (Bjerk*) *Wint*), фузариоз (*Fusarium graminearum Schw*) и черный зародыш (*Alternaria tenuis Ness et Fr.; Cladosporium herbarum Fris.*). По результатам анализа цифровых данных пораженности не выявлено потенциально толерантных сортов озимой пшеницы к возбудителям указанных заболеваний из-за агрессивности существующих штаммов *P. tritici-repentis (Died.), A. tenuis Ness et Fr., C. herbarum Fris.* Все испытанные сорта озимой пшеницы выносливы к возбудителям септориоза, видов ржавчин, твердой головни, но восприимчивы к возбудителям пиренофороза и черного зародыша. Средневзвешенный процент пораженности листьев пиренофорозом составил от 20,5 до 59,6%. Самыми устойчивыми к данному заболеванию оказались сорта Памяти Шатилова и Чегет, а восприимчивыми – сорта Лауреат, Корона, Граф, Москвич и Таня, у которых средневзвешенный процент пораженности был выше 46,7%. Исследовано вредоносное заболевание черный зародыш, который проявляется в период молочно-восковой спелости зерна. Средневзвешенный процент пораженности от данной болезни был выше 50% на сортах Алиевич, Таулан, Таня, Москвич, Граф. Максимальный процент пораженности зерна на сорте Чегет составил 60,2%. Фузариоз колоса отмечен в депрессивном состоянии, так как в период формирования зерна устанавливается сухая и жаркая погода. Благоприятным условием для развития данного заболевания является дождливая погода.

Ключевые слова: озимая пшеница, сорт, возбудитель, фитопатокомплекс, вредоносность, устойчивость, восприимчивость

RESISTANCE OF WINTER WHEAT VARIETIES TO PATHOGENS IN THE CONDITIONS OF THE STEPPE ZONE OF THE KABARDINO-BALKAR REPUBLIC

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Results of the studies (2019-2021) of species composition of the disease complex under conditions of steppe arid zone of Kabardino-Balkaria are presented, which have scientific and practical significance for determining the degree of resistance of winter wheat varieties under study to phytopathogens. Phytosanitary monitoring was conducted on 10 released varieties of winter wheat. The following

diseases and their pathogens were identified: pyrenophorosis (*Pyrenophora tritici-repentis (Died.)*), septoriosis (*Septoria tritici Rob. et Desm.*), powdery mildew (*Erysiphe graminis DC. f. sp.tritici Em. Marchal*), brown and yellow rusts (*Puccinia recondite Rob. et Desm.f.sp.tritici; P. striiformis West*), head smut (*Tilletia tritici (Bjerk) Wint*), fusarium blight (*Fusarium graminearum Schw.*) and glume mold (*Alternaria tenuis Ness et Fr.; Cladosporium herbarum Fris.*). According to the results of the analysis of digital lesion data, no potentially tolerant winter wheat varieties to the pathogens of these diseases were identified due to the aggressiveness of the existing strains of *P. tritici-repentis (Died.), A. tenuis Ness et Fr., C. herbarum Fris.* All tested varieties of winter wheat are resistant to the causative agents of septoriosis, rusts, head smut, but are susceptible to the causative agents of pyrenophorosis and glume mold. The average weighted percentage of leaf infestation with pyrenophorosis ranged from 20.5 to 59.6%. The most resistant to this disease were the varieties Memory of Shatilov and Cheget, and the susceptible varieties were Laureate, Korona, Graf, Moskvich and Tanya, in which the weighted average percentage of the disease was above 46.7%. The malignant disease glume mold, which manifests itself in the period of milky-wax ripeness of grain, was studied. The average weighted percentage of lesions from this disease was higher than 50% in varieties Alievich, Taulan, Tanya, Moskvich, Graf. The maximum percentage of grain infestation in the variety Cheget was 60.2%. Fusarium head blight was noted to be depressed as dry and hot weather set in during the period of grain formation. Rainy weather is a favorable condition for the development of this disease.

Keywords: winter wheat, variety, pathogen, phytopathocomplex, harmfulness, resistance, susceptibility

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INTRODUCTION

Creation and manufacturing application of new more productive complex-valuable varieties of winter cereal crops are among the most highly effective and economically most profitable ways to increase the yield and control diseases and pests [1]. Winter wheat crops are susceptible to phytopathocomplexes, among which the most economically significant are pyrenophorosis (causative agent *P. tritici-repentis (Died.) Drechsler*) and glume mold disease (causative agents *A. tenuis Ness et Fr.; C. herbarum Fris.*). These diseases are harmful not only in the Kabardino-Balkar Republic, but also in the south of Russia and all over the world where winter wheat is produced [2-5].

According to studies by many scientists, winter wheat yield losses during the mass spread and maximum development of diseases can be up to 40% [6]. Tolerance of sown winter wheat varieties to progressive diseases is one of the important factors in obtaining a stable grain yield. Therefore, breeding and genetic method is economically justified, and safer to protect wheat from pathocomplex and the environment. In this regard, regular phytosanitary monitoring of experimental crops of different varieties of winter wheat for infection load is necessary.

The Institute of Agriculture of the Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences (Institute of Agriculture, KBSC RAS) carries out annual phytosanitary monitoring to study resistance of released and promising varieties to the most harmful diseases of winter wheat.

The purpose of the research is to study the species composition of pathogens in wheat agrocenosis in the steppe zone of the Kabardino-Balkar Republic. This will make it possible to further develop the elements of a biological

system of integrated protection of winter wheat crops.

The relevance of the research is to identify progressive diseases of winter wheat which annually cause significant damage to grain yield.

The main objectives of the conducted research work are to determine the species composition of pathogens on experimental crops of different varieties of winter wheat, to study the harmfulness based on the data obtained, to identify relatively hardy varieties to the dominant pathogens of pyrenophoresis and glume mold disease.

MATERIAL AND METHODS

Trial establishment was performed according to the methods[1] [7, 8]. Disease prevalence in experimental winter wheat crops was determined as a weighted average taking into account the affected plants and the surveyed area according to the formula

$P_c = \Sigma SP/\Sigma S$,

where P_c is the weighted average prevalence of the disease, %; ΣSP is the sum of the products of the field area (in hectares) by the corresponding prevalence percentage; ΣS is the total amount of the examined area (in hectares) [9]. The resistance of the winter wheat varieties under study was determined by the following sources[2] [10, 11].

Differentiation of winter wheat samples according to their resistance to winter wheat diseases was carried out according to the following sequence: 1 - resistant sample (number of susceptible plants in the population up to 10%); 2 - slightly susceptible (10 to 40%); 3 - moderately susceptible (40 to 65%); 4 - highly susceptible (65 to 100%).

Research and production tests were conducted in the steppe zone of the Kabardino-Balkar Republic on crops of winter wheat varieties: Yuzhanka, Cheget, Alievich, Memory of Shatilov, Taulan, Tanya, Moskvich, Graf, Korona, and Laureate. The soil of the experimental plots is southern chernozem, located in a relatively narrow strip between ordinary chernozems and dark-chestnut soils. Southern chernozems are characterized by low humus content in the horizon (A 3.5-5.0%) and gradual distribution along the soil profile. These soils are mainly intensively used for the cultivation of grain crops, sunflower, corn for grain and silage [12].

RESULTS AND DISCUSSION

In 2019-2021, phytosanitary monitoring of diseases of five varieties of winter wheat selected by the Lukyanenko National Grain Center, joint and own selection of the Institute of Agriculture KBSC RAS was conducted on the seeds of ecological variety trials of grain crops: Yuzhanka, Cheget, Taulan, Alievich, Memory of Shatilov. he varieties Tanya, Moskvich, Graf, Korona, Laureate are among those recommended by the regional commission on the formation of proposals for changes in the State Register of breeding achievements, approved for use varieties and hybrids of crops in the Kabardino-Balkarian Republic (see the table).

According to long-term observations of 10 winter wheat varieties under study, the diseases were detected sporadically. Pyrenophorosis (*P. tritici-repentis (Died.)*) with the maximum distribution of 100% is the progressive disease in varieties Cheget and Korona. The mentioned varieties have expressed resistance to rust diseases (*Puccinia striiformis West.; Puccinia recondite Rob. et Desm. f. sp. tritici*), to fusarium head blight (*Fusarium spp*.) and septoriosis of leaves (*Septoria tritici Rob. et Desm.*). Powdery mildew (*Erysiphe graminis DC.)* has monocyclic type of development, clestothecia are formed early and leave for wintering at the end of April. During milky-wax ripeness, "glume mold" is widespread in all wheat varieties under study and its main causative agents are *A. tenuis Ness et Fr.; C. herbarum Fris*.

Phytosanitary monitoring for detection of phytopathocomplex on experimental crops of winter wheat was carried out during the last years. As a result of observations, 28 pathogens

[1] Usmanov R.R., Khokhlov N.F. Experimental methods (with calculations in Excel), practical work: Moscow, RSAU – MTAA named after K.A. Timiryazev. 2020. pp. 46-49.

[2] Radchenko E.E., Krivchenko V.I., Solodukhina O.V. et al. Study of genetic resources of cereal crops on resistance to pests: Manual, Moscow, 2008. pp. 5-1.

Определение восприимчивости изучаемых сортов озимой пшеницы к возбудителям болезней (степная зона Кабардино-Балкарской Республики, 2019–2021 гг.)
Determination of the susceptibility of the studied varieties of winter wheat to pathogens (Kabardino-Balkar Republic steppe zone, 2019–2021)

S No.	Variety name	Weighted average disease prevalence rate							
		P. tritici-repentis	*S. tritici*	*E. graminis*	*P. striiformis*	*P. recondite*	*T. caries*	*A. tenuis*	*Fusarium spp.*
1	Yuzhanka	31,4	20,4	22,6	19,6	17,2	1,8	48,4	1,1
2	Cheget	28,2	26,5	32,3	24,7	23,6	1,7	60,2	0,8
3	Alievich	41,2	31,0	27,6	23,2	28,6	1,4	51,8	0,6
4	In Memory of Shatilov	20,5	15,2	18,5	19,1	15,7	1,1	43,1	0,2
5	Taulan	43,4	25,6	20,8	22,8	24,9	1,6	54,7	0,5
6	Tanya	46,7	31,8	29,6	32,3	24,5	1,5	56,2	0,8
7	Moskvich	48,3	34,2	30,7	28,4	26,7	1,7	47,5	1,1
8	Graf	54,6	23,8	26,5	25,7	28,2	1,6	53,6	0,9
9	Korona	52,8	18,6	21,7	28,8	16,2	1,3	55,2	0,5
10	Laureat	59,6	20,4	25,3	36,1	27,3	1,9	50,6	1,0

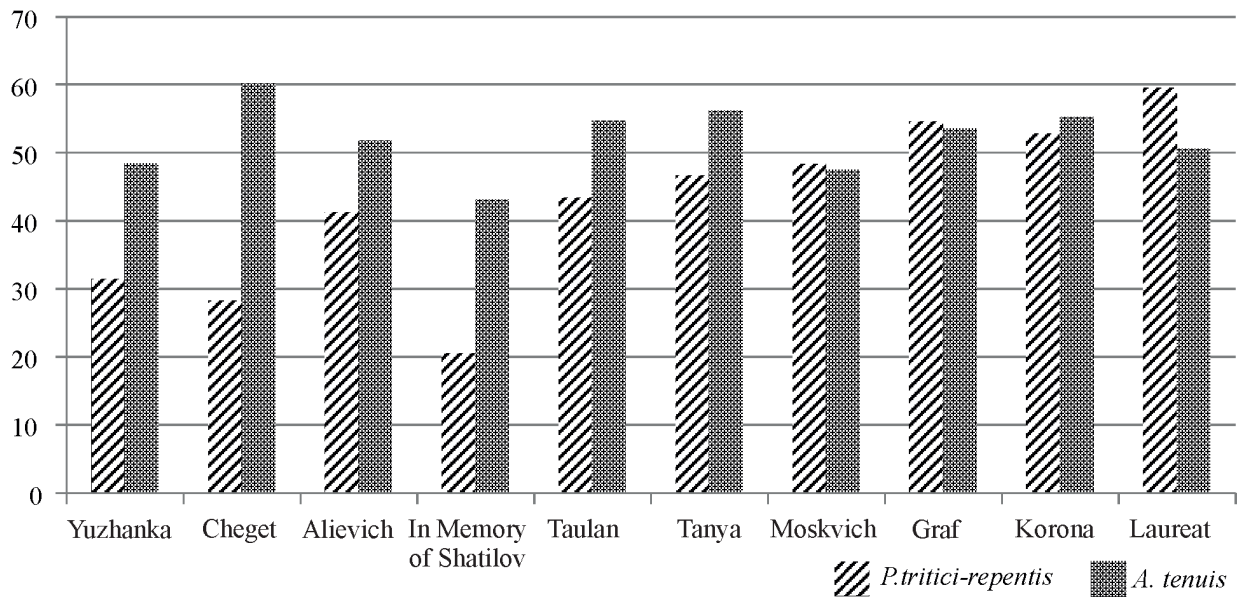
of fungal and bacterial origin were observed. Annual spread has 7 pathogens, and progressive - 2 species. The explanation is the aggressiveness of the pathogen strain *P. triticii-repentis*.

"Glume mold" disease is another progressive disease of winter wheat during the milky-wax phase of grain ripening. The probability of mass infection is associated with a high concentration of *Alternarium spp.* spores both in the air and on the soil surface. Wet weather due to frequent or drizzling rains during grain formation in the ear is considered to be a favorable factor for active infestation (see the figure).

CONCLUSIONS

1. The winter wheat varieties under study are resistant to the following diseases: *S. tritici, E. graminis, P. striiformis, P. recondite, T. caries, Fusarium spp. except for causative agents P. tritici-repentis, A. tenuis*.

2. Identification of phytopathogens at the beginning of their manifestation contributes to



Средневзвешенный процент пораженности прогрессирующими заболеваниями изучаемых сортов озимой пшеницы (степная зона Кабардино-Балкарской Республики, 2019–2021гг.)

Weighted average percentage of progressive diseases of the studied winter wheat varieties (steppe zone of the Kabardino-Balkar Republic, 2019–2021)

timely detection and effective protective measures against progressive diseases of winter wheat.

3. Phytosanitary monitoring of pathocomplex contributed to the detection of 28 pathogens. Of these, 7 were annually spreading and 2 species (pyrenophorosis and glume mold) were progressing.

4. No winter wheat varieties were found to be relatively resistant to the causative agents of pyrenophorosis and glume mold.

5. Scientific novelty of the research is that for the first time in the conditions of arid steppe zone of the Kabardino-Balkarian Republic a study on comparative assessment of winter wheat plants resistance to pathocomplex was conducted. This made it possible to study the degree of resistance to progressive diseases in new and promising varieties of winter wheat.

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ВЛИЯНИЕ БИОЛОГИЧЕСКИ АКТИВНЫХ ВЕЩЕСТВ СКОРЛУПЫ КЕДРОВОГО ОРЕХА НА ПРОДУКТИВНЫЕ ПОКАЗАТЕЛИ МОЛОДНЯКА ПЕРЕПЕЛОВ

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Представлены результаты использования для перепеловодства вторичного сырья растительного происхождения (скорлупы кедровых орехов) в качестве кормовой добавки. Приведен обзор изучения биологически активных веществ скорлупы ореха кедровой сосны сибирской (*Pínus sibírica*) и их влияния на организм животных. Исследования выполнены на цыплятах японских перепелов до 80-дневного возраста в условиях перепелиной фермы. В суточном возрасте сформированы три группы цыплят по 40 гол. в каждой. Контрольная группа получала основной рацион (ОР), 1-я опытная – 99,05% ОР + 0,05% порошка скорлупы кедрового ореха, 2-я опытная – 99,9% ОР + 0,1% порошка скорлупы кедрового ореха. Установлено, что лучшие результаты получены при включении кормовой добавки в рацион в количестве 0,1% от состава: повышение абсолютного прироста живой массы на 10,44%, сохранности на 7,5%, снижение потребления корма на 12,2 %. Контрольный убой петушков 2-й опытной группы в конце исследований подтвердил положительное влияние добавки – повышение предубойной живой массы на 7,98%, убойного выхода – на 3,01% по сравнению с контрольной группой. Химический состав мяса петушков 2-й опытной группы отличался от контроля повышением сухого вещества на 4,28%, сырого жира на 3,86%, снижением сырой золы на 0,33%. Аминокислотный состав был более полноценным по содержанию лизина, аргинина, аланина, аспарагина, глутамина и по сумме незаменимых и заменимых аминокислот в отличие от контрольной группы, что свидетельствует об улучшении качества мяса опытных перепелов.

Ключевые слова: молодняк перепелов, биологически активные вещества, скорлупа кедрового ореха, интенсивность роста, потребление корма, сохранность, качество мяса

EFFECT OF BIOLOGICALLY ACTIVE SUBSTANCES OF PINE NUT SHELLS ON PRODUCTIVE INDICATORS OF YOUNG QUAILS

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The results of the use of secondary raw materials of plant origin (pine nutshells) as a feed additive for quail breeding are presented. A review of the study of biologically active substances of Siberian pine nut shells (*Pínus sibírica*) and their effects on the body of animals is given. The studies were performed on Japanese quail chicks up to the age of 80 days in the conditions of a quail farm. At one day of age, three groups of chickens were formed with 40 animals in each group. The control group received the basic diet (BD), the 1st experimental group - 99.05% BD + 0.05% powder of pine nutshells, the 2nd experimental group - 99.9% BD + 0.1% powder of pine nutshells. It was

found that the best results were obtained when including 0,1% of the feed additive into the basic diet: 10,44% increase in the absolute live weight gain, 7,5% increase in safety, 12,2% decrease in feed consumption. The control slaughter of the 2nd experimental group cockerels at the end of the studies confirmed the positive effect of the additive - increasing the pre-slaughter live weight by 7.98%, the slaughter yield - by 3.01% compared with the control group. The chemical composition of meat of the 2nd experimental group differed from the control by an increase in the dry matter by 4.28%, crude fat by 3.86%, a decrease in crude ash by 0.33%. The amino acid composition was more complete in the content of lysine, arginine, alanine, asparagine, glutamine and the amount of essential and substitutable amino acids compared with the control group, indicating improved meat quality of the experimental quails.

Keywords: young quails, biologically active substances, pine nut shell, growth intensity, feed consumption, safety, meat quality

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INTRODUCTION

Currently, in many countries there is positive growth dynamics of such poultry industry as quail breeding. Quails have a set of distinctive economic and productive advantages compared with other farm birds - high body temperature, intensive metabolism in the body, small size, early maturity, high egg productivity. The search for new biologically active feed additives is necessary to realize their productive potential.

A huge number of organic substances, which include biologically active ingredients, can be obtained from secondary raw materials of plant origin during processing. Currently, work on the use of biologically active components derived from wood raw materials as feed additives in animal diets has intensified [1-3].

The solution of the problems of integrated processing of plant biomass into valuable food and technical products is particularly relevant for the Siberian region, where up to 60% of the world's reserves of cedar pine and up to 80% of the world's reserves of Siberian stone pine are concentrated [4].

Healing properties of Siberian cedar have been known for a long time. Almost all parts of the plant - needles, young shoots, bark, oleoresin - are used as medicinal raw materials. Of great interest is the cedar nut shell (CNS).

The first researcher of the chemical composition of Siberian cedar (Pínus sibírica) shells distributed in the Tomsk province was S.M. Kochergin [5]. At a later date the chemical composition of CNS was studied in more detail [6].

The components of the CNS belonging to non-saccharide-like polysaccharides possess prebiotic [7], antioxidant [8], antitumor [9] effects, and hepatoprotective activity [10]. It should be taken into account that the composition of plant cell polysaccharides is not constant and their antioxidant properties depend on the ratio of different monosaccharides in the composition. Polysaccharides with a molecular weight of 4000-100,000 have higher antioxidant activity [11]. CNS contains a wide range of phenolic compounds that have important biological properties. They include phenolic acids, flavonoids, tannins, phenolic lignans, and stilbene derivatives [12].

When studying the phenolic composition of the CNS, the following components were identified: protocatechinic acid, catechin, epicatechin, vanillinic acid, syringic acid, taxifolin,

eryodictiol, trans-cinnamic acid, naringenin, eryodictiol, flavan-3-ol, isolaricyresinol, laricyresinol and secoisolaricyresinol, gallic acid and ellagic acid (structural units of hydrolyzed tannins [13]. The highest values of antioxidant capacity are associated with large amounts of phenols and/or ellagic acid [14]. Flavonoids (polyphenols) isolated from the CNS show high antioxidant [15] and anti-inflammatory [16] activities. The main polyphenols of seed shells are tannins, which have the ability to change the colloidal state of proteins in the gastrointestinal tract. They have astringent, antimicrobial, anti-inflammatory effects [17].

CNS essential oils have a wide range of antimicrobial action and do not exhibit allergenic activity. The dominant components of the CNS essential oils are considered to be: hexanal, α-pinene, pentylfuran, palmitic acid, nonanal, borneol, myrtenol[1].

The carbohydrate-mineral complex from the CNS has a positive effect on the body of animals [18]. The extracts of cedar nut shells contain mostly the following macronutrients - K, Cl, Mg, P and minor-nutrient elements - Zn, Mn, Fe [19]. Essential amino acids, carotenoids, a small level of vitamins C, E and group B[2] were extracted from the cedar nut shells.

No information on the use of the CNS in quail diets has been found in available literature sources.

The purpose of the research is to determine the optimal delivery rate of the crushed cedar nut shells in the compound feed for young quail with subsequent monitoring of their productive performance.

The research objectives are to determine the effect of different doses of crushed cedar nut shells on the safety, live weight gain and feed consumption of young quails, to study the biochemical parameters of blood and meat (minced meat), to evaluate the quality of the meat products.

MATERIAL AND METHODS

The scientific and economic experiment was conducted from August to October 2020 on Japanese quails in the physiological yard of the Siberian Research and Technological Design Institute of Animal Husbandry, Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences (Siberian Research and Technological Design Institute of Animal Husbandry SFSCA RAS).

Three groups of Japanese quails with 40 birds in each group were formed at one day of age in order to study the set task, taking into account the requirements of the generally accepted methods. The birds were kept in cage batteries designed by the SRTDIAH Experimental Design and Development Bureau. The keeping and feeding conditions were in accordance with zootechnical recommendations.

Chickens of the control group received the basic diet (BD), young chicks of the 1st and 2nd experimental groups received cedar nut shell flour milled to 1 mm in the amount of 0.05 and 0.1% of its composition in the diet. Feed consumption was monitored daily with constant monitoring of quail health. Control weighing of quails was carried out individually at the age of one day, then at the age of 30, 60 and 80 days with the accuracy of 1 g. At the age of 80 days, three quail cockerels from each group were slaughtered. Samples were taken to study the biochemical composition of blood and muscle tissue; studies were carried out in the biochemistry laboratory of SRTDIAH SFSCA RAS and the Institute of Experimental Veterinary Science of Siberia and the Far East of Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences (IEVSS&FE SFSCA RAS) according to the generally accepted methods. Before slaughtering, the birds were kept for 8 hours without food, but with free access to water, then individually weighed. Slaughtering was performed by decapitation.

[1]Shiretorova V.G. Composition of essential oils of cone husks and seed shells of Pinus Sibirica Du Tour and Pinus Koraiensis L. Collected papers. Proceedings of the VI All-Russian Conference with international participation, Barnaul, April 22-24, 2014: New advances in chemistry and chemical technology of plant raw materials. Barnaul, Altai State University Press. 2014. pp. 217-218.

[2]Patent (RU) No 2667781 A 23 L 33/10, A 23 K 10/30, A 61 K 36/15, A 61 K 8/97. Biologically active additive from cedar shells and the method of its production. A.M. Leonchikov, S.M. Ermakov, application 06. 26. 2017., publ. 09. 24. 2018., Bulletin No. 18.

During anatomical cutting the necessary sanitary and hygienic rules were observed. Each carcass was weighed separately. All dressed parts were weighed to the accuracy of 1 g. The data obtained in the experiment were processed by the method of variation statistics using Microsoft Office 2007 (Excel).

RESULTS AND DISCUSSION

The formula for the basic diet (BD) for quails was developed according to the age requirements (see Table 1) from the available components.

Feed consumption by chicks in all groups was at the same level at the beginning of the experiment until 7 days of age, then the most efficient use of feed was observed in the quails receiving CNS. As a result, feed consumption decreased in the 1st and 2nd experimental groups by an average of 5.75 and 12.28% per 1 goal, respectively (see Table 2), but negative effects on the growth energy were not observed and live weight gain over the control period was higher by 8.04 and 10.44%, respectively.

The addition of CNS had a positive effect on increasing the safety of the experimental groups of quails. In the control group, 15.5% of the chicks supplied to the experiment died during the first month of the study, and 5.0% during the second month. As a result, the best safety was observed in both experimental groups - 87.5%, which is higher than the control group by 7.5% (see Table 3).

Табл. 1. Структура комбикормов для перепелов, %

Table 1. The structure of feed for quails, %

Component	Age, days	
	0–30	older than 31
Wheat	57	54
Extruded soybeans	10	10
Sunflower meal	10	10
Tankage	5	10
Fish meal	5	–
Nutrient yeast	5	5
Chalk	3	3
Mineralcium phosphate	4	4
Premix	1	1
Shell	–	3

Control slaughter was performed at 80 days of age of quail cockerels. Cockerels with average group indices were selected before the slaughter. The cockerels of groups 1 and 2 had a higher body weight before the slaughter; the difference was 7.5% and 8.0% ($p < 0.001$), respectively, compared to the control. The best slaughter yield of 78.27% was obtained in the 2nd experimental group (see Table 4).

The weight of the liver was not adversely affected by CNS addition, but the heart weight was significantly higher in the cockerels of the 2nd experimental group by 14,86% ($p < 0,01$) compared with the control.

General animal analysis showed a decrease in the level of moisture in the meat (minced meat) of the cockerels of the 2nd experimental group by 4.28% ($P > 0.999$) and an increase in the dry matter compared to the control group by 4.28% (see Table 5). The meat of the chickens of the 2nd experimental group differed from the intact cockerels by an increase in the level of crude fat by 3.86% ($P > 0.999$) and a decrease in ash elements by 0.33% ($P > 0.95$). The level of minerals, in particular calcium and phosphorus, was not affected by the addition of CNS.

The amino acid composition of meat also had differences between the groups. In meat samples from from the 1st experimental group quails a decrease in crude protein in the dry matter by 5.4% ($P > 0.999$) compared with the control and by 8.7% ($P > 0.999$) compared with the 2nd experimental group, accompanied by a decrease in all essential and most dispensable amino acids compared with the intact birds (see Table 6) was observed. This indicates a decrease in the quality indicator of the product. In the samples of the 2nd experimental group the amount of essential amino acids (lysine, methionine, tryptophan) and dispensable amino acids (alanine, asparagine, glutamine) is significantly higher than the control, therefore, the meat of this experimental group has a more complete composition.

Analysis of a number of biochemical data of blood serum allowed us to conclude that, despite the differences in the indicators between the groups, they are mostly within the reference values (see Table 7), therefore, no negative ef-

Табл. 2. Показатели интенсивности роста, расхода корма на прирост цыплят перепелов за период выращивания, в среднем на 1 гол.

Table 2. Indicators of the growth intensity, feed consumption for the growth of quail chickens during the growing period, on average per 1 head

Indicator	Group		
	control	1-st experimental	2-nd experimental
Live weight, g: at the start of the experiment	7,59 ± 0,12	8,66 ± 0,09	8,66 ± 0,09
at 30 days age	70,29 ± 1,57	76,86 ± 1,06**	79,80 ± 1,03**
at 60 days age	168,08 ± 2,38	182,13 ± 2,30**	185,9 ± 2,60***
Live weight gain for the period, g: 1–30 days	62,70 ± 1,55	68,20 ± 0,99	71,14 ± 0,74*
31–60 days	97,79	105,20	106,11
1–60 days	160,49 ± 2,26	173,40 ± 2,15***	177,25 ± 2,49***
Consumed fodder for the period, kg: 1–30 days	0,437	0,408	0,385
31–60 days	0,938	0,888	0,822
For the whole period	1,375	1,296	1,207*
Feed consumption per 1 g of growth for the entire period, g	8,57	7,47*	6,81*
Average daily gain of live weight for the whole period, g	2,67 ± 0,06	2,89 ± 0,05	2,95 ± 0,07

Note. Here and in tables 4-7. The difference is reliable:* $p < 0,05$, **$p < 0,01$, *** $p < 0,001$.

Табл. 3. Показатели сохранности перепелов в период выращивания

Table 3. Quail safety indicators during the growing period

Indicator	Group		
	control	1-st experimental	2-nd experimental
The number at the beginning of the experiment, heads:	40	40	40
in 30 days, heads	34	36	36
in 60 days, heads	32	35	35
Livability, % in 1–30 days:	85,00	90,00	90,00
in 31–60 days	95,00	97,22	97,22
for the whole period	80,0	87,50	87,50

Табл. 4. Результаты контрольного убоя подопытных петушков в 80-дневном возрасте, в среднем на 1 гол.

Table 4. The results of the control slaughter of experimental cockerels at 80 days of age, on average per 1 head.

Indicator	Group		
	control	1-st experimental	2-nd experimental
Pre-slaughter live weight, g	169,0 ± 0,27	181,6 ± 0,39***	182,49 ±0,5***
Percentage of the control group	100,00	107,46	107,98
Weight of gutted carcass, g	127,67 ± 0,82	138,17 ± 0,32	142,83 ± 0,99
Liver weight, g	4,3 ± 0,16	4,21 ± 0,20	4,32 ± 0,18
Heart weight, g	1,48 ± 0,01	1,56 ± 0,05	1,7 ± 0,04**
Slaughter yield	75,54 ± 0,61	76,08 ± 0,35	78,27 ± 0,55

Табл. 5. Химический состав мяса (фарша) петушков перепелов, %
Table 5. Chemical composition of meat (minced meat) of quail males, %

Indicator	Group		
	control	1-st experimental	2-nd experimental
Moisture content	66,14 ± 0,62	66,85 ± 0,60	61,86 ± 0,36***
Dry matter	33,86 ± 0,62	33,15 ± 0,60	38,14 ± 0,36***
Crude protein	21,03 ± 0,23	19,9 ± 0,19***	21,79 ± 0,23
Crude fat	10,82 ± 0,54	11,39 ± 0,62	14,68 ± 0,61***
Crude ash	2,01 ± 0,04	1,86 ± 0,18	1,68 ± 0,13*
Calcium	1,519 ± 0,056	1,443 ± 0,047	1,457 ± 0,023
Phosphorus	0,457 ± 0,024	0,447 ± 0,034	0,467 ± 0,021

Табл. 6. Аминокислотный состав мяса (фарша) петушков перепелов
Table 6. Amino acid composition of meat (minced meat) of quail cockerels

Indicator	Group		
	control	1-st experimental	2-nd experimental
Essential amino acids			
Lysine	1,380 ± 0,049	1,210 ± 0,014**	1,530 ± 0,035*
Methionine	0,360 ± 0,012	0,253 ± 0,012***	0,267 ± 0,020***
Tryptophane	0,217 ± 0,011	0,143 ± 0,011***	0,230 ± 0,035
Arginine	1,150 ± 0,044	1,020 ± 0,007**	1,323 ± 0,034**
Histidine	0,393 ± 0,019	0,333 ± 0,003**	0,407 ± 0,003
Leucine, isoleucine	2,017 ± 0,068	1,790 ± 0,007**	2,073 ± 0,020
Threonine	0,703 ± 0,022	0,590 ± 0,005***	0,710 ± 0,009
Phenylalanine	0,767 ± 0,031	0,667 ± 0,009**	0,847 ± 0,024
Valine	0,617 ± 0,024	0,540 ± 0,003**	0,610 ± 0,021
Sum of essential amino acids	7,604	6,546	7,997
Dispensable amino acids			
Alanine	1,200 ± 0,028	0,987 ± 0,011***	1,313 ± 0,033*
Serine	0,723 ± 0,020	0,553 ± 0,014***	0,727 ± 0,019
Asparagine	1,850 ± 0,024	1,677 ± 0,70*	2,283 ± 0,128**
Glutamine	2,950 ± 0,031	2,760 ± 0,098	3,413 ± 0,173*
Cystine	0,507 ± 0,018	0,390 ± 0,024***	0,577 ± 0,051
Tyrosine	0,613 ± 0,027	0,560 ± 0,042	0,557 ± 0,018
Proline	0,787 ± 0,008	0,660 ± 0,005***	0,757 ± 0,013
Sum of dispensable amino acids	8,630	7,587	9,617

Табл. 7. Биохимические показатели сыворотки крови петушков перепелов
Table 7. Biochemical parameters of blood serum of quail cockerels

Indicator	Measurement unit	Group		
		control	1-st experimental	2-nd experimental
Total protein	g/l	52,81 ± 0,01	48,21 ± 0,93***	51,38 ± 1,04
Albumins	g/ l	24,98 ± 1,48	25,09 ± 1,01	19,86 ± 0,69**
Globulins	g/l	27,66 ± 1,40	22,70 ± 1,95*	31,53 ± 0,82*
Creatinine	m/mol	42,07 ± 0,40	39,50 ± 1,48	40,85 ± 0,76
SGOT	unit/l	235,8 ± 0,04	270,37 ± 12,82*	208,10 ± 2,80***
SGPT	unit/l	8,29 ± 0,36	7,04 ± 0,43*	8,55 ± 0,81
ALP	unit/l	260,73 ± 19,00	179,43 ± 7,68***	281,73 ± 53,94
Calcium	m. mol/l	2,98 ± 0,12	2,82 ± 0,09	3,06 ± 0,02
Phosphorus	m. mol/l	1,36 ± 0,01	2,48 ± 0,16***	2,07 ± 0,03***

fect of the CNS supplementation on blood was detected.

The conducted research allowed us for the first time to determine the optimal rate of crushed cedar nut shells in the diet of quails during rearing.

CONCLUSION

Inclusion of the CNS *Pínus sibírica* in the diet of the 2nd experimental group in an amount of 0.1% of the weight of mixed fodder had a positive effect on the zootechnical performance of young quails compared to the control group:

– during chick rearing, the survival rate increased by 7.5%, the growth rate increased by 10.44%, while the feed consumption decreased by 12.22%;

– increase in carcass slaughter yield by 2.73%, improving the quality of meat (minced meat) – increase of the level of essential amino acids;

– no negative impact on the studied vital signs of young quails were detected.

After the production test it is possible to recommend the inclusion of the studied biologically active stimulating bio-additive - crushed to 1 mm cedar nut shells in an amount of 0.1% of mixed fodder in the diet of young quails.

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ЭКОЛОГО-ФИЗИОЛОГИЧЕСКИЕ МЕХАНИЗМЫ АДАПТАЦИИ МОЛОДНЯКА ОВЕЦ В УСЛОВИЯХ ЗАБАЙКАЛЬЯ

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Представлены результаты изучения адаптационных способностей молодняка овец в зависимости от происхождения и их взаимосвязи с продуктивностью. Температура, скорость движения и влажность воздуха при рождении ягнят (апрель) составили 4,7 °С, 4,2 м/с и 17,7%, в возрасте 6 мес (октябрь) – 1,0 °С ниже ноля, 4,9 м/с и 33,7% соответственно. Лучшие показатели по живой массе до 6-месячного возраста имеет полугрубошерстный молодняк агинской породы. Баранчики в возрасте 6 мес по средней живой массе имели преимущество над тонкорунными аналогами забайкальской породы на 3,7%, ярки на 6,3% ($p > 0,05$). Баранчики забайкальской породы имели лучшие высотные промеры статей тела по высоте в холке на 0,4 см, по высоте в крестце на 1,3 см. Сверстники агинской породы отличались лучшими показателями объемных и широтных промеров, в том числе косой длины туловища и глубине груди. У особей агинской породы по сравнению с тонкорунными аналогами длиннее уши (на 23,2–23,8%), шея (на 9,7–17,5%) и голова (1,2–2,5%), уже лоб (на 11,5–17,6%) и менее объемная шея (на 5,1–7,2%). Клинико-гематологические показатели находились в пределах физиологической нормы. Наименьшая температура тела на поверхности кожи у подопытного молодняка при рождении и в 6-месячном возрасте отмечена в области уха (25,2–26,0 °С), наибольшая – на центральной части живота (29,3–33,4 °С). По толщине кожи в зависимости от происхождения овец наибольшая разница отмечена в области ЦЧЛ, СР-12 и ЦЧЖ. У тонкорунных особей она на ЦЧЛ толще на 28,0–39,1%, на СР-12 – на 9,7–46,2%, на ЦЧЖ – на 25,0–43,5%. У подопытных особей выявлена положительная корреляция живой массы с высотой в крестце (0,591–0,906), с обхватом пясти (0,133–0,240), с шириной лба (0,173–0,590). Отмечена взаимосвязь живой массы с длиной головы и шеи у полугрубошерстных особей (0,060–0,463 и 0,147–0,394), а также слабая сопряженность с толщиной кожи на СР-12. У тонкорунных аналогов установлена средняя корреляция между живой массой и обхватом шеи (0,490–0,553) и толщиной кожи в области ЦЧЖ (0,469–0,755).

Ключевые слова: овцы, забайкальская порода, агинская порода, живая масса, физиологические показатели, корреляция

ECOLOGICAL AND PHYSIOLOGICAL MECHANISMS OF ADAPTATION OF YOUNG SHEEP IN THE CONDITIONS OF TRANSBAIKAL

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The results of studying the adaptive abilities of young sheep depending on their origin and their relationship with productivity are presented. Temperature, velocity and humidity at birth of lambs (April) were 4.7 °C, 4.2 m/s and 17.7%, at the age of 6 months (October) - 1.0 °C below zero, 4.9 m/s and 33.7% respectively. The best indicators of live weight up to 6 months of age are shown by medium-wool young Aginskaya breed. Young rams at the age of 6 months had an advantage over their fine-wool counterparts of Transbaikal breed by 3.7% in terms of average live weight, and the gimmers by 6.3% ($p > 0.05$). The rams of the Transbaikal breed had the best height measurements of the body by 0.4 cm at the withers and by 1.3 cm in the height at hips. The Aginskaya breed peers

were distinguished by better volume and latitude measurements, including oblique torso length and chest depth. The Aginskaya breed has longer ears (23,2-23,8%), neck (9,7-17,5%) and head (1,2-2,5%), narrower forehead (11,5-17,6%) and less voluminous neck (5,1-7,2%) than their fine-wool counterparts. Clinical and hematological parameters were within the physiological norm. The lowest body temperature on the skin surface of the experimental youngsters at birth and at 6 months of age was noted in the ear area (25.2-26.0 °C), the highest - on the central part of the abdomen (29.3-33.4 °C). In terms of skin thickness, depending on the origin of the sheep, the greatest difference was noted in the SCP, MR-12, and SCP areas. In fine-wool individuals, it is 28.0-39.1% thicker in the SCP, 9.7-46.2% thicker in the MR-12, and 25.0-43.5% thicker in the SCP. In test specimens a positive correlation of live weight with the height at hips (0.591-0.906), with the girth of the metacarpel (0.133-0.240), and with the width of the forehead (0.173-0.590) was detected. There was a correlation between live weight and head and neck length in medium-wool breed individuals (0.060-0.463 and 0.147-0.394), as well as a weak correlation with skin thickness on MR-12. In fine-wool counterparts, there is a medium correlation between live weight and neck girth (0.490-0.553) and skin thickness in the SCP area (0.469-0.755).

Keywords: sheep, Trans-Baikal breed, Aginskaya breed, live weight, physiological indicators, correlation

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INTRODUCTION

For productive animals, the process of adaptation, along with the state of health, is evaluated taking into account the development of their economically useful traits. F. Komarov, B. Korovkin [1] note that at the present stage of development of animal health science the importance of clinical diagnosis by biochemical blood indices has increased. The level of animal productivity, the duration of their use and the ability of the livestock to expanded reproduction[1] can serve as indicators of adaptability from a zootechnical point of view [2]. From the physiological point of view, the level of basic metabolism, respiration rate and skin temperature are the main indicators of adaptation to rearing conditions [3-6]. Moreover, skin is an important pathway of heat exchange between the body and the environment in mammals [7].

Any "genotype-environment" interaction can disrupt the breed or herd improvement achieved by selection, since the development of an organism takes place under the influence of genes, which are manifested under relevant external factors, which include not only natural and climatic conditions, but also changes in technological processes of feeding and housing [8].

The influence of environmental factors (radiation, temperature, relative humidity and air velocity) and heat exchange can lead to heat stress in sheep due to changes in the thermal energy balance between an animal and the environment [9].

The purpose of the research is to study the ecological and physiological mechanisms of adaptation and their relationship with the productivity of young sheep depending on their origin.

[1]Katsy G.D. Experience of studying animal acclimatization. Proceedings of the International Scientific and Practical Conference "Modern technologies of agricultural production and priority directions of development of agricultural science". DonGAU, 2014. pp.

MATERIAL AND METHODS

The object of the research were lambs (n = 15) and gimmers (n = 15) of Transbaikal (TB) and Aginskaya (AG) breeds. The experimental part of the work was conducted in Tsokto-Khangil AC (Tsokto-Khangil village, 500 54' N and 1140 39' E) of Aginsky district of the Transbaikal region located in the steppe zone of Eastern Siberia, in the south-east of Transbaikalia at 500 to 700 m above sea level.

The climate is sharply continental. Winter with low temperatures, weak winds, little precipitation. The height of snow cover is from 3-6 to 10 cm. The average monthly temperature is -22 ÷ -26°C in January (absolute minimum -51°C), +16 ÷ +20°C in July (absolute maximum +37°C). Summers are hot: the first half is dry; the second half is rainy. The growing season lasts from 120 to 150 days. Distribution of precipitation is uneven and is 200-250 mm/year, with fluctuations from 130 to 400 mm/year.

The experimental groups of young sheep were formed according to the principle of peer groups. Animal housing was year-round grazing, the main feed was pasture grass. Clinical and physiological parameters (rectal temperature (RT), respiratory rate (RR) and heart rate (HR)) were studied using methods generally accepted in veterinary medicine, surface skin temperature (SST) on various topographic body areas (ears (E), neck (N), central part of the shoulder-blade (SCP), middle of 12th rib (MR-12), sacrum (S)) - using an AKIP-9302 laser infrared non-contact thermometer (Russia) during daytime. Skin thickness (ST) in young sheep - in the central parts of the shoulder-blade (SCP), 12th rib (MR-12), thigh (TCP), back (BCP) and abdomen (ACP).

Morphological (white blood cell (WBC), red blood cell (RBC), platelet (PLT), hemoglobin (HGB)) on a PCE 90 Vet hematology analyzer and biochemical blood parameters (total protein (OB), calcium (Ca), phosphorus (P)) on a Stat Fax 1904 and URIT 800 Vet biochem analyzer were studied to determine hematological parameters.

Exterior and constitutional features of young sheep were studied by taking the main body article measurements: height at withers (HW) and rump (HH), oblique body length (OBL), depth (ChD), width (ChW) and chest girth (ChG), hook bone width (HBW), canon bone girthl (CBG), additionally - head length (HL), forehead length (FL) and width (FW), ear length (EL) and width (EW), neck length (NL), neck girth at the level of the 4th cervical vertebra (NG-4).

Live weight (LW) was studied by weighing animals on electronic scales TB-S-200.2 (Russia) with an accuracy of 0.1 kg.

The experimental data were processed by Student's method of variation statistics [10] using a personal computer, Microsoft Office Excel and PAST Version 3.25 (2001), within the following levels of significance: $p < 0.05$, $p < 0.01$, $p < 0.001$.

RESULTS AND DISCUSSION

The temperature-humidity regime and air velocity at the time of the study (day) are presented according to the data of the Transbaikal Department for Hydrometeorology and Environmental Monitoring (see Fig. 1).

The temperature, velocity and humidity at birth of lambs (April) were 4.7 °C, 4.2 m/s and 17.7%, at the age of 6 months (October) - minus 1.0 °C, 4.9 m/s and 33.7% respectively. It is noted that for newborn lambs the temperature of 25-30 °C is considered a thermoneutral zone. When the wool is short, the cold has a stimulating effect on the growth of wool [11, 12].

Table 1 shows the dynamics of live weight and intensity of growth and development of experimental young sheep.

Analysis of the obtained data shows that the best indicators in terms of live-weight dynamics up to 6 months of age are shown by medium-wool young lambs of Aginskaya breed. Thus, lambs at the age of 6 months of age had an advantage over their fine-wooled counterparts of the Transbaikal breed by 3.7% in average live weight, gimmers - by 6.3% ($p > 0.05$), thus, the intensity of growth and development during this period was higher by 6 and 13 g a day.

One of the methods of studying the growth and development of young animals is to evaluate their exterior appearance by taking the main measurements of the body articles and calculat-

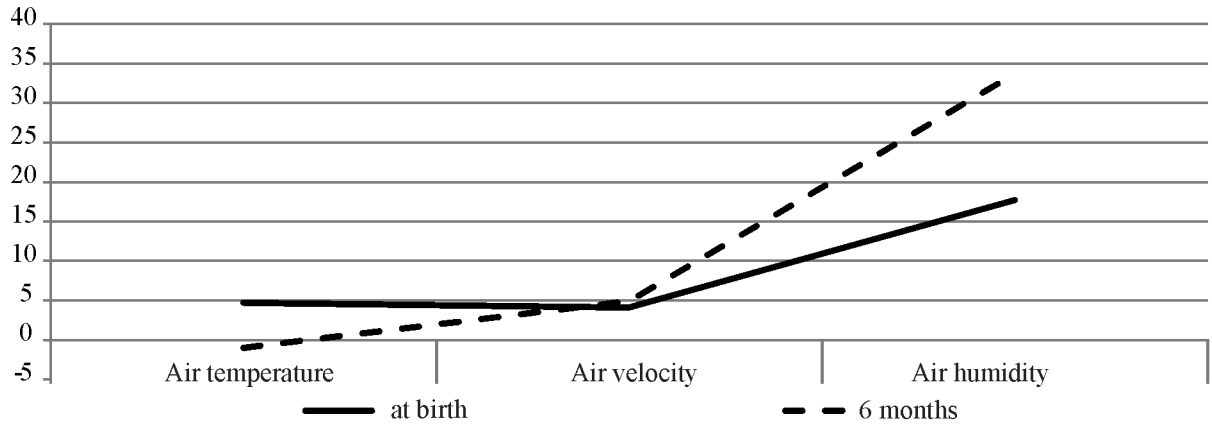

Рис. 1. Температура воздуха (°С), скорость движения воздуха (м/с), влажность воздуха (%)
Fig. 1. Air temperature (°C), air speed (m/s), air humidity (%)

Табл. 1. Динамика средней живой массы и интенсивность роста ягнят
Table 1. Dynamics of average live weight and growth intensity of lambs

Age	Breed			
	TB		AG	
	♂	♀	♂	♀
	Live weight, kg			
At birth	3,8 ± 0,10	3,7 ± 0,11	4,1 ± 0,26	3,6 ± 0,80
6 months	37,9 ± 1,02	35,1 ± 1,13	39,3 ± 1,40	37,3 ± 0,91
	Average daily gain, g			
0–6 months	189	174	195	187

ing body mass indices on their basis. Table 2 shows the results of the measurements of experimental young animals at birth and at the age of 6 months.

The results show that medium-wool lambs at birth are somewhat larger than their Transbaikal breed counterparts, both lambs and gimmers, as evidenced by their weight indicators.

In the process of growth and development, it was revealed that by the age of 6 months the lambs of Transbaikal breed had better height measurements. Thus, the difference in their favor was 0.4 cm in the height at the withers and 1.3 cm in the rump, while their peers of the Aginskaya breed were distinguished by better indices of the measurements of volume and width, including oblique body length and chest depth. When evaluating the growth and development of the body articles of gimmers, it was found that medium-wool individuals of the Aginskaya breed had an advantage in all the studied measurements of the body articles. Based on the data obtained on the measurements of body parts, body mass indices of the test youngsters were calculated at birth and at the age of 6 months (see Table 3).

As a result of the calculations carried out, it was found that at birth the lambs under test have no pronounced differences in body indices, except for the overgrowth index. At the age of 6 months both fine-wooled and medium-wool young lambs showed a marked increase in the indices of elongation, compactness and massiveness, a decrease in the bony index, which is directly related to the process of intensive growth and development during this period.

According to researchers, body size and shape are the main morphological characteristics affecting the mechanisms of thermoregulation of an animal under rearing conditions [13, 14].

In addition to the main body article measurements, additional measurements were taken (see Table 4).

Табл. 2. Промеры статей тела ягнят, см
Table. 2. Measurements of body parts of lambs, cm

Measurement	Breed							
	TB				AG			
	at birth		6 months		at birth		6 months	
	♂	♀	♂	♀	♂	♀	♂	♀
HW	30,9 ± 1,20	28,7 ± 1,34	51,2 ± 1,48	48,3 ± 1,16	31,3 ± 1,06	29,5 ± 1,27	50,8 ± 1,14	49,3 ± 1,16
HH	29,6 ± 1,26	28,1 ± 1,37	52,1 ± 0,99	48,8 ± 1,48	32,6 ± 1,51	31,1 ± 1,37	50,9 ± 1,91	50,1 ± 1,45
OBL	32,6 ± 1,07	32,5 ± 1,18	60,4 ± 1,78	58,1 ± 1,20	33,0 ± 1,25	32,8 ± 1,03	62,3 ± 1,49	58,9 ± 1,20
ChD	13,4 ± 0,52	12,9 ± 0,34	27,3 ± 0,95	23,8 ± 1,32	13,9 ± 0,74	13,6 ± 0,52	28,7 ± 0,82	24,3 ± 0,95
WCh	7,8 ± 0,63	7,4 ± 0,52	15,5 ± 0,97	14,8 ± 0,79	8,2 ± 0,63	7,7 ± 0,67	16,1 ± 0,74	15,5 ± 1,08
ChG	34,3 ± 1,16	32,5 ± 1,51	74,7 ± 1,25	67,9 ± 1,29	35,2 ± 1,14	32,7 ± 0,95	76,3 ± 1,77	68,7 ± 1,64
HBW	6,6 ± 0,52	6,4 ± 0,52	16,2 ± 0,78	15,0 ± 1,05	7,1 ± 0,74	6,7 ± 0,48	17,0 ± 0,82	16,0 ± 1,33
CBG	5,3 ± 0,48	5,2 ± 0,42	7,5 ± 0,53	6,8 ± 0,79	5,4 ± 0,84	5,4 ± 0,52	7,9 ± 0,57	7,3 ± 1,06

Табл. 3. Индексы телосложения ягнят, %
Table 3. Body indices of lambs, %

Index	Breed							
	TB				AG			
	at birth		6 months		at birth		6 months	
	♂	♀	♂	♀	♂	♀	♂	♀
Legginess	56,6	55,1	46,7	50,7	55,6	53,9	43,5	50,7
Lengthiness	105,5	113,2	118,0	120,3	105,4	111,2	122,6	119,5
Chest	58,2	57,4	56,8	62,2	59,0	56,6	56,1	63,8
Blockiness	105,2	100,0	123,7	116,9	106,7	99,7	122,5	116,6
Ponderosity	111,0	113,2	145,9	140,6	112,5	110,8	150,2	139,4
Boniness	17,2	18,1	14,6	14,1	17,3	18,3	15,6	14,8
Overgrowth	95,8	97,9	101,8	101,0	104,2	105,4	100,2	101,6

The results obtained show insignificant difference in all additional measurements depending on the origin and sex of young sheep. Thus, the Aginskaya breed has longer ears, neck and head compared to its fine-wooled counterparts, which is probably due to thermoregulatory features and their ability to forage in hard-to-reach places due to their elongated neck. Thin-skinned young animals are distinguished by a broad forehead and a shorter, more voluminous neck.

It is known that adaptability of animals to these or those conditions can be judged by interior traits, in particular blood indices, which

Табл. 4. Промеры головы, уха и шеи ягнят, см
Table 4. Head, ear and neck measurements of lambs, cm

Measurement	Breed							
	TB				AG			
	at birth		6 months		at birth		6 months	
	♂	♀	♂	♀	♂	♀	♂	♀
HL	9,6 ± 0,52	8,9 ± 0,74	16,9 ± 0,74	15,8 ± 1,14	10,2 ± 0,79	9,1 ± 0,75	17,1 ± 0,99	16,2 ± 0,92
FL	3,6 ± 0,70	3,5 ± 0,53	5,5 ± 0,97	5,2 ± 0,79	3,9 ± 0,74	3,6 ± 0,52	5,4 ± 0,52	5,3 ± 0,42
FW	5,6 ± 0,52	5,1 ± 0,57	8,7 ± 0,75	8,0 ± 0,82	5,2 ± 0,59	5,1 ± 0,57	7,8 ± 0,71	6,8 ± 0,71
EL	8,4 ± 0,52	8,1 ± 0,57	10,5 ± 0,41	9,9 ± 1,20	8,9 ± 0,88	8,1 ± 0,57	13,0 ± 1,05	12,2 ± 1,03
EW	4,8 ± 0,48	4,5 ± 0,47	6,0 ± 0,71	5,7 ± 0,82	4,5 ± 0,53	4,5 ± 0,47	6,5 ± 0,47	6,1 ± 0,57
NL	13,9 ± 0,74	13,0 ± 0,67	24,6 ± 1,77	23,8 ± 1,55	15,3 ± 0,82	14,5 ± 0,53	28,9 ± 1,20	26,1 ± 1,20
NG	16,5 ± 0,71	15,8 ± 0,79	28,7 ± 2,07	25,2 ± 1,81	16,2 ± 1,03	15,5 ± 1,08	27,3 ± 1,42	23,5 ± 2,27

to a certain extent can also characterize productive qualities (see Table 5).

In the present studies, hematological parameters of experimental young animals were within the physiological norm. Significant difference in the studied blood parameters depending on the breed and sex was not revealed. It was noted that the ratio of calcium to phosphorus in the blood of experimental youngsters varies from 3.3 : 1 to 5.4 : 1, which is higher than the norm (1.5-2 : 1).

To assess the adaptive properties of the experimental young animals, clinical parameters were investigated (see Table 6).

The results of clinical studies in the experimental youngsters indicate that the respiratory rate and heart beat decrease naturally with age in both fine- and medium-wool individuals, and it can be assumed that youngsters of the Aginskaya breed regulate the thermoregulation process in correlation with environmental conditions due to lower indices.

A significant increase in the respiration rate is the first physiological mechanism used by sheep and goats to overcome environmental heat stress [15]. Sheep capable of walking long distances are characterized by increased body temperature and respiration rate during grazing stress [16, 17].

The body temperature on the skin surface of the experimental young animals was different at different topographic sites (see Table 7).

The lowest body temperature on the skin surface of experimental young animals was observed in the ear area (25.2-26.0 °C), the highest - on the central part of the abdomen (29.3-33.4 °C) both at birth and at 6 months of age. The increased body temperature on the skin surface in the abdominal area can be explained by the fact that young animals often come into contact with the cold floor and the ground during the resting period (at birth - spring, at 6 months - autumn). No significant differences in the topographic areas of the body between individuals depending on their origin and sex were revealed.

Табл. 5. Гематологические показатели подопытного молодняка в возрасте 6 мес
Table 5. Hematological parameters of experimental young animals at the age of 6 months

Indicator	Breed			
	TB		AG	
	♂	♀	♂	♀
RBC, 10^{12}/л	7,8 ± 1,35	8,6 ± 0,97	9,2 ± 1,61	7,2 ± 0,24
WBC, 10^{9}/л	11,4 ± 0,98	10,7 ±	11,2 ± 1,55	11,6 ± 2,56
PLT, 10^{9}/л	168,2 ± 28,21	172 ± 30,24	170,3 ± 31,6	168,0 ± 25,0
HGB, г/л	88,7 ± 4,58	91,4 ± 5,66	85,2 ± 5,97	83,0 ± 6,02
TP, g/l	94,6 ± 9,56	96,4 ± 8,47	97,0 ± 10,15	92,8 ± 10,7
Ca, mmol/l	6,8 ± 0,47	5,7 ± 0,27	7,6 ± 0,50	4,7 ± 0,30
P, mmol/l	1,5 ± 0,17	1,7 ± 0,16	1,4 ± 0,11	1,2 ± 0,10

Табл. 6. Клинические показатели молодняка овец
Table 6. Clinical indicators of young sheep

Indicator	Breed							
	TB				AG			
	at birth		6 months		at birth		6 months	
	♂	♀	♂	♀	♂	♀	♂	♀
RT, °C	36,9 ± 0,74	37,1 ± 0,74	37,3 ± 0,67	37,1 ± 0,86	36,7 ± 0,82	37,0 ± 0,82	37,2 ± 0,79	38,0 ± 0,94
RR, times/min	58,4 ± 2,12	62,9 ± 2,96	35,2 ± 0,78	36,2 ± 1,40	55,4 ± 1,88	65,4 ± 3,89	33,8 ± 1,93	35,0 ± 1,94
HR, times/min	111,9 ± 5,55	120,8 ± 6,89	90,6 ± 2,22	91,7 ± 3,27	108,6 ± 6,96	120,2 ± 3,99	88,7 ± 2,79	89,2 ± 1,93

Табл. 7. Температура тела на поверхности кожи, °С
Table 7. Body temperature on the skin surface, °С

Body part	Breed							
	TB				AG			
	at birth		6 months		at birth		6 months	
	♂	♀	♂	♀	♂	♀	♂	♀
E	25,2 ± 1,31	25,9 ± 0,34	27,7 ± 1,45	24,5 ± 1,35	25,0 ± 1,31	26,0 ± 1,12	24,1 ± 1,42	24,1 ± 1,15
N	28,2 ± 1,29	29,9 ± 0,21	26,7 ± 1,28	27,4 ± 1,25	27,7 ± 0,89	27,8 ± 0,64	26,6 ± 0,84	26,9 ± 1,51
SBC	29,4 ± 0,94	31,7 ± 2,49	28,8 ± 1,41	29,6 ± 0,75	29,7 ± 0,77	29,7 ± 0,44	28,2 ± 1,46	28,8 ± 0,78
RM-12	29,5 ± 0,88	30,1 ± 1,38	30,2 ± 2,05	29,5 ± 0,64	29,1 ± 0,75	30,6 ± 1,55	27,7 ± 1,32	28,4 ± 0,78
R	29,5 ± 1,35	31,8 ± 2,61	28,2 ± 1,15	29,2 ± 0,87	29,3 ± 0,80	28,8 ± 0,73	28,0 ± 2,01	27,7 ± 0,74
SC	30,5 ± 1,25	33,4 ± 1,37	31,7 ± 1,18	31,2 ± 0,74	30,8 ± 0,68	32,6 ± 1,40	29,3 ± 1,36	30,9 ± 1,09

Figure 2 shows data on skin thickness at different topographic areas of the body of young sheep at birth and at 6 months of age.

The results obtained show that there are some differences in skin thickness at different topographic areas of the body in the experimental lambs depending on the breed. So, fine-wooled young lambs have thicker skin at birth on all sections in comparison with their medium-wool counterparts. At the same time, it was noted that it is thicker in females of the Transbaikal breed than in males and Aginskaya bulls. The smallest skin thickness in females of the Transbaikal breed was recorded in the abdomen, the largest - in the back, while that of the Aginskaya breed - in the shoulder blade and back, respectively. At the age of 6 months, the experimental young animals had a regular thickening of the skin in all the studied areas. At the same time, more significant changes in this indicator occurred in the region of the shoulder blade, on the side and on the thigh. It was noted that females had thicker skin in the abdomen than males.

The knowledge of the correlative dependence between individual traits and its quantitative determination allow the selection for one or more traits, to provide for the change of one trait while selecting for others, which is important for successful breeding work (Tables 8-10).

Analysis of the results shows that in the experimental young animals at the age of 6 months a strong positive correlation with the live weight is shown by a measure of height at hips (+0.591-+0.906), weak - the measure of cannon bone girth (+0.133-+0.240). This indicates that these measurements should be taken into account when selecting young animals. In

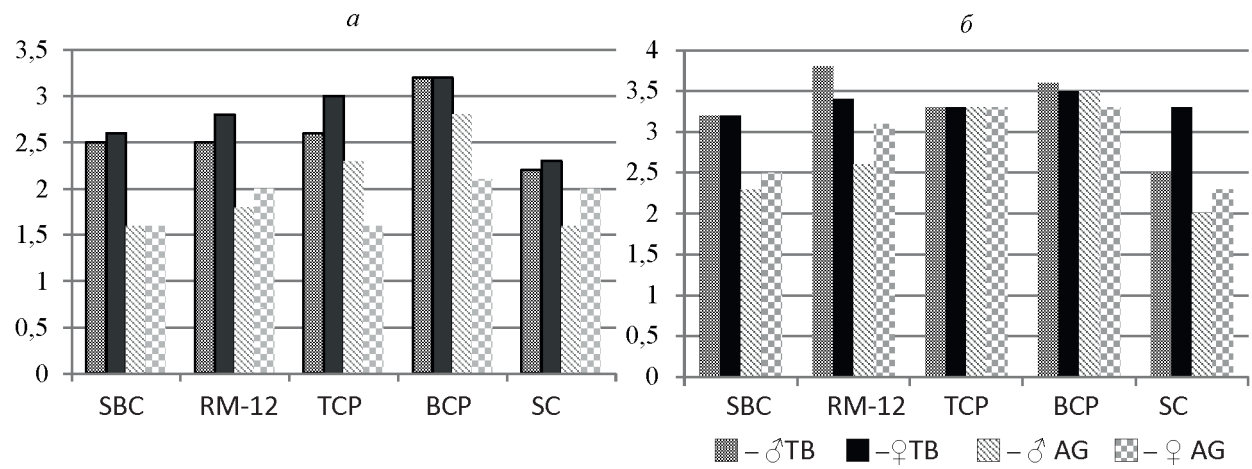

Рис. 2. Толщина кожи ягнят при рождении (*а*) и в возрасте 6 мес (*б*), мм
Fig. 2. Skin thickness of lambs at birth (*а*) and at the age of 6 months (*б*), mm

fine-wooled individuals, live weight weakly correlates with chest depth in contrast to medium-wool counterparts in which it is negative.

The analysis of conjugation of live weight with additionally taken measurements revealed that a weak and medium relationship of traits in the experimental youngsters is present with the width of the forehead. A distinctive point is a weak and average correlation of live weight with the length of head and neck length in medium-wool individuals. The average correlation between live weight and neck girth was established in the fine-wooled counterparts.

Medium to strong correlation between live weight and skin thickness on the central part of the abdomen was found in fine-wooled youngsters, while a weak correlation between live weight and skin thickness on the middle of the 12th rib was noted in medium-wool youngsters.

CONCLUSION

The results of the study of ecological and physiological mechanisms of adaptation indicate that under year-round grazing in the harsh natural and climatic conditions of the dry steppes of Transbaikalia the experimental young sheep show fairly high rates of growth and development, and the best indices are shown by the medium-wool young Aginskaya breed.

Табл. 8. Взаимосвязь живой массы с промерами статей тела подопытного молодняка в возрасте 6 мес
Table 8. The relationship of live weight with measurements of body parts of experimental young animals at the age of 6 months

Correlatable characteristics	r			
	TB		AG	
	♂	♀	♂	♀
LW – HW	–0,099	+0,210	+0,098	–0,063
LW – HH	+0,591	+0,753	+0,758	+0,906
LW – OBL	–0,214	+0,579	–0,455	+0,134
LW – ChD	+0,119	+0,155	–0,280	–0,460
LW – WCh	–0,181	+0,385	–0,128	–0,054
LW – ChG	–0,502	+0,635	+0,827	–0,031
LW – HBW	–0,383	+0,328	–0,077	+0,356
LW – CG	0	+0,133	+0,240	+0,239

Табл. 9. Взаимосвязь живой массы с дополнительными промерами статей тела подопытного молодняка в возрасте 6 мес
Table 9. The relationship of live weight with additional measurements of body parts of experimental young animals at the age of 6 months

Correlatable characteristics	*r*			
	TB		AG	
	♂	♀	♂	♀
LW – HL	–0,467	–0,177	+0,463	+0,06
LW – FL	–0,232	–0,322	–0,303	+0,115
LW – FW	+0,229	+0,173	+0,241	+0,590
LW – EL	–0,452	+0,341	+0,516	–0,090
LW – EW	+0,192	–0,485	–0,224	+0,151
LW – NL	–0,177	+0,209	+0,394	+0,147
LW – NG	+0,553	+0,490	–0,046	–0,470

Табл. 10. Взаимосвязь живой массы с показателями толщины кожи подопытного молодняка в возрасте 6 мес
Table 10. Relationship between live weight and skin thickness in experimental young animals at the age of 6 months

Correlatable characteristics	*r*			
	TB		AG	
	♂	♀	♂	♀
LW – TCP	–0,223	+0,203	+0,363	–0,194
LW – RM–12	+0,398	–0,508	+0,049	+0,036
LW – SBC	–0,304	+0,156	+0,132	–0,071
LW – BCP	–0,424	+0,749	–0,422	–0,029
LW – SC	+0,469	+0,755	–0,739	–0,012

Positive correlation of live weight in experimental young animals at the age of 6 months was revealed with the height in the hips and the girth of the cannon bone. A distinctive feature is the weak to medium correlation of live weight with the length of head and neck length in medium-wool individuals. The average correlation between live weight and neck girth was found in the fine-wooled counterparts.

Based on the data obtained, we can conclude about the possibility of their use in breeding and pedigree work with fine-wool and medium-wool sheep of Transbaikal and Aginskaya breeds, which will make it possible to predict the effectiveness of breeding.

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ВЛИЯНИЕ ПРЕОБРАЗОВАННОЙ ЛУЗГИ ПОДСОЛНЕЧНИКА НА ФЕРМЕНТАТИВНЫЕ ПРОЦЕССЫ В РУБЦЕ ЖВАЧНЫХ ЖИВОТНЫХ *IN VITRO*

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Изучены процессы ферментации в рубце жвачных при использовании лузги подсолнечника, подвергнутой ультразвуковой обработке, в сочетании с фитобиотиками. В ходе эксперимента определяли образование конечных метаболитов в рубцовой жидкости, а также образование метана. Объектом исследования являлась рубцовая жидкость, которая отобрана у бычков казахской белоголовой породы в возрасте 12 мес средней массой 230–235 кг. Хроническая фистула рубца ($n = 3$) была установлена по методике А.А. Алиева. Методом *in vitro* при помощи прибора «ANKOM Daisy II» (модификации D200 и D200I) по специализированной методике проинкубированы следующие образцы: контроль (образец № 1): лузга, подвергнутая механическому измельчению, + гидромодуль (вода) + обработка УЗ при 20 °С, 15 мин, 27 кГц; образец № 2: образец № 1 + гамма-окталактон (0,25 мл); образец № 3: образец № 1 + кверцетин (10,0 мг); образец № 4: образец № 1 + 7-гидроксикумарин (2,0 мг). Каждый эксперимент проведен в пяти повторностях. Определены переваримость сухого вещества, концентрация летучих жирных кислот, образование азотистых метаболитов и концентрация метана. Полученные данные статистически проанализированы с использованием программного обеспечения. Получены новые данные о влиянии лузги подсолнечника совместно с фитобиотиками на образование конечных метаболитов в рубцовой жидкости. Установлено, что добавление биологически активных веществ гамма-окталактона, кверцетина, 7-гидроксикумарина способствовало повышению переваримости сухого вещества относительно контроля на 2,0% ($p \leq 0,05$), 3,1 ($p \leq 0,01$) и 4,3% ($p \leq 0,05$) соответственно. Отмечено повышение концентрации летучих жирных кислот и азотистых фракций при использовании данных веществ. Уровень концентрации метана был ниже, чем в контроле, при использовании 7-гидроксикумарина в образце № 4 на 10% ($p \leq 0,01$).

Ключевые слова: лузга подсолнечника, кавитация, рубцовая жидкость, фитовещества

EFFECT OF TRANSFORMED SUNFLOWER HUSK ON ENZYMATIC PROCESSES IN THE RUMEN *IN VITRO*

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Fermentation processes in the rumen of ruminants when using sunflower husk subjected to ultrasound treatment in combination with phytobiotics were studied. During the experiment, the formation of terminal metabolites in the ruminal fluid as well as the formation of methane were determined. The object of the study was the rumen fluid, which was selected from bulls of Kazakh white-headed breed at the age of 12 months with the average weight of 230-235 kg. Chronic rumen fistula ($n = 3$) was identified according to the method of A.A. Aliev. The following samples were incubated by *in vitro* method using the ANKOM Daisy II device (modifications D200 and D200I) according to a specialized technique: control (sample N 1): Mechanically ground husk + hydromodulus (water) + ultrasound treatment at 20 °C, 15 min, 27 kHz; sample N 2: sample N 1 + gamma-octalactone (0.25 ml); sample N 3: sample N 1 + quercetin (10.0 mg); sample N 4: sample N 1 + 7-hydroxycoumarin (2.0 mg). Each experiment was conducted in five replications. The digestibility of dry matter,

concentration of volatile fatty acids, formation of nitrogenous metabolites and methane concentration were determined. The data obtained were statistically analyzed using software. New data were obtained on the effect of sunflower husk together with phytobiotics on the formation of final metabolites in the rumen fluid. The addition of biologically active substances of gamma-octalactone, quercetin, 7-hydroxycoumarin was found to increase the digestibility of dry matter relative to control by 2.0 ($p \leq 0.05$), 3.1 ($p \leq 0.01$) and 4.3% ($p \leq 0.05$), respectively. An increase in the concentration of volatile fatty acids and nitrogenous fractions was noted when using these substances. The level of methane concentration was 10% lower than that of the control with 7-hydroxycoumarin in sample N 4 ($p \leq 0.01$).

Keywords: sunflower husk, cavitation, rumen fluid, phytomaterials

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INTRODUCTION

The development of technological solutions for the transformation of secondary raw materials, in particular sunflower husk, for its further use in growing and fattening cattle is a promising topic. With the expansion of cultivated areas in 2021, according to the preliminary results of the sowing campaign, the area of sunflower in Russia reached 9643.5 thousand hectares[1], which will increase the secondary product in the processing of sunflower seeds - husk. There are various ways to use sunflower husk, for example, it can be used as a nutrient medium [1]. There is evidence of the use of pre-treated sunflower husks as an additive to the soil, which improves its physical, chemical and hydrological properties [2]. Untreated sunflower husk was studied by introducing it into the diet of pigs. It was found that the content of nitrogen in the diet was the highest in the groups of pigs fed with sunflower husk [3].

The use of sunflower husks as a feed additive in agriculture was proposed in the work[2]. The specificity of the husk itself should be noted, which consists of 40% lignocellulosic fiber [4]. The presence of structural carbohydrates in the husk indicates that it can be used in feeding cattle, since only the rumen microorganisms of these animals are able to destroy them, except for lignin. It can be processed by fungi inhabiting the rumen [5-7]. Pre-cavitation treatment of sunflower husk improves its use as forage[3].

When the proportion of structural carbohydrates in the diet of cattle increases, the load on the entire digestive system increases, to a greater extent on the rumen [8, 9]. Special biologi-

[1]FSBI "Center of Agroanalytics" of the Ministry of Agriculture of Russia, Oilseeds Market. https://mcx.gov.ru/analytics/ https://specagro.ru/analytics/markets.

[2]Antimonov S.V., Solovyh S.Yu. Technology of obtaining feed mixtures and additives using non-traditional plant raw materials. Food technology: collected theses of the VIII All-Russian Conference of young scientists with international participation (Kazan, 2007). Kazan: Publishing House "Fatherland", 2007. 222 p.

[3]Bykov A.V., Kvan O.V., Duskaev G.K. The influence of cavitation processing on biotechnological aspects of feed application // International Conference on World Technological Trends in Agribusiness: IOP Conference Series: Earth and Environmental Science. 2021. P. 121–192. DOI: 10.1088/1755-1315/624/1/012192.

cally active substances (small molecules)[4] can be used to maintain its normal function. Previously, the use of biologically active substances and their effect on digestibility in animals were evaluated and a positive effect was noted [10].

The search for new technological solutions for the use of sunflower husks in combination with small molecules to process waste products and further feed them to ruminants is of particular interest.

The purpose of the study was to study the fermentation processes in the rumen of ruminants in an *in vitro* model using biologically active substances and sunflower husk.

MATERIAL AND METHODS

The object of the study was rumen fluid sampled from Kazakh white-headed breed steers with chronic rumen fistula (n = 3) established by the method of A.A. Aliev[5], the average weight of 230-235 kg at the age of 12 months. The studies were carried out using the Latin square method.

Animal care and experimental studies were performed in accordance with the instructions and recommendations of Russian regulation acts (Order No. 755 of the USSR Ministry of Health dated August 12, 1977 "On Measures for Further Improvement of Organizational Forms of Work with the Use of Experimental Animals") and "Guide for the Care and Use of Laboratory Animals" (National Academy Press, Washington, D.C., 1996). Measures have been taken to minimize animal suffering and to reduce the number of experimental specimens studied.

The following samples were incubated *in vitro* using the ANKOM Daisy II device (modifications D200 and D200I) according to a specialized technique (see Table 1).

Coumarin-IUPAC: 7-hydroxycoumarin, molecular formula - C9H6O3, molar mass - 162.144 g/mol; CAS: 93-35-6, 1391-97-5; quercetin dihydrate, 95+% AL33795-1, molecular formula is $C_{15}H_{10}O_7 \times 2H_2O$, molar mass is 338.3 g/mol; CAS: 6151-25-3. Gamma-octalactone: molecular formula - C8H14O2, molar mass - 142.20 g/mol; CAS: 104-50-7 were used for the study.

The studied substances were introduced directly into the rumen fluid. Sunflower husk was ground on a laboratory mill to a particle diameter of 1.0 mm. Then, a hydromodule of the product with water was prepared. The ultrasound parameters were chosen within 27 kHz, treatment time 15 min. The temperature of cavitation treatment of cellulose-containing mixtures was 20 °C. Distilled water was used as a dispersion medium. Each experiment was performed in three repetitions.

Laboratory studies were conducted at the Test Center of the Central Clinical Hospital of the Federal Research Center of Biological Systems and Agrotechnologies of the Russian Academy of Sciences. The level of volatile fatty acids (VFAs) in the rumen content was determined by gas chromatography on gas chromatograph "Kristallux-4000M", determination of nitrogen forms - according to GOST 26180-84.

After incubation, air samples were taken to determine methane levels on a Crystallux-2000M device by gas chromatography. The

Табл. 1. Качественный состав образцов
Table 1. Qualitative composition of samples

Sample No.	Qualitative composition
1 (control)	Husk: mechanical grinding + water + ultrasonic treatment at 20 ° C, 15 min, 27 kHz
2	Husk: mechanical grinding + water + ultrasonic treatment at 20 ° C, 15 min, 27 kHz + gamma octalactone 0.25 ml
3	Husk: mechanical grinding + water + ultrasonic treatment at 20 ° C, 15 min, 27 kHz + quercetin 10.0 mg
4	Husk: mechanical grinding + water + ultrasonic treatment at 20 ° C, 15 min, 27 kHz + 7-hydroxycoumarine 2.0 mg

[4]Karimov I., Kondrashova K., Duskaev G., Kvan O. Evaluation of effects of rumen fluid in combination with probiotic preparations and vanillin on the luminescence of a recombinant strain E. coli // E3S Web of Conferences. 2020. Vol. 143. P. 20–34. DOI: 10.1051/e3sconf/202014302034.

[5]Aliyev A.A. Operative methods of research of farm animals. L.: Kolos,1974. 61 p.

data obtained as a result of this study were statistically analyzed using SPSS software version 21.0[6].

RESULTS AND DISCUSSION

In the course of the studies, metabolome in the rumen fluid was studied based on the tests of sunflower husk subjected to ultrasound treatment, separately and in combination with biological active substances (see Table 1).

Indicators of feed digestibility and fermentation in the rumen are the main indicators of its selection in cattle diets. During the study it was established that the effect of ultrasonic treatment of husk with additional inclusion of gamma-octalactone during incubation increased the digestibility of dry matter by 2,0% ($p \leq 0,05$), with addition of quercetin - by 3,1 ($p \leq 0,01$), 7-hydroxycoumarin - by 4,3% ($p \leq 0,05$) (see Table 2).

The quality of feed cleavage by rumen microorganisms can be judged by the level of formation of volatile fatty acids. The maximum increase was found when 7-hydroxycoumarin was introduced (sample No. 4). Relative to the control (sample #1), the concentration of acetic acid in the rumen fluid increased by more than 99% ($p \leq 0,01$), propionic acid by 98,6 ($p \leq 0,01$), oily acid by 96,4, valerian acid by 85,2 and capronic acid by 92% ($p \leq 0,05$) (see Table 3).

During the enzymatic processes of microflora in the rumen, methane is formed, as a consequence of which energy loss occurs in the animal. When sunflower husk was evaluated, it was found that additional inclusion of 7-hydroxycoumarin in sample No. 4 contributed to a 10% decrease in methane formation ($p \leq 0.001$) compared to the control. The addition of gamma-octalactone to sample #2 and the introduction of quercetin to sample #3 increased the methane concentration by 44 ($p \leq 0.05$) and 67.7%, respectively, compared to control (see Table 4).

Табл. 2. Переваримость сухого вещества лузги подсолнечника *in vitro,* %

Table 2. Dry matter digestibility of sunflower husk in vitro, %

Sample No.	Digestibility
1 (control)	40,2 ± 0,11
2	42,2 ± 0,38*
3	43,3 ± 0,19**
4	44,3 ± 0,26*

*$p \leq 0,05$.
**$p \leq 0,01$.

Nitrogen metabolism in the rumen indicates the activity of microorganisms in the ability to ferment carbohydrates. The extent to which they are able to transform the feed will affect the formation of various protein fractions. In our study, the inclusion of 7-hydroxycoumarin in combination with sunflower husk exposed to ultrasound (sample #4) increased total nitrogen by 44.4% ($p \leq 0.01$), protein by 75.6 ($p \leq 0.05$), and ammonia by 58.8% ($p \leq 0.05$) relative to control. When gamma-octalactone was added to sample #2, the values for the nitrogen fractions were also higher than in the control, for total nitrogen by 39.8% ($p \leq 0.05$), protein nitrogen by 60.2 ($p \leq 0.01$), non-protein form nitrogen by 16.5%, ammonia form was higher by 63.7% ($p \leq 0.05$). The concentration of ammonia nitrogen in the samples No. 2-4 was approximately at the same level, with an average difference of 1.7% ($p \leq 0.05$) (see the figure).

Табл. 3. Концентрация летучих жирных кислот в рубцовой жидкости, моль/л

Table 3. Concentration of volatile fatty acids in the scar fluid, mol/l

Sample No.	Volatile fatty acids				
	Acetous	Propionic	Oleic	Valerianic	Capronic
1 (control)	0,016 ± 0,002	0,013 ± 0,003	0,012 ± 0,001	0,009 ± 0,002	0,008 ± 0,001
2	2,66 ± 0,22	0,18 ± 0,21	0,09 ± 0,006*	0,04 ± 0,06*	0,007 ± 0,001
3	2,06 ± 0,14	0,16 ± 0,08*	0,09 ± 0,011	0,02 ± 0,04*	0,09 ± 0,01
4	5,9 ± 0,08**	0,95 ± 0,012**	0,31 ± 0,014	0,06 ± 0,11	0,1 ± 0,08*

*$p \leq 0,05$.
**$p \leq 0,01$.

[6]SPSS. (2012). IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.

Табл. 4. Концентрация метана (CH_4) в условиях *in vitro*, моль/л

Table 4. Concentration of methane(CH_4) under *in vitro* conditions, mol/l

Sample No.	Methane concentration
1	0,02 ± 0,002
2	0,036 ± 0,002*
3	0,062 ± 0,002*
4	0,018 ± 0,001***

*$p \leq 0,05$.
***$p \leq 0,001$.

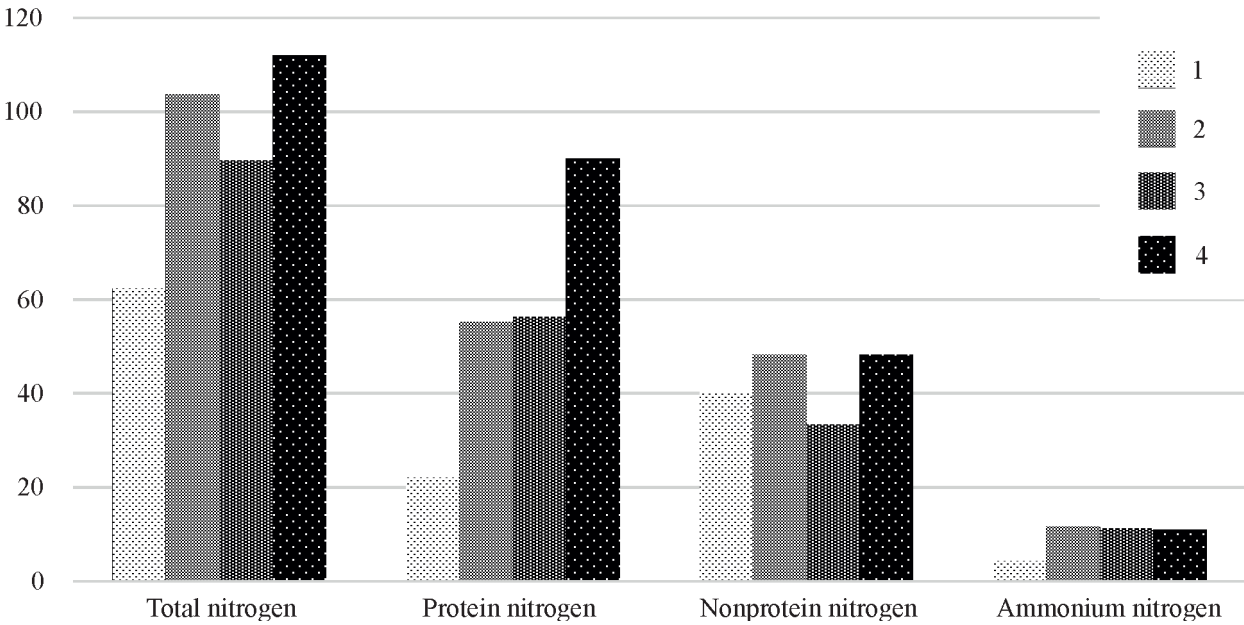
Analysis of the literature shows that similar studies have previously been conducted on the value of cocoa husks, one of the main by-products of the roasting process, in order to improve the extraction of compounds with high added value using ultrasound and hydrodynamic cavitation. These methods produce valuable extracts that are rich in the antioxidant flavanols (catechins and epicatechins), theobromine (32.7 ± 0.12 mg/g shell), caffeine (1.76 ± 0.08 mg/g shell) and cocoa butter [11].

In addition, the possibility of using activated ultrasound to clean hay from bacterial contamination was studied. The results showed that exposure to ultrasound for 60 seconds was able to remove bacterial contamination by 87.94% [12].

The results of *in vitro* animal studies are consistent with those obtained by other authors [13]. Thus, plant extracts can solve problems with improved digestibility, fermentation characteristics and reduction of greenhouse gas emissions to protect the environment. The leaves of *Azadirachta indica*, *Moringaoleifera*, *Ocimum gratissimum* and spices (the bulb of *Allium sativum*), rootstock of *Zingiber officinale* were used as additives in different concentrations (50, 100 and 150 µl) to corn substrate for biogas production in vitro. The plants had a pronounced mitigating effect on the pressure and volume of the biogas produced.

Herb and spice extracts as feed additives reduce methane production in the rumen and improve fermentation characteristics in West African dwarf sheep [14]. Replacing corn grain with soybean husks (agricultural residues) in the presence of *M. oleifera* extract can reduce greenhouse gas emissions and improve digestion in a study on buffalo steers [15].

In an experiment on beef cattle raised on feeding stations in Spain [16], six essential oils (tea tree - TetR, oregano - Ore, clove buds - Clo, thyme - Thy, rosemary - Ros and sage - Sag) in the experiment 1 and various combinations of selected oils in the experiment 2 were evaluated in four doses in an *in vitro* microbiological fermentation system using rumen fluid of beef



Концентрация азотистых метаболитов в рубцовой жидкости, мг/%

Concentration of nitrogenous metabolites in the scar fluid, mg/%

cattle obtained in the straw diet: concentrate (10 : 90). In the experiment 1, TetR, Ore, Clo, and Thy improved the rumen fermentation profile in the direction corresponding to better feed utilization. In the experiment 2, TetR mixed with Thy, Ore, Thy + Ore, or Clo at 200 and 400 mg/L increased the molar fraction of propionate and decreased the molar fraction of acetate as well as the ratio of acetate to propionate.

The effects obtained in the works described above are consistent with the results of our studies.

CONCLUSION

Evaluation of the secondary products of oilseed crops, in particular sunflower husk, as a feed for cattle showed that its pretreatment with ultrasound in combination with biological active substances (gamma-octalactone, quercetin, 7-hydroxycoumarin) increased the digestibility of dry matter from 2.0 ($p \leq 0.05$) to 4.3% ($p \leq 0.05$) compared to the control, and also increased the formation of volatile fatty acids and nitrogen fractions in the rumen content.

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ВЛИЯНИЕ ПРИЕМОВ ВОЗДЕЛЫВАНИЯ НА УРОЖАЙНОСТЬ КЛЕВЕРА ПАННОНСКОГО СОРТА ПРЕМЬЕР В ЛЕСОСТЕПИ ЗАПАДНОЙ СИБИРИ

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Проведены исследования по влиянию приемов возделывания на урожайность зеленой массы и структуру травостоя многолетнего кормового растения клевера паннонского Премьер в лесостепи Западной Сибири. Для исследования заложен трехфакторный опыт. Изучено влияние сроков посева весеннего под покров овса (II декада мая) и летнего беспокровного (II декада июля), способов посева – рядового (15 см) и широкорядного (60 см) и двух норм высева – 1 и 2 млн всхожих семян на 1 га. Показано, что на второй год жизни у клевера еще не формируется хозяйственно значимый уровень урожайности надземной массы вследствие биологических особенностей. В то же время именно в этот год прослеживается влияние разных приемов возделывания. Лучший результат получен при посеве весной рядовым способом – 35 ц сухой массы/га. При переходе растений во взрослое генеративное состояние, начиная с третьего года, отмечено возрастание урожайности на всех вариантах опыта до 80–100 ц/га за счет увеличения высоты и густоты стояния наиболее продуктивных генеративных побегов. Интенсивность побегообразования различалась по вариантам. Самая высокая отмечена на низкопродуктивных с наименьшим числом генеративных побегов второго года летних широкорядных посевах. Отмечена способность клевера паннонского к саморегуляции густоты стояния побегов в зависимости от площади питания. В результате к четвертому году жизни нивелировались различия по урожайности травостоя между весенним и летним сроками посева, низкой и высокой (1 и 2 млн шт./га) нормами высева, рядовым и широкорядным способами посева.

Ключевые слова: клевер паннонский, способы возделывания, генеративный и вегетативный побег, густота стояния побегов, урожайность зеленой массы, Западная Сибирь

INFLUENCE OF CULTIVATION METHODS ON THE PREMIER CULTIVAR OF HUNGARIAN CLOVER YIELD IN THE FOREST-STEPPE OF WESTERN SIBERIA

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Studies have been carried out on the influence of cultivation methods on the green mass yield and the herbage structure of the perennial fodder plant - Premier cultivar of Hungarian clover in the forest-steppe of Western Siberia. A three-factor experience was laid out for the study. The effect of the timing of sowing spring oats under a cover (II ten-day period of May) and summer coverless oats (II ten-day period of July), sowing methods - row (15 cm) and wide-row (60 cm) and two rates of seeding - 1 and 2 million germinated seeds per 1 ha was studied. It is shown that in the second year

of life, clover does not yet form an economically significant level of yield of aboveground mass due to biological features. At the same time, this is the year when the influence of different cultivation methods can be traced. The best result was obtained when sowing in the spring in a row - 35 cwt/ha of dry weight. In the transition of plants to the adult generative state, starting from the third year, an increase in the yield in all variants of the experiment to 80-100 c/ha due to the increase in height and density of the most productive generative shoots was recorded. The intensity of shoot formation differed by variants. The highest was noted on low-productive with the lowest number of generative shoots of the second year - summer wide-row crops. The ability of Hungarian clover to self-regulate the density of shoots depending on the feeding area was noted. As a result, by the fourth year of life, differences in herbage yield between spring and summer sowing dates, low and high (1 and 2 million pcs/ha) seeding rates, row and wide-row sowing methods were leveled.

Keywords: Hungarian clover, cultivation methods, generative and vegetative shoot, standing shoot density, green mass yield, Western Siberia

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INTRODUCTION

The search for optimal methods of cultivation of this or that crop is aimed at creating conditions conducive to the maximum manifestation of its biological potential. An important requirement for the created technologies is resource-saving. Based on these provisions, the use of perennial legumes in agricultural production, in particular in forage production, is relevant and promising. One such crop is Hungarian clover (*Trifolium pannonicum* Jacq.), the representative of the flora of South-Western and Eastern Europe (the eastern border of the areal is in the Carpathians). Due to its high ecological plasticity, it has been successfully introduced both in areas close to the places of its natural growth - Ukraine, Belarus, and in the remote areas - the Urals, Western Siberia [1,2] [1]. In addition to such positive properties as drought- and frost-resistance and low susceptibility to diseases and pests, Hungarian clover has a high shoot-forming capacity. If placed freely, by the age of 5-6 years it produces a shoot area up to 30-40 cm in diameter with a number of shoots over 200. The bush has both generative and elongated vegetative shoots. The ratio of the two depends on the weather conditions and, possibly, on the cultivation methods. Generative shoots, as a rule, are uniaxial with apical inflorescence, and can branch to 3-4 lateral shoots when well moistened [2]. Hungarian clover is not inferior to meadow clover in its fodder merits [3, 4]. To date, three varieties of Hungarian clover have been created in Russia: Premier (originators - Siberian Research Institute of Fodder Crops and Central Siberian Botanical Garden, Novosibirsk), Anik (Penza State Agricultural Academy), and Snezhok (N.V. Rudnitsky

[1]Ilina E.A. Growth, development and productivity of Hungarian clover (*Trifolium pannonicum* Jacq.) as an indicator of successful introduction in the Middle Urals. Ontogenesis of herbaceous polycarpic plants. Sverdlovsk, 1986. pp. 150-170.

[2]Kupenko N.P., Ostapko I.N. Introduction of Hungarian clover (*Trifolium pannonicum* Jacq.) to Donetsk Botanical Garden: Proceedings of VIII All-Russian Symposium on New Fodder Plants. Syktyvkar, 1993. pp. 92-93.

Zonal Research Institute of Agriculture for the North-East[3]) [5, 6].

As the studies have shown, the requirements of this crop for obtaining economically significant yields in different soil and climatic conditions vary[4] [7, 8].

For the forest-steppe zone of Western Siberia, optimal cultivation conditions for Premier Hungarian clover have not been sufficiently developed [9].

The purpose of the study is to examine the effect of cultivation methods on the yield and structure of Hungarian clover Premier herbage in the forest-steppe zone of Western Siberia.

MATERIAL AND METHODS

The experimental plot was located in the left-bank part of Priobskaya forest-steppe (Novosibirsk region) (geographical coordinates: N 54°54'34.0", E 083°00'35.0"). According to the agroclimatic zoning the territory belongs to the moderately warm, insufficiently humidified sub-area (GTC 1.0 - 1.2). The soil is gray forest clayey, poor in humus (1.70%), mobile phosphorus and exchangeable potassium - 0,65 and 18,4 mg/100 g, respectively. The reaction of the soil solution is neutral[5].

Three-factor experience was used for the study. The effect of the sowing dates of spring oats (II ten-day period of May) and summer coverless oats (II ten-day period of July), sowing methods - row (15 cm) and wide row (60 cm) and two rates of seeding - 1 and 2 million germinated seeds per 1 ha were studied. The area of the experimental plots is 40 m^2, triple repetition. Experimental material was statistically processed according to B.A. Dospekhov using Snedecor [6,7] software.

Observations of the crops were carried out for 7 years, starting from the establishment of the experiment in 2015. Vegetation seasons were varied. The most favorable conditions for moisture and air temperature were in the year of the experiment, as well as in 2017 and 2018. In 2016, 2019, 2020 and 2021 there was a lack of precipitation and increased air temperature in the spring and early summer, which had an adverse effect on clover development.

RESULTS AND DISCUSSION

Hungarian clover is a perennial crop, so in the first 2 years of its life its above-ground part develops slowly, since at this time the root system is intensively formed, which consumes up to 22% of the assimilants[8]. In our studies, during spring sowing under cover of oats harvested for green mass, clover experienced significant shading. Favorable moisture in the early summer in the year of sowing contributed to the powerful development of clover plants, which reached the height of 95-114 cm and yielded 46.6 c/ha of dry matter by the time of harvesting. By the end of vegetation 6-9 leaves were formed on the main shoots in the plants sown in spring, and some individuals proceeded to stemming, which influenced the increase in the average height of the plants to 12 cm. Tillering was almost not observed, only lateral buds were developed.

At the summer sowing term, plants reached a height of 8-9 cm by the end of the growing season, 5-6 leaves grew on the shortened main shoot, and the majority of plants showed tillering - formation of 3-4 side shoots. In terms of the number of plants per unit area, the spring sowing term under the influence of the cover

[3]Gripas M.N., Arzamasova E.G., Popova E.V. Introduction of Hungarian clover (Trifolium pannonicum Jacq.) in the European North-East of Russia. Actual and new directions in breeding and seed production of agricultural crops: Proceedings of the International Scientific-Practical Conference Vladikavkaz: Gorsky State Agrarian University, 2017. pp. 108-110.

[4]Penkina E.V. Productivity of pannon clover (Trifolium pannonicum Jacq.) depending on the methods of cultivation in the forest-steppe of the Middle Volga region: thesis abstract of the Candidate of Agricultural Sciences, Penza, 2010. 19 p.

[5]Yakutina O.P., Bogolyubova E.V., Nechaeva T.V., Smirnova N.V., Tanasienko A.A., Chumbaev A.S. Assessment of soil fertility when growing Hungarian clover (Trifolium pannonicum Jacq.) in the south of Western Siberia. Soil resources of Siberia: challenges of the XXI century. Tomsk: Tomsk State University Publishing House, 2017. pp. 230-234. DOI: 10.17223/9785946216453/54.

[6]Dospekhov B.A. Methodology of field experience. Moscow: Kolos, 1985. 267 p.

[7]Sorokin O.D. Applied statistics on the computer. Krasnoobsk: RPO SB RAAS, 2004. 162 p.

[8]Bagautdinova R.I. Photosynthesis, growth and productivity of Hungarian clover of different years of life. Growth, development and productivity of herbaceous fodder plants. Sverdlovsk, 1987. pp. 105-112.

crop was 1.5-2.0 times inferior to the summer coverless one. In the first year by the end of vegetation the best by the number of plants per unit area was summer row sowing at the increased (2 mln/ha) seeding rate. Row sowing was superior to wide-row sowing in both terms, but the difference was 1.5-2.0 times in summer sowing and 2-3 times in spring sowing.

In the second year of clover's life, the density of shoots sharply increased in all the variants. It was impossible to identify individual plants as a result of active spring tillering; only shoots were counted. Shoot formation was the most intensive in sparse spring sowings. The number of shoots increased here by 4.1-5.8 times compared with the first year, which reduced the difference with summer crops to insignificant. As before, row crops were 1.8-2.5 times more dense than broad-row crops, and high seeding rate was 1.1-1.3 times more dense than low seeding rate. In terms of total shoot density, our data differed significantly from those of the Middle Volga region. The number of stems in Hungarian clover crops in the second year was 558-758 pcs/m^2, or 1.5 times more than in our variants, and in the fourth year it reached 1117-2276 pcs/m^2 [9] [10].

Fundamental changes in the second year of clover's life occurred in the structural composition of the herbage. On spring sowings, the participation of generative shoots increased significantly - up to 21-34%. On summer sowings this indicator was only 7-16% (see table).

The greatest number of generative shoots was noted on spring row crops -119-126 pcs/m^2, on the same-named summer crops- only 48-56 pcs/m^2. The same trend was observed on broad-row sowing with a difference in the number of shoots - 51-64 units/m^2 at spring sowing and 16-17 units/m^2 at summer sowing.

According to the density of generative shoots, the herbage yield differed by vari-

Влияние агротехнических приемов на густоту стояния особей и побегов у клевера паннонского Премьер
The influence of agricultural practices on the individual and shoot density in the Premier cultivar of Hungarian clover

Seeding method	Seeding rate, mln/ha	Shoots						
		Clover year of life						
		1-st	2-nd	3-rd	4-th	5-th	6-th	7-th
Spring sowing date under the oat shelter (II ten-day period of May)								
Row (15 cm)	1	65	375 31,8	520 71,3	629 56,4	497 58,3	527 64,9	658 54,2
	2	102	401 31,5	665 69,0	685 51,5	602 54,1	555 54,9	696 47,0
Wide-row (60 cm)	1	34	188 34,0	404 65,3	541 61,3	502 68,9	437 67,4	552 57,7
	2	39	159 21,0	409 73,7	431 69,4	467 68,0	511 70,2	533 62,2
Summer coverless sowing (II ten-day period of July)								
Row (15 cm)	1	82	362 16,3	599 66,2	602 60,5	541 58,1	516 64,4	627 60,3
	2	156	458 10,6	658 62.6	650 55,9	541 55,5	584 57,5	683 55,1
Wide-row (60 cm)	1	61	201 8,2	460 68,8	502 65,9	499 68,1	504 69,6	545 68,9
	2	89	224 7,1	403 65,0	563 63,9	535 66,1	500 67,6	549 53,4
LSD $_{05}$		7,6	32,8	53,0	47,6	47,2	44,4	53,4

Note. Numerator is the total number of shoots, units/m^2, denominator is the share of generative shoots in the total composition of the herbage, %.

[9] *Куликов Д.И.* Приемы возделывания клевера паннонского в условиях Среднего Поволжья: автореф. дис. … канд. с.-х. наук. Пенза, 2009. 19 с.

ants of experience, since these two indicators closely correlate (r = 0.83). This can be explained by higher height and mass of generative shoots compared with the vegetative one. Thus, the mass of the generative shoot in Hungarian clover Premier in the second year of life was 1.52-2.05 g at a height of 45-54 cm. In subsequent years, when plants were in their adult generative state and reached a height of 80-100 cm, the weight of this type of shoot increased to 2.38-3.00 g. The weight of vegetative shoot varied insignificantly by years and amounted to 0.41-0.61 g. In the Middle Volga Region in Hungarian clover crops the weight of generative shoot did not exceed 1.0 g.

Differences in the density of generative shoots in the second year of life led to a significant difference in herbage yield by variants of experience. The highest harvest of aboveground mass was noted on spring row crops - 35 c/ha of dry matter, the lowest yield - on summer wide-row crops - 12-15 c/ha. In general, summer crops were 1.1-1.8 times inferior to the spring ones.

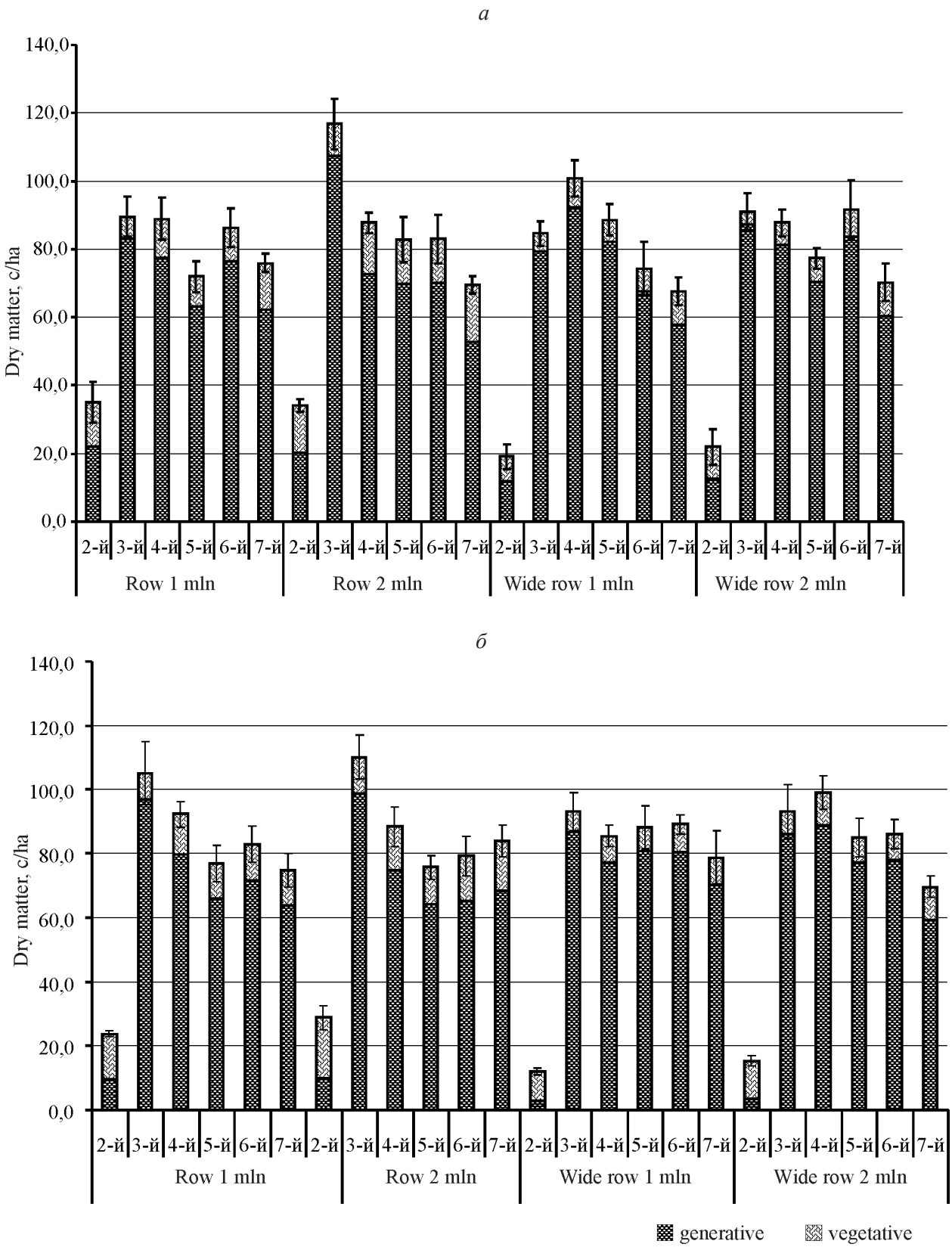
In the third year the yield of Hungarian clover crops increased in comparison with the second year by 2.5-7.8 times. The smallest increase was observed on the best variants of the second year - spring row crops, the largest - on the lowest productive variants of the previous year - summer wide row crops. As a result, the leveling of yield at different methods of cultivation was observed. Thus, the influence of sowing dates and seeding rates decreased to insignificant. There was still only the influence of the sowing methods - wide row crops were inferior to row crops - 90.4 and 105.3 c/ha, respectively.

The high yields in the third year of life reflected an explosive increase in the density of generative shoots. By variants the increase was uneven. In spring crops it increased 3-6 times, in summer crops - 7-20 times. The greatest increase was noted on summer wide-row crops with the lowest number of generative shoots in the second year. In the young generative age, clover's ability to achieve a stable balanced state in relation to feeding area and weather conditions was clearly demonstrated. In addition to the increase in the number of generative shoots, the high yield in the third year was promoted by favorable weather conditions - warm with sufficient moisture in the first half of the growing season (see the figure).

In subsequent years, the conditions of the beginning of the season were unfavorable. Lack of moisture in the spring months was accompanied by late return frosts, which had a negative impact on the development of the generative sphere on the row crops. Despite the fact that the total density of shoots by the fourth year of clover's life with this method of sowing still slightly increased, but the participation in their composition of generative shoots decreased by 21-27%, or from 370-450 to 290-325 pcs/m^2. At the same time, the number of generative shoots on broad-row crops, on the contrary, increased and equaled in density to row crops. This oppositely directed dynamics led to the leveling indices of green mass yield not only at different terms and rates of seeding, but also the methods of seeding - 81-85 kg of dry weight/ha.

Starting from the fourth year of clover's life there were no significant differences in the yield of green mass by the experimental variants. However, there was a gradual decrease by year of aboveground mass harvesting. Yield in the seventh year was only 73-85% compared with the most productive third year or 68-78 t/ha The standing density of the most productive generative shoots remained constant during these years at the level of the fourth year, and the drop in productivity, most noticeable in the seventh year, is explained by a decrease in the weight of the generative shoot from 2.00-2.30 to 1.70-1.90 g, which is most likely due to very unfavorable conditions at the beginning of the growing season.

Along with the equivalence of the variants in the yield of above-ground mass during the last years of observations, the difference in the structure of the herbage at different methods of sowing was noted. The increased proportion of vegetative shoots - 12-17% compared



Влияние приемов возделывания на урожайность зеленой массы клевера паннонского Премьер:
а – весенний срок посева; *б* – летний

Influence of cultivation methods on the Premier cultivar of Hungarian clover green mass yield:
а - spring sowing period; *б* - summer sowing period

with 8-10% on row crops was invariably preserved on row crops.

The study of agrotechnics of cultivation of Hungarian clover Premier in the forest-steppe of Western Siberia showed its good adaptability, sustainably high level of green mass yield for more than 5 years, while leveling the influence of different cultivation techniques over the years.

CONCLUSIONS

1. Economically significant yield of green mass of Hungarian clover Premier (80-100 centners of dry matter/ha) in the forest-steppe zone of Western Siberia is formed from the third year of life and is maintained at a high level for more than 5 years.

2. The ability of Hungarian clover Premier to self-regulate the density of shoots depending on the feeding area by the fourth year of life levels out the effect of terms, norms and sowing methods on the yield of green mass.

3. Against the background of no differences in the yield of above-ground mass under the influence of cultivation methods, a higher participation of vegetative shoots in the structure of Hungarian clover Premier herbage on the row crops compared to wide-row crops was noted.

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ПРОДУКТИВНОСТЬ КОРМОВЫХ АГРОЦЕНОЗОВ В УСЛОВИЯХ СЕВЕРНЫХ РЕГИОНОВ АРХАНГЕЛЬСКОЙ ОБЛАСТИ

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Исследования проведены в 2019–2021 гг. в условиях северной части Архангельской области. Цель исследований – изучение многолетних агрофитоценозов, состоящих из перспективных злаковых и бобовых трав, для улучшения кормовой базы в условиях северных регионов. Изучали травостои 3 лет жизни, сформированные из различных комбинаций злаковых и бобовых трав, определяли их продуктивность и участие компонентов травосмесей в формировании урожайности. Метеорологические условия в годы проведения исследований разнились. В 2019, 2020 гг. вегетационные периоды были избыточно увлажненными (гидротермический коэффициент (ГТК) 1,80 и 1,76), в 2021 г. период отмечен достаточно увлажненным (ГТК 1,38). Установлено, что в 1-й год жизни формирование урожая зеленой массы происходит за счет бобового компонента. При этом в структуре урожая клевера лугового содержится 73%, люцерны синей – 59–67%. В дальнейшем в фитоценозах наблюдают снижение участия бобовых трав в урожае, на 3-й год жизни содержание клевера лугового составило 15–20%, люцерна синяя выпала из травостоя. Травостой, состоящий из овсяницы тростниковой и клевера лугового, выделился как наиболее продуктивный. Двухукосное использование данного агрофитоценоза позволяет в первые 2 года интенсивного пользования получить от 10,71 до 11,41 т сухого вещества/га, 114,12–129,01 ГДж обменной энергии/га и 1,43–1,51 т сырого протеина/га. Как наиболее перспективная культура выделилась овсяница тростниковая. При выпадении люцерны синей из травостоя вариант опыта с овсяницей тростниковой превосходит контрольный вариант по урожайности сухого вещества и выходу обменной энергии.

Ключевые слова: многолетние травы, овсяница тростниковая, клевер луговой, урожайность, структура урожая, сбор протеина, питательность зеленой массы

PRODUCTIVITY OF FODDER AGROCENOSES IN THE NORTHERN TERRITORIES OF THE ARKHANGELSK REGION

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The studies were conducted in 2019-2021 in the conditions of the northern part of the Arkhangelsk region. The aim of the research is to study perennial agrophytocenoses consisting of promising cereals and legumes to improve the fodder base in the conditions of northern regions. Herbage grasses of 3 years of life formed from various combinations of cereals and legumes were studied, their productivity and participation of components of grass mixtures in the formation of yields were determined. Meteorological conditions varied during the years of the study. In 2019 and 2020, the growing seasons were excessively wet (hydrothermal coefficient (HTC) 1.80 and 1.76), in 2021, the period was noted as quite wet (HTC 1.38). It was found that in the 1st year of life the formation of green mass yield is due to the legume component. At the same time, 73% of red clover and 59-67% of alfalfa are contained in the structure of the crop. Later in the phytocenosis there is a decrease in the participation of leguminous grasses in the yield, in the 3rd year the content of red clover was 15-20%, alfalfa fell out of the herbage. The herbage, consisting of reed fescue and red clover, stood out as the most productive. Two-cuts use of this agrophytocenosis allows for the first 2 years of intensive

use to get from 10.71 to 11.41 t/ha of dry matter, 114.12-129.01 GJ/ha of exchange energy and 1.43-1.51 t/ha of crude protein. Reed fescue stands out as the most promising crop. When alfalfa falls out of the herbage, the experiment variant with reed fescue is superior to the control variant in dry matter yield and exchange energy yield.

Keywords: perennial grasses, reed fescue, red clover, productivity, crop structure, protein yield, nutritional value of green mass

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INTRODUCTION

The northern territories of the Russian Federation, including the Arkhangelsk region, are the regions where dairy cattle breeding is the leading branch of agricultural production. In this regard, there is a need to create a solid fodder base, which should be based on high-quality energy-full fodder of own production in sufficient quantity and at low cost [1-3].

Based on the fact that the natural and climatic conditions of the northern territories do not allow the cultivation of most high-energy crops, perennial grasses are of great importance. Due to the optimal ratio of metabolizable energy and protein in the dry matter, perennial plants are superior to other crops in terms of fodder. By saturating the forage area with perennial grasses, there is a decrease in the consumption and cost of forage per unit of production [4-7].

Introduction of perennial grasses in forage production contributes to rational nature management, fuller use of shallow contour of agricultural lands, management of sod process, improvement of physical, water and physical properties of soil, reduction of mineral fertilizers application, reduction of water and wind erosion of soil[1].

Perennial grasses are mainly represented by plants of the legume and cereal families. Legumes can be the most profitable feed due to their high protein content. However, because of their low sugar content and energy content, the sugar/protein ratio worsens and the efficiency of forage utilization decreases. Creating herbage from mixtures of cereals and legumes, in the structure of which the share of legumes should be at 40-50%, will make it possible to achieve an optimal ratio of protein and sugar in the feed [8-10].

Meadow clover is the main legume used in agrocenoses in the conditions of the north of Russia. The cereal component of grasses is

[1]Shpakov A.S., Bychkov G.N. Specialization of forest zone in the production of dairy and meat products and its environment-forming role in agroecosystems. Food security of agriculture in Russia in the XXI century. Zhuchenkov readings II: collection of scientific papers, vol. 11 (59). M.: Ugreshskaya printing house, 2016. pp. 69-77.

represented by meadow fescue, timothy grass, awnless bromegrass, meadow foxtail. Currently, the introduction of alfalfa into phytocenoses has become urgent. Studies conducted within the framework of expanding the assortment of fodder crops for the conditions of the Arkhangelsk region revealed a number of promising fodder crops to create highly productive grass stands. These included Hungarian clover, common alfalfa, reed fescue, oriental fescue, broad-leaved fescue, giant bentgrass, and burnet androgynous [11-13].

The purpose of the research is to study perennial agrophytocenoses consisting of promising cereals and legumes to improve the fodder base in the conditions of the northern regions of the Arkhangelsk region.

The research objectives are to study the phenology of perennial grasses in herbages of the first 3 years of life; determine the productivity of phytocenoses and participation of grass mixture components in the formation of yields; identify the most promising cereal-legume herbages.

MATERIAL AND METHODS

Perennial grasses were studied in the field experiment in 2019-2021. The place of the experiment was "Kholmogorskaya" Agrofirma" LLC, Kholmogorsky district, Arkhangelsk region. The research object was grass stands of cereal and legume perennial grasses represented by the following species and varieties: meadow fescue (*Festuca pratensis* Huds) Severodvinskaya 130; meadow clover (*Trifolium pretense* L.) Tayozhnik; reed fescue (*Festuca arundinacea* Schreb) Baltika; common alfalfa (*Medicaco sativa* L.) Kevsala.

Grass mixture was composed according to the following scheme: meadow fescue + meadow clover (standard); meadow fescue + common alfalfa; reed fescue + meadow clover; reed fescue + common alfalfa. Seeds of perennial grasses were included in the grass mixture in the following rates: meadow fescue - 7 kg/ha, meadow clover - 8, reed fescue - 6, common alfalfa - 6 kg/ha. The experiment was laid in four replications, the plot size was 10.5 m^2 (3.5 × 3.0 m).

The forecrop was an oatvetch mixture for silage with the percentage of legume and cereal components of 40 and 60%. Soil preparation consisted of discing in autumn, plowing in spring and cultivation before sowing. Legume grass seeds were scarified. Seeding was done manually on June 17-18, 2019, in a row-less manner with a row spacing of 15 cm. The soil of the experimental plot was sod-podzolic sandy loam, OM content - 3.15%, pH_{sal} - 5.2, P_2O_5 - 300 mg/kg soil, K_2O - 458 mg/kg soil.

Meteorological conditions of vegetation periods in the years of research were different (see Table 1). Throughout 3 years of research there was a shift of air temperatures towards increase, although in 2019 average daily air temperature in July and August differed from mean annual values by -1.9 and -1.6 °C, respectively. The greatest deviation from the mean annual value was noted in 2022 - in May (+4.2 °C) and June (+5.0 °C). Under the prevailing conditions the growing seasons 2019 and 2020 are marked as excessively humid (according to G.T. Selyaninov HTC_{2019} = 1,80 and HTC_{2020} = 1,76), the growing season in 2021 - quite humid (HTC_{2021} = 1,38). From the peculiarities of the weather conditions it is necessary to note several moments. In May 2020 the amount of precipitation exceeded the norm by 176% (+72.3 mm) with the formation of snow cover of 6 cm in height on the 13th of May. In 2021, against the background of high air temperatures in May and June, the drying of the upper layer of soil was observed, which remained until mid-August.

Experiment setting, observations, recordings, and sampling were carried out according to the methodological guidelines for field experiments[2,3]. Nutritional analysis of plant

[2]Dospekhov B.A. Methodology of field experience. Moscow: Agropromizdat, 1985. 351 p.

[3]Methodological guidelines for field experiments with fodder crops. Moscow: All-Russian Institute of Animal Husbandry, 1987. 198 p.

Табл. 1. Метеорологические условия вегетационного периода 2019–2021 гг.
Table 1. Meteorological conditions of the growing season 2019-2021

Indicator	Long-run annual average	2019	Departure	2020	Departure	2021	Departure
Average daily air temperature, °C	10,9	11,4	0,5	12,3	1,4	13,1	2,2
May	5,9	9,0	3,1	6,9	1,0	10,1	4,2
June	12,3	13,6	1,3	14,1	1,8	17,3	5,0
July	15,8	13,9	–1,9	17,3	1,5	17,3	1,5
August	13,2	11,6	–1,6	13,2	0,0	14,4	1,2
September	7,5	9,0	1,5	10,2	2,7	6,6	–0,9
Sum of precipitation, mm	294,0	370,7	76,7	408,3	114,3	270,2	–23,8
May	41,0	32,5	–8,5	113,3	72,3	37,7	–3,3
June	59,0	55,9	–3,1	32,0	–27	143,8	84,8
July	60,0	86,0	26,0	94,8	34,8	19,0	–41,0
August	73,0	96,7	23,7	92,7	19,7	48,9	–24,1
September	58,0	99,6	41,6	75,5	17,5	20,8	–37,2
Selyaninov HTC	–	1,80	–	1,76	–	1,38	–

samples was carried out by infrared spectroscopy[4]. To assess the energy nutrition of green mass of fodder crops the methodological guidelines for assessing the quality and nutrition of forages were used[5].

RESULTS AND DISCUSSION

Most perennial crops in the 1st year of their life do not reveal their full potential (see Fig. 1, 2). Thus, in our studies, none of the components included in the composition of herbage in the year of sowing passed the full life cycle. Emergence of sprouts was noted on the 10th day after the sowing. Counting of the plants that sprouted at the plots showed that the actual standing density of each species in the grass mixture was 3 mln pcs/ha, which corresponds to the calculated norm. Cereal grasses reached the "tillering" phase during the growing season, with plant height of 40 cm for meadow fescue and 35 cm for reed fescue, respectively. Development of meadow clover plants was completed at the phase of root rosette. The height of clover plants was 30 cm. Common alfalfa at a height of 45 cm reached the branching phase, weak flowering was noted. Mowing was carried out on 21 August 2019, at least 40 days before the onset of persistent frosts, so that the plants had time to grow and prepare for wintering. In the conditions of the area of research, which is equated to the Far North, stable frost starts from the second ten-day period of October. The degree of plant development directly affects the productivity of the phytocenosis. In the year of sowing, the dry matter yield was from 0.97 t/ha in the variant "common alfalfa + reed fescue" to 1.83 t/ha in the variant "meadow clover + meadow fescue". Analysis of the yield structure showed the predominance of legume components in the herbage. Meadow clover accounted for 73% irrespective of the experimental variant, and alfalfa - for 59% of the variant with meadow fescue and 67% of the variant with reed fescue.

From the 2nd year of life intensive use of perennial grasses begins, which implies their multicut use. In conditions of short vegetation period, typical for the area of research, optimal is the twocut use. Alienation of above-ground mass of plants was carried out according to the

[4]Methodical guidelines for assessing the quality and nutritional value of forages. M.: CINAO, 2002. 76 p.

[5]GOST 32040-12. Fodder, mixed fodder, feed raw materials. Method for determination of crude protein, crude fiber, crude fat and moisture content using near-infrared spectroscopy. Moscow: Standartinform, 2020. 7 p.

Рис. 1. Клеверо-злаковый травостой в 1-й год жизни
Fig. 1. Clover-cereal herbage in the first year of life

Рис. 2. Люцерново-злаковый травостой в 1-й год жизни
Fig. 2. Alfalfa-cereal herbage in the first year of life

phase of development of the dominant crop, which was determined by the method of eyeball estimation of the projective cover. Grass component dominated in the herbage with a projective cover in the 1st year of use from 55 to 75% and in the 2nd year of use from 60 to 100%. In both the 1st (70-75%) and 2nd (100%) years of use cereal grasses had the greatest projective cover in phytocenoses with common alfalfa. Mowing was carried out according to the development phase of cereal crops: the 1st mowing - at the "beginning of earing" phase, the 2nd - "tillering-booting", but not later than 30 days before the end of the growing season. In accordance with the phases of development of the cereal component, legume grasses were in the phase "beginning of budding" in the 1st harvest and "branching" in the 2nd harvest. The

first cut of the herbage with meadow fescue in the 1st crop year was made on 16 June, and in the 2nd crop year on 19 June. Grass stands with reed fescue in the 1st cut were cut on 22 June in the 1st year and on 24 June in the 2nd year. The second cut of the herbage with meadow fescue was made on 21 August in year 1, and on 24 August in year 2. Grasses with reed fescue were mowed for the second time during the growing season on August 20 (in the 1st year) and on August 26 (in the 2nd year).

Perennial herbage is composed of cereal and legume grasses, so the number of plants of different botanical families in the phytocenosis affects the yield of green mass, determines the yield of dry matter and nutrition. The percentage of leguminous and cereal grasses differed by variants and by the mowing (see Table 2).

Following the decrease in the projective cover of leguminous grasses there was a decrease in their content in the yield. Thus, in the control variant "meadow clover + meadow fescue" in the first year of use the ratio of legume and cereal components on average for two mowing was equal (1 : 1), in the second year this ratio was 1 : 4, the content of meadow clover in the green mass decreased by more than 2 times. When meadow fescue was replaced by reed fescue in the herbage (the 4th version) in the 1st year of use the ratio of legume and cereal components was on average 1 : 2.2, in the 2nd year of use this ratio was 1 : 5.6, the content of meadow clover decreased by fifty percent. In the variants of experiments where herbage consisted of cereals mixed with common alfalfa, in the 1st year of use the content of the latter in the yield of green mass was 6-8%, and in the 2nd year of use - not more than 1%. Thus, the participation of meadow clover in the formation of the crop decreases with increasing age of the grass stand. Common alfalfa fell out of the herbage after the first wintering, which led to the dominance of cereals.

The studied perennial grasses have different humidity of green mass, which provides different dry matter collection. The most productive agrocenoses both in the 1st year of use and in the 2nd year were grasses where reed fescue was the cereal component (see Table 3). The presence of meadow clover in this grass ensured a slightly higher dry matter yield than the presence of common alfalfa, although statistically the differences between these variants are insignificant. This pattern can also be traced by the conducted cuttings.

Grass mixture of common alfalfa and meadow fescue was characterized by the lowest yield among the variants both by years and by mowing. In assessing the overall dynamics of changes in the dry matter yield of grasses, it was noted that the most productive was the 1st cut of the 2nd year of use, and the 2nd cut in the same year, on the contrary, was the least productive, which is typical for all the studied agrocenoses. To increase the profitability of milk production the yield of the dry matter of

Табл. 2. Структура урожая, %
Table 2. Harvest structure, %

Option	Culture	1-st year of use			2-nd year of use		
		1-st cut	2-nd cut	Average	1-st cut	2-nd cut	Average
1	Meadow clover, standard	46	54	50	20	21	20
	Meadow fescue, standard	54	46	50	80	79	80
2	Alfalfa	8	7	8	1	1	1
	Meadow fescue	92	93	92	99	99	99
3	Meadow clover	29	33	31	10	21	15
	Reed fescue	71	67	69	90	79	85
4	Alfalfa	6	7	7	1	1	1
	Reed fescue	94	93	93	99	99	99

Табл. 3. Урожайность сухого вещества, т/га
Table 3. Dry matter yield, t/ha

Herbage	Herbage of the 1st year of use				Herbage of the 2nd year of use			
	1-st cut	2-nd cut	Total for 2 cuts	+/– to the standard	1-st cut	2-nd cut	Total for 2 cuts	+/– to the standard
Meadow clover + meadow fescue, standard	4,09	4,51	8,60	–	5,59	3,77	9,36	–
Alfalfa + meadow fescue	3,68	3,54	7,22	–1,38	5,19	2,12	7,31	–2,05
Meadow clover + reed fescue	6,18	5,23	11,41	+2,81	6,69	4,02	10,71	1,35
Alfalfa + reed fescue	5,92	5,14	11,06	+2,46	6,68	3,86	10,54	1,18
$LSD_{0,5}$	1,17	0,49	1,46	–	0,80	0,22	0,88	–

green plants should contain a sufficient amount of energy and protein.

Grasses with reed fescue were the most energy-intensive both in the 1st year of phytocenosis use and in the 2nd year (see Table 4). Grasses "meadow clover + reed fescue" produced the highest yield of metabolizable energy in the total for two cuttings: in the 1st year - 129,0 GJ/ha (+24% to the standard), in the 2nd year - 114,12 GJ/ha (+11% to the standard). The phytocenosis created from a mixture of common alfalfa and meadow fescue was characterized by the lowest energy intensity.

In the 1st year of use, the grass stand "meadow clover + reed fescue" stood out in terms of protein collection, where the yield increase was 0.22 t/ha compared to the control (see Fig. 3). In the 2nd year of use the leading position by this indicator was taken by the phytocenosis created on the basis of traditional grasses - meadow clover and meadow fescue. However, on average for 2 years of intensive use of grass mixture with meadow clover provides the same amount of protein regardless of the type of fescue used. The lowest collection of crude protein was characterized by the variant "common alfalfa + meadow fescue".

In the 2nd year of use the herbage was more productive in terms of crude protein collection. This may be due primarily to the higher

Табл. 4. Выход обменной энергии, ГДж/га
Table 4. Exchangeable energy output, GJ/ha

Herbage	Herbage of the 1st year of use				Herbage of the 2nd year of use			
	1-st cut	2-nd cut	Total for 2 cuts	+/– to the standard	1-st cut	2-nd cut	Total for 2 cuts	+/– to the standard
Meadow clover + meadow fescue, standard	44,42	54,03	98,45	–	62,20	39,25	101,45	–
Alfalfa + meadow fescue	39,39	37,17	76,56	–21,89	53,73	21,03	74,76	–26,69
Meadow clover + reed fescue	67,30	61,71	129,01	30,56	70,77	43,35	114,12	12,67
Alfalfa + reed fescue	62,57	57,27	119,84	21,39	69,98	40,98	110,96	9,51
$LSD_{0,5}$	12,69	5,67	16,02	–	8,57	2,30	9,36	–

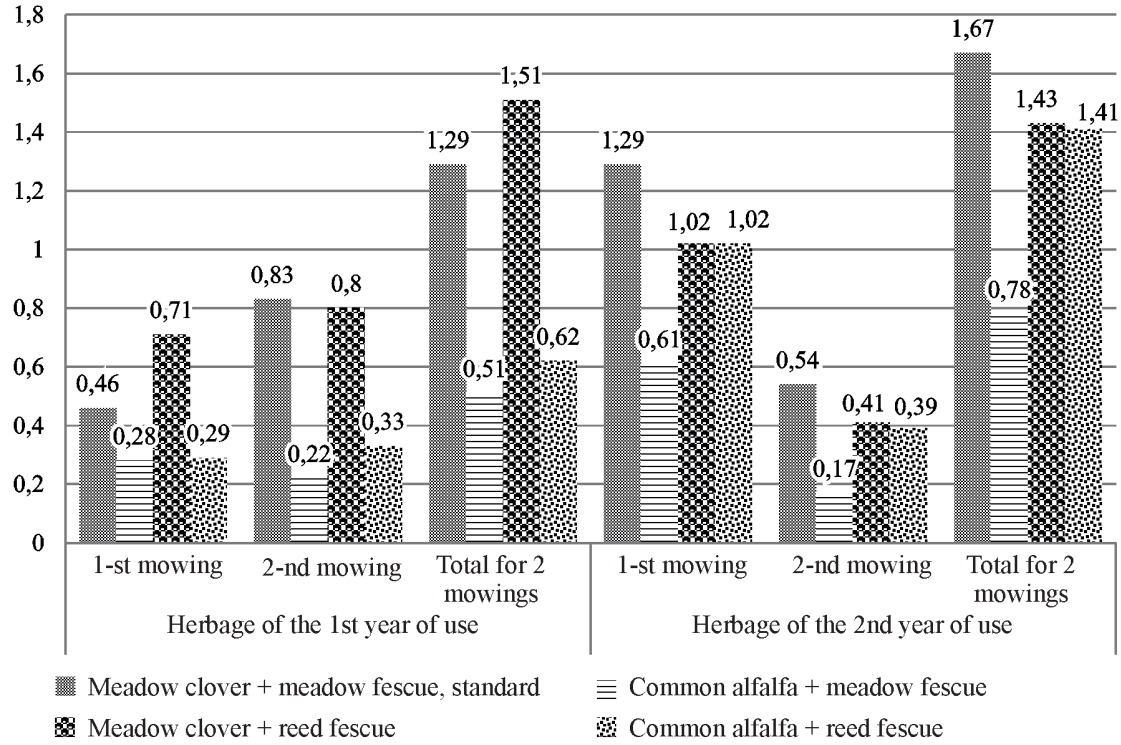

Рис. 3. Сбор сырого протеина, т/га

Fig. 3. Collection of crude protein, t/ha

average daily air temperatures in May and June 2021. In spite of the fact that the 2nd mowing of this year provided the minimum yield of protein, in the total of two mowings the 2nd year of use was more productive in almost all variants. The exception is the grass mixture of meadow clover and reed fescue, where the total values differed slightly by year.

CONCLUSION

In the study of cereal-legume perennial agrocenoses in the conditions of the northern districts of the Arkhangelsk region the grass stand consisting of a mixture of meadow clover with reed fescue was distinguished. In the first 2 years, such a phytocenosis ensures the dry matter yield from 10.71 to 11.41 t/ha (+1.35-+2.81 t/ha compared to the standard), the exchange energy yield from 1 ha 114.12-129.01 GJ (+30.56-12.67 GJ to the standard) and the crude protein yield from 1.43 to 1.51 t/ha.

It should be noted that during the 3 years of life of the studied agrocenoses we observed a decrease in the participation of leguminous grasses in the formation of biomass. In the structure of yield the content of meadow clover decreased from 73% in the 1st year of life to 15-20% in the 2nd mowing of the 3rd year, and common alfalfa fell out of the herbage in the 3rd year, although in the 1st year it comprised on average 63%. The sharp decrease in the proportion of common alfalfa in the herbage is primarily due to the influence of the climatic conditions during the overwintering period. The lack of zoned varieties and adaptive technology of cultivation of this crop for the region is also a negative factor.

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МЕТОДИКА ОБОСНОВАНИЯ ТЕХНИЧЕСКИХ СРЕДСТВ ДЛЯ ВОЗДЕЛЫВАНИЯ ЗЕРНОВЫХ КУЛЬТУР

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Представлена методика оценки почвообрабатывающих и посевных агрегатов с учетом почвенных и климатических условий хозяйств. Предложен комплексный показатель оценки работы посевных машин и комплексов при посеве зерновых культур, который учитывает производительность, топливную экономичность, качество посева и надежность выполнения технологического процесса к определенному моменту времени. Приспособленность агрегатов к техническому обслуживанию оценивается отношением производительности агрегата за основное время к производительности за сменное время. Показателем расхода топлива у агрегатов является отношение глубины обработки почвы, у сеялок – глубины посева к удельному расходу топлива. Качество обработки почвы оценивается показателями гребнистости и крошения почвы, полученными в результате испытаний, качество посева – отношением фактической нормы высева и глубины заделки семян к заданным по техническим условиям. В качестве показателя оценки надежности применяют интегральные функции распределения вероятностей безотказной работы в виде экспоненциального закона распределения. Для расчетов используют результаты агротехнической и экономической оценки, взятые из протоколов испытаний машин на машиноиспытательных станциях. На основании проведенных исследований предложены эффективные наборы машин для возделывания зерновых культур, которые отличаются низкими затратами, высокими качеством выполнения работ и надежностью. На первом месте оказались зерновые сеялки С-6ПМ2, СЗП-3,6Б, СЗР-5,4, AMAZONE D9-60 Super; посевные комплексы КСКП-2,1Д × 5 ОМИЧ, Кузбасс ПК-8,5, John Deere «730». Второе место заняли сеялки John Deere 455, ASTRA SZT-5,4, СКП-2,1 × 5, Pronto 12NT Хорш, DMC Primera 9000; посевные комплексы Иртыш-10, AGRATOR-combidisk-9000, Кузбасс ПК-9,7А.

Ключевые слова: сеялка, посевной комплекс, технологический процесс, комплексный показатель

TECHNICAL EQUIPMENT JUSTIFICATION METHODOLOGY FOR THE CULTIVATION OF GRAIN CROPS

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The article presents a methodology for evaluating tillage and seeding aggregates, taking into account soil and climatic conditions of farms. We offer a comprehensive assessment index of the

performance of sowing machines and complexes for sowing crops, which takes into account productivity, fuel efficiency, sowing quality and reliability of the technological process to a certain point in time. Unit serviceability is measured by the ratio of the unit's capacity during the main time to the capacity during the shift time. Fuel consumption indicator for machines is the ratio of tillage depth, for seeders it is the sowing depth to specific fuel consumption. Soil cultivation quality is assessed by indicators of ridging and crumbling of the soil, the quality of sowing by the ratio of the actual seeding rate and the depth of seeding to the given technical specifications. The integral functions of the distribution of probabilities of failure-free operation in the form of an exponential law of distribution are used as an indicator of reliability assessment. For calculations, the results of agrotechnical and economic evaluation, taken from the protocols of machine tests at machine test stations, are used. Based on the research, effective sets of machines for the cultivation of crops, which are characterized by low costs, high quality of work and reliability, were proposed. In first place were taken by the grain seeders S-6PM2, SZP-3,6B, SZP-5,4, AMAZONE D9-60 Super; seeding complexes KSKP-2,1D × 5 OMICH, Kuzbass PK-8,5, John Deere "730". The second place was taken by John Deere 455, ASTRA SZT-5,4, SKP-2,1D × 5, Pronto 12NT Horsch, DMC Primera 9000; seeding complexes Irtysh-10, AGRATOR-combidisk-9000, Kuzbass PK-9,7A.

Keywords: seeder, seeding complex, technological process, integrated indicator

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The authors declare no conflict of interest.

INTRODUCTION

The problem of technical modernization of agriculture has become particularly urgent in recent years. Its basis is the replacement of morally and physically obsolete tractors and working machines [1]. It is assumed that the more sizes of agricultural machinery that meet the requirements of agricultural production in different regions of the country will be produced by industry, the more completely the needs of farms can be met and the efficiency of their work increased [2]. New energy-intensive machinery makes it possible to expand the use of resource-saving technologies of agricultural production, at the same time, the extensive range makes it difficult to choose the technical means[1] [3-5]. One of the central tasks of providing agricultural enterprises with machinery is the choice of units that fully meet the soil and climatic conditions of the farm. The analysis of the works on the problem under consideration showed that insufficient attention is paid to the reasonable choice of the type of agricultural aggregate for farms of a particular zone. The choice of the optimal composition of units is carried out mainly by the minimum capital investment, the quality of their work is not taken into account [6]. When justifying agricultural units are based on existing technologies that reflect a list of options for technological operations. The work is done in accordance with typical methods of optimization of units of different types and purposes. In this case it is necessary to choose correctly the optimization parameters by selecting the most informative ones.

As a result of analysis of scientific and technical literature, there is no single criterion evaluating the performance of agricultural ma-

[1]Dokin B.D., Novoselov M.V. Assessment of energy costs in different technologies of cultivation of grain crops. Agrarian science to agriculture: Proceedings of the 15th International Scientific and Practical Conference in two volumes, Barnaul, 2020. pp. 25-29.

chinery, both individual working bodies and as part of the combined units [7]. In order not to complicate the calculations, the number of optimization parameters, which must be independent and sufficiently stable, must be minimized. For example, let us carry out the evaluation of sowing machines, because sowing of grain crops seeds is one of the important technological operations. Consequently, sowing units are represented by the most complex and expensive machines, on the quality of which the yield of the sown crop is dependent.

The purpose of the study is to develop a methodology for evaluating sowing units, taking into account the quality of their work.

The research objectives are to:

– select the most informative indicators of the integrated assessment of the work of sowing units during the sowing of grain crops;

– justify effective technical solutions that allow you to perform the work with high quality and at the lowest cost.

MATERIAL AND METHODS

For a comprehensive assessment of the work of sowing units it is necessary to determine the technology of cultivation of crops, the components of which are the technological operations. It is necessary to justify effective technological solutions, the most acceptable for a given zone, allowing to reduce total costs and increase the yield of grain crops through the full use of soil fertility, destruction of weeds and improving the quality of seeding. The compatibility of technology with zonal conditions, which determine the feasibility of specific technological solutions, is taken into account. The aggregate of evaluation indicators should include data on soil-climatic and production conditions of aggregates and complexes operation. The aggregate should include the following: the use of only soil-protecting technology; use of machine-tractor units only with tractors providing minimum pressure on the soil; the use of resource-saving technological methods, etc. Having chosen technology and justified effective technological solutions for the appropriate zone, you can begin to develop a flow chart, where the entire technological process of cultivation of crops must be painted by operations [8]. Each operation is carried out by a certain type of machines or units, which are currently represented by a wide range of models and individual types. In advertising brochures, each company presents its products in the best possible way, so it is a difficult task to understand what is needed for a farm with its soil and climatic characteristics. Many imported machines and complexes that work in the fields of Russia are tested at machine-testing stations (MTS), where their main agrotechnical and operational indicators are determined. However, the wide range of indicators does not allow determining the choice of a machine. In this regard, there is a need for one comprehensive indicator, which will assess the machines and units when carrying out agricultural work on the chosen technology[2] [9]. Comprehensive assessment of the unit performance when carrying out technological operations of cereal crops cultivation should be carried out taking into account a set of constraints and in accordance with the quality requirements of the technological process implementation. At the stage of evaluation of sowing units the following particular indicators are used: coefficient of machine use, which characterizes the ratio of machine productivity during basic time to machine productivity during shift time; specific fuel consumption related to the depth of tillage; evaluation of reliability of technological operation by a certain time; quality of technological operation performance. When assessing the quality of crop sowing the following particular indicators are used: seeding-down average depth, uniformity of distribution over the sowing area, non-uniformity of seeding by depth, etc. In view of this comment, the structure of indicators for assessing the technical level of machines and implements used in the performance of seeding crops is proposed. To assess the technical level of machines the matrixes of the type Table 1 are used. Relative values of the indicators are used to bring them to a dimensionless form.

[2]Yakovlev N.S., Nazarov N.N., Rassomakhin G.K., Markin V.V., Chernykh V.I. Technologies of sowing grain crops. Agrarian Science to Agriculture: Proceedings of XVI International Scientific-Practical Conference in two books, Barnaul, 2021. pp. 53-54.

The serviceability of machines is evaluated by the ratio of the productivity of the machine for the main time to the productivity for the shift time [10]. The machine evaluation index will be determined from the following formula

$$C(t) = \frac{Q(t)}{Q_m(t)}, \quad (1)$$

where $Q(t)$ is the productivity of the machine during the main time; $Q_m(t)$ is the productivity of the machine during the shift time.

Fuel consumption is estimated by the ratio of tillage depth to specific fuel consumption, for seeders - sowing depth to specific fuel consumption:

$$C_T(t) = \frac{h}{g}, \quad (2)$$

where h is the tillage depth, cm; g is the specific fuel consumption, kg/ha.

Soil cultivation quality is assessed by the indices of ridgeness $Cg(t)$ and soil pulverisation $C_K(t)$ (fraction size up to 25 mm), obtained as a result of tests on MTS, to the allowable technological requirements of STO AIST[3]:

$$C_Г(t) = \frac{D}{d}, C_K(t) = \frac{k}{K}, \quad (3)$$

where d is the height of ridges determined during testing of the machine at MTS, cm; D is the permissible height of ridges according to technological requirements and AIST, cm; k is the number of soil fractions up to 25 mm according to the results of tests at MTS, %; K is the number of soil fractions up to 25 mm according to agronomic requirements for soil treatment technology, %.

The quality of sowing is estimated by the ratio of the actual seeding rate and the depth of seeding to the specified specifications[4]. Due to the fact that the quality of sowing is assessed by the accuracy of seeding rate or depth of seeding, the deviation to a greater or lesser side will be considered a violation of agricultural requirements, so the following formula is used:

Табл. 1. Комплексная оценка работы сеялок и посевных комплексов
Table 1. Comprehensive evaluation of the work of seeders and seeding complexes

Tractor and machine make	Assessment relative index					Comprehensive assessment
	performance	fuel consumption	failure interval	seeding rate	seeding depth	
1	$\frac{Q_1^0}{Q_1^1}$	$\frac{h_1^0}{g_1^1}$	$\frac{P_1^0}{P_1^1}$	$\frac{p_1^0}{G_1^1}$	$\frac{h_1^0}{H_1^1}$	$\sum \delta_j \cdot q_i^j$
2	$\frac{Q_2^0}{Q_2^1}$	$\frac{h_2^0}{g_2^1}$	$\frac{P_2^0}{P_2^1}$	$\frac{p_2^0}{G_2^1}$	$\frac{h_2^0}{H_2^1}$	$\sum \delta_j \cdot q_i^j$
3	$\frac{Q_3^0}{Q_3^1}$	$\frac{h_3^0}{g_3^1}$	$\frac{P_3^0}{P_3^1}$	$\frac{p_3^0}{G_3^1}$	$\frac{h_3^0}{H_3^1}$	$\sum \delta_j \cdot q_i^j$
4	$\frac{Q_4^0}{Q_4^1}$	$\frac{h_4^0}{g_4^1}$	$\frac{P_4^0}{P_4^1}$	$\frac{p_4^0}{G_4^1}$	$\frac{h_4^0}{H_4^1}$	$\sum \delta_j \cdot q_i^j$

Note. $Q_i^j, h_i^j, P_i^j, p_i^j$ – values of the estimated factors; i – machine index; j – parameter index:

0 – obtained in tests, 1 – STO AIST (Agricultural Machinery and Technology Testers Association Standards) requirements; δ_j, – the coefficient of significance of the indicators in this evaluation system; q_i^j – o relative value of the assessment index.

[3]STO AIST 4.2-2010. Machines and implements for surface and shallow tillage. Methods of evaluation of functional indicators. Replacement of STO AIST4.2-2004. 15.07.2011. Moscow: Rosinformagrotech, 2012. 40 p.

[4]Tests of agricultural machinery. Methods of operational and technological evaluation: GOST R 52778-2007. Introduced on 13.11.2007. Moscow: Standartinform, 2008. 24 p.

$$C_P(t) = \frac{P}{G} \text{ или } C_P(t) = \frac{G}{p}, \quad (4)$$

where p is the actual seeding rate, kg/ha; *G* is the target seeding rate, kg/ha.

The integral probability distribution function of failure-free performance in the form of an exponential distribution is used as a measure of reliability [10]

$$C_N(t) = \frac{P_i(t)}{P_N(t)}, P_i(t) = e^{-\lambda_i t}, \quad (5)$$

where λ is the intensity of the flow of failures; *t* is the operating time of the machine per shift, h. The appearance of this distribution in reliability is related to the use of the Poisson distribution

$$P(m) = \frac{(\lambda t)^m}{m!} e^{-\lambda_i t}. \quad (6)$$

Suppose the segment [0; *t*] is empty, i.e., $m = 0$ (no point falls on the segment), but the Poisson distribution determines the probability of falling on the segment of some number of points, and "0" is not a number.

The intensity of the flow of failures λ and the parameter of the flow of failures ω have the following property: if the flow of failures is stationary, then $\omega(t) = \omega = {}_1\lambda$. The parameter of the flow of failures $\lambda = \frac{1}{T}$ 1T and the MTBF T characterize the reliability of the repaired product. The coefficient δi of the significance of the *i*-th parameter is understood as the degree of its influence on the general indicator of the technological process.

There are several methods to determine the coefficient of significance. The method of partial derivatives can be taken as the most acceptable in our case. We will determine the influence of the partial quality indicator on the main indicator by taking the full differential of the function *E*[5]:

$$dE = \frac{\partial E}{\partial y_1} dy_1 + \frac{\partial E}{\partial y_2} dy_2 + \frac{\partial E}{\partial y_3} dy_3 + ... + \frac{\partial E}{\partial y_i} dy_i. \quad (7)$$

The partial derivatives before the values of dyi can be regarded as a functional dependence with the main index *E*. Indeed, the weight coefficients of private quality indicators $y_1, y_2, \ldots, y_n$, associated with the expression dE/dy_i show how the system efficiency *E* changes when the private quality indicator y_i changes (with fixed values of other indicators), i.e. determine the degree of influence on the main indicator *E*. Based on the above, we can write: $bi = dE/dy_i$, where bi is the weight coefficient of the *i*-th quality indicator. By fixing the values of the other quality indicators, equation (7) can be written in the following form

$$dE = b_1 dy_1 + b_2 dy_2 + \ldots + b_n dy_n. \quad (8)$$

Equation (8) is a consequence of linearization of the function *E* at the point, the coordinates of which are $y_i = y_{i\,0}$, i = (1, *n*). The obtained expressions show that the weighting coefficients b_i depend on specific values of particular quality indicators yi, hence, they are also connected by certain dependences between each other:

$$b_i = f_i(y_{1,} y_{2,\ ...,} y_n). \quad (9)$$

Economic evaluation of the aggregates is the most important part in the cost of crop production. The main components are direct operating costs for the work to ensure the technological process and the yield of cultivated crops. In turn, direct operating costs per a unit of operating time (I, r./ha) are determined by the formula[6]

$$I = S + F + M + O, \quad (10)$$

where S - specific value of the maintenance personnel salary with all kinds of additional payments and deductions, p./ha; F - specific costs of fuel and lubricants, heat and electricity, p./ha; M - specific costs of maintenance, current and overhaul repair, storage of equipment, p./ha; O - other specific direct costs of basic and auxiliary materials, p./ha.

When making the assessment it is necessary to take into account the specific conditions of the application of this unit in relation to the natural and climatic zone, as well as take into

[5]Chumakov N.M., Serebryany E.I. Estimation of Efficiency of Complex Technical Devices. Moscow: Soviet Radio, 1980. 192 p.

account the requirements defined by the applied technology of cereal crops cultivation. Calculation of direct operating costs for the work of planting complexes and seeders on an area of 1000 hectares is made in accordance with the process charts.

When calculating operating costs, there is a question of the cost of the machine, instrument or a complex. Different vendors have prices that can differ greatly from the factory price and vary depending on the season and the demand, as well as inflation or other factors. Therefore, the prices of machines, instruments and complexes must be brought to a single denominator below which the price cannot fall. The simplest empirical way to calculate the cost of a machine is to find the price of the metal necessary to produce the product, and multiply that figure by five. The error in this case can reach 20-25%. The formula is only suitable for preliminary calculations with subsequent adjustment:

$$M_P = M_M \cdot M_P + S + T_S + O_C + P = \\ = 5 \cdot M_M \cdot M_P, \quad (11)$$

where M_M - mass of the machine (tool), tons; M_P - complex metal price, p./t; S - salary for the manufacture of a machine or tool with all kinds of surcharges, p.; T_S - the sum of taxes per machine, p.; O_C - the sum of overhead costs per machine, p.; P - enterprise profit of 20% from the sale of each machine.

In practice, the price of a machine is made up of five components, with the cost of wages to make the machine, as is the case in manufacturing, being equal to the cost of metal. The wages for the manufacture of components are also taken into account. The sum of all taxes (VAT, personal income tax, corporate income tax, insurance contributions to non-budgetary funds, corporate property tax, transport tax) is approximately equal to the amount of the wages. Overhead costs are accrued at the rate of 100% of the wages. In this regard, the cost of the machine or tool can be taken equal to five times the cost of metal used to manufacture the machine. In order to determine the price of a sowing unit, in view of the high intellectual investment in its manufacture, the calculated price must be increased by 2, applying a factor of 10. An example of the ratio of the calculated price of the sowing machines to the sales price in the market is presented in Table 2.

RESULTS AND DISCUSSION

Comprehensive assessment of the units during technological operations in the cultivation of grain crops was carried out taking into account the set of constraints and in accordance with the requirements of the quality of the technological process. When calculating the indicators, the data published in the protocols of the Altai and Siberian MTS were used. Relative indices of the aggregates evaluation during

Табл. 2. Пример расчета цены посевных машин
Table 2. Example of seeding machine price calculation

Machine make	Machine weight, t	Coefficient	Year	Metal price, thous.r/t	Machine price, thous.r/t		Error, %
					on the market	estimated	
SZP-3,6A seeder	2,84	5	2015	35	443	496	10,7
S-6PS seeder	2,30	5	2019	45	1237	1190	3,8
Seeding complex “Agrator-4800M”	2,40	10	2016	40	1050	960	9,4
Seeding complex “Kuzbass PK-8,5”	10,55	10	2018	40	3959	4220	6,2
Seeding complex “KPK-990AP”	12,63	10	2020	50	6205	6315	1,8

[6]ГОСТ 34393-2018. Техника сельскохозяйственная. Методы экономической оценки. Введ. 01.09.2019. М.: Стандартинформ, 2018. 15 с.

the performance of the corresponding types of work are presented in table 3.

For a comprehensive assessment of the entire nomenclature of indicators according to the MTS protocols, those whose coefficient of significance was equal to one were selected. The indicators included the following parameters: productivity of the machine during the main and shift time, specific fuel consumption, seed sowing depth, tillage depth, ridge height, uniformity of seed sowing by depth, deviation from the specified seeding rate, machine operating time to failure. The sum of indicators is a comprehensive assessment of the machine when it performs a certain type of work in the unit with a traction vehicle.

Calculation of operating costs for a particular type of work was carried out on a field of 1,000 hectares. The results of qualitative and economic evaluation of the machines are presented in Table 4.

Each aggregate, depending on the composite score, is assigned an appropriate rank (the first rank is assigned to the aggregate that has a

Табл. 3. Оценка качества работы сеялок и посевных комплексов при возделывании зерновых культур
Table 3. Evaluation of the quality of seeders and seeding complexes in the cultivation of crops

Tractor and machine make	Assessment relative index					Comprehensive assessment
	performance	fuel consumption	failure interval	seeding rate	seeding depth	
Grain seeders						
Pronto 12NT «Khorsh»	0,72	1,81	0,98	1,52	1,06	6,09
Ob-4-3T	0,67	1,20	1,24	0,98	1,00	5,09
SKP-2,1 × 5 K-701	0,70	1,68	1,22	0,97	0,97	5,54
S-6PM2	0,64	1,82	0,99	1,2	1,70	6,35
John Deere 455	0,51	1,65	1,27	0,99	1,08	5,50
SZR-5,4	0,63	1,96	1,20	0,99	1,04	5,82
AMAZONE D9-60 Super	0,66	1,05	1,31	0,98	1,25	5,25
ASTRA SZT-5,4	0,60	2,48	0,21	0,99	1,12	5,40
CASE IH-SD × 30	0,66	1,08	0,97	1,41	1,17	5,29
ASTRA + KD-720MK	0,74	0,83	1,30	0,94	1,03	4,84
SZP-3,6B	0,64	3,29	1,20	0,99	1,03	7,15
DMC Primera 9000	0,65	1,28	0,98	1,29	1,25	5,45
D9-60	0,72	2,22	0,26	0,98	1,05	5,23
Sowing machines						
Kuzbass PK-9,7	0,71	1,33	0,31	0,99	1,11	4,45
Kuzbass PK-9,7A	0,70	1,33	0,31	0,99	1,11	4,44
Kuzbass -T PK-9,7	0,72	1,03	0,45	0,99	1,16	4,35
Kuzbass PK-8,5	0,70	1,14	1,20	0,98	1,05	5,07
Tom PK-10,6	0,73	0,86	1,01	0,99	1,15	4,74
KPK -850MB	0,73	0,68	0,31	0,97	1,10	3,79
KSKP -2,1Д “OMICH” × 5	0,73	1,14	1,28	0,98	0,87	5,00
Irtysh -10	0,61	0,94	1,01	0,94	1,01	4,51
KPK-990MB	0,73	1,08	0,33	0,97	1,04	4,15
John Deere «730»	0,69	0,96	1,20	0,99	1,20	5,04
AGRATOR-combidisk-9000	0,66	1,06	0,80	0,99	1,12	4,63
AGRATOR-6000M	0,71	0,76	1,28	0,98	1,14	4,87
AGRATOR 11000	0,70	1,01	0,25	0,97	1,04	3,97

high score). The ranks are summed up to reveal the composite score. The unit that received the lowest total rank has an advantage in equipping the technological process according to the chosen technology.

When analyzing the results of Table 5, it should be noted that the seed drills S-6PM2, SZP-3,6B, SZP-5,4, AMAZONE D9-60 Super; seeding complexes KSKP-2,1D × 5 OMICH, Kuzbass PK-8,5, John Deere "730" took the first place. The second place was taken by John Deere 455, ASTRA SZT-5,4, SKP-2,1D × 5, Pronto 12NT "Horsch", DMC Primera 9000; seeding complexes Irtysh-10, AGRATOR-combidisk-9000, Kuzbass PK-9,7A. Such sowing machines as SZP-3,6 or SKP-2,1 were in the first place because they are easy to set up and affordable, but morally outdated and their performance no longer satisfies the consumer. For the final choice it is necessary to introduce the restrictions, which should take into account the requirements of the consumer (adaptability to the advanced technology, productivity per shift, ease of transportation, seed loading speed, the use of precision farming system, compliance with environmental requirements, etc.).

In conclusion, it should be noted that the optimization parameters for the choice of the agricultural machinery and complexes most appropriate for the area must be carefully chosen directly for the conditions of the area where they are planned for use, taking into account the requirements of the time and the market for agricultural products.

CONCLUSIONS

Табл. 4. Оценка качества работы сеялок и посевных комплексов при возделывании зерновых культур

Table 4. Evaluation of the quality of seeders and seeding complexes in the cultivation of crops

Tractor and machine make	Qualitative		Economic		Ranks sum	Rating position
	assessment	rank	assessment	rank		
Grain seeders						
Pronto 12NT «Khorsh»	6,09	3	579,3	11	14	5
Ob-4-ZT	5,09	12	407,4	8	20	7
SKP-2,1 × 5 K-701	5,54	5	356,8	7	12	4
S-6PM2	6,35	2	209,1	2	4	1
John Deere 455	5,50	6	287,7	6	12	4
SZR-5,4	5,82	4	268,0	5	9	2
AMAZONE D9-60 Super	5,25	10	162,0	1	11	3
ASTRA SZT-5,4	5,40	8	233,2	4	12	4
CASE IH-SDx30,	5,29	9	632,4	12	21	8
ASTRA + KD-720MK	4,84	13	419,9	9	22	9
SZP-3,6B	7,15	1	221,8	3	4	1
DMC Primera 9000	5,45	7	511,5	10	17	6
Sowing machines						
Kuzbass PK-9,7	4,45	8	898,4	10	18	7
Kuzbass PK-9,7A	4,44	9	863,7	8	17	6
Kuzbass -T PK-9,7	4,35	10	981,4	11	22	9
Kuzbass PK-8,5	5,07	1	843,5	6	7	3
«Tom» PK-10,6	4,74	5	1055,3	13	18	7
KPK-850MV	3,79	13	842,7	5	18	7
KSKP-2,1Д "OMICH" × 5	5,00	3	404,9	1	4	1
Irtysh -10	4,51	7	795,2	3	10	5
KPK-990MV	4,15	11	893,1	9	20	8
John Deere «730»	5,04	2	857,1	7	9	4
AGRATOR-combidisk-9000	4,63	6	805,1	4	10	5
AGRATOR-6000M	4,87	4	559,6	2	6	2
AGRATOR 11000	3,97	12	998,0	12	24	10

1. We offer a comprehensive assessment index of the performance of the sowing machines and complexes when sowing crops, which takes into account the productivity, fuel efficiency, sowing quality and reliability of the technological process by a certain point in time.

2. The most effective sets of machines for the cultivation of grain crops, which are characterized by low costs, high quality of work performance and high reliability of the machines, were offered. The grain seeders S-6PM2, SZP-3,6B, SZP-5,4, AMAZONE D9-60 Super; seeding complexes KSKP-2,1D × 5 "OMICH", Kuzbass PK-8,5, John Deere "730" took the first place. The second place was taken by seeders John Deere 455, ASTRA SZT-5,4, SKP-2,1D × 5, Pronto 12NT "Horsch", DMC Primera 9000; seeding complexes Irtysh-10, AGRATOR-combidisk-9000, Kuzbass PK-9,7A.

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КИНЕМАТИЧЕСКАЯ СХЕМА МЕХАНИЗМА И АЛГОРИТМ УПРАВЛЕНИЯ ШИРИНОЙ ВЫТЯЖНОГО ПРОЕМА КУЛЬТИВАЦИОННОГО СООРУЖЕНИЯ

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Приведены результаты теоретических исследований возможности снижения недостатка и избытка тепла в культивационном сооружении за счет обоснования параметров и алгоритма работы механизма управления шириной вытяжного проема в режиме реального времени. Разработана кинематическая схема плоского рычажного механизма управления шириной вытяжного проема с приводом от электрического линейного актуатора. Определены зависимости угла наклона ведущего звена механизма и ширины вытяжного проема от хода штока электропривода. Максимальная величина хода штока электропривода составляет 225 мм, что позволяет изменять ширину вытяжного проема от 0 до 900 мм. При этом угол наклона оси датчика положения ведущего звена механизма изменяется от 0 до 90 град. На основании анализа процесса работы механизма и требований растений к температуре окружающего воздуха разработан алгоритм управления шириной проема, предусматривающий три возможных ситуации. При условии соответствия температуры воздуха биологическим требованиям растений ширина вытяжного проема не изменяется. Если температура воздуха превышает верхний предел, то ширина проема увеличивается на величину, определяемую шагом изменения угла ведущего звена механизма. Если температура воздуха меньше нижнего предела, то контроллер включает линейный актуатор на уменьшение ширины проема. Это обеспечивает изменение угла наклона ведущего звена на величину шага *dA*, которая задается при программировании. Логические операторы сравнивают текущее значение угла наклона ведущего звена с расчетным и производят включение и выключение актуатора. Предлагаемый алгоритм осуществляет последовательное приближение состояния системы к зоне оптимума и реагирует на изменение внешних условий.

Ключевые слова: температура воздуха, приточно-вытяжная вентиляция, электрический линейный актуатор, кинематическая схема, алгоритм

KINEMATIC DIAGRAM OF THE MECHANISM AND ALGORITHM FOR CONTROLLING THE WIDTH OF THE INDOOR STRUCTURE EXHAUST OPENING

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The results of theoretical studies of the possibility of reducing the lack and excess of heat in the cultivation structure by substantiating the parameters and algorithm of the mechanism of real-time control width of the exhaust opening are presented. A kinematic diagram of a flat lever mechanism for controlling the width of the draft opening with a drive from an electric linear actuator has been developed. Dependences of the angle of inclination of the leading link of the mechanism and the width of the exhaust opening on the stroke of the actuator rod are determined. The maximum travel of the actuator rod is 225 mm, which allows you to change the width of the exhaust opening from 0 to 900 mm. In this case, the angle of the axis of the master link position sensor varies from 0 to 90 degrees. Based on the analysis of the operation process of the mechanism and the requirements of the plants to the ambient air temperature, an algorithm for controlling the width of the opening was developed, providing for three possible situations. As long as the air temperature meets the biological requirements of the plants, the width of the exhaust opening does not change. If the air temperature exceeds the upper limit, the width of the opening is increased by the value determined by the angle change step of the mechanism driving link. If the air temperature is less than the lower limit, the controller turns on the

linear actuator to reduce the opening width. This ensures that the tilt angle of the master link changes by the step *dA*, which is set during the programming. Logic operators compare the current value of the angle of inclination of the master link with the calculated value and switch the actuator on and off. Thus, the proposed algorithm consistently approximates the state of the system to the optimum zone and reacts to the changes in external conditions.

Keywords: air temperature, supply and exhaust ventilation, electric linear actuator, kinematic scheme, algorithm

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INTRODUCTION

A global trend in the development of vegetable production is the transition to energy-saving technologies and the relocation of areas of protected ground to the southern regions of the country [1-3]. Another way to reduce heat loss is the use of sheet and cellular plastic to manufacture the enclosing structures of cultivated buildings [4, 5].

Increasing the heat supply of the growing season is possible through the use of temporary cultivation structures. This provides a reduction of the impact of negative environmental factors and tomato yield of about 4 kg/m^2 [1] [6]. During the intervals when the air temperature does not fall below the biological requirements of plants, heat supply ceases to be a limiting factor, and high daytime temperatures create the danger of overheating. At this time, it is necessary to solve the opposite problem - to ensure removal of the heated air from the cultivation facilities by means of ventilation. The problem is that during the day it is possible to observe both lack and excess of heat inside the cultivation structure [7, 8].

The purpose of the work is to present the results of research on the reduction of shortage and excess heat by justification of parameters and algorithm of the real-time control mechanism of the exhaust aperture width.

Biological requirements of tomatoes to the air temperature are extensively studied and given in the literature [9-11]. The minimum air temperature at which the processes of plant growth and development take place should not be less than 15 °C, because at a lower temperature there are unfavorable conditions for pollen germination and fertilization. In addition, the ripening fruits do not take the characteristic coloring. An increase in the air temperature above 30 °C, especially with high humidity, promotes adhesion and sterilization of pollen, which leads to a decrease in the yield.

MATERIAL AND METHODS

To implement natural supply and exhaust ventilation, it is necessary to have two controllable openings: supply and exhaust.

The intensity of heat and mass exchange between the cultivation structure and the outside environment depends on the area of the exhaust opening and the speed of the ascending air flows.

The process of ventilation control consists in the automatic change of openings area depend-

[1] Tulupov Yu.K., Grinberg E.G., Ovchinnikov V.A. Vegetable production of Western Siberia: Monograph. Moscow: Kolos, 1981. 255 p.

[2] Yegiazarov A.G. Heating and ventilation of buildings and structures of agricultural complexes: monograph. Moscow: Stroyizdat, 1981. 239 p.

ing on the air temperature inside the cultivation structure[2] [2]. Application of hydraulic cylinders is the simplest and cheapest way to control ventilation opening. This method of ventilation control by means of thermal expansion of fluid contained in hydraulic cylinders is used in greenhouses, seed beds and other cultivation facilities. Regularities of the ventilation process for capital buildings and greenhouses are sufficiently studied[3] [12], but design features of temporary cultivation constructions limit their use and require additional research.

To study the parameters of the air flows in the shelters, a laboratory setup was used. Measurement of temperature and velocity the air flows were carried out in the planes of the inflowing and exhaust openings and inside the shelter using thermo-anemometers TTM 2-04. Additionally, the air temperature inside the shelter and the temperature of the hydraulic cylinder body surface were measured by installing temperature sensors DTS034-50M. To register and archive the results of the measurements a set of devices was used, which included a data acquisition module MSD 100, RS485-USB adapters and a notebook computer. The equilibrium condition between the heat influx from heaters and its removal was established at an air temperature in the shelter of about 30 °C and an exhaust opening width of 0.5 m. The duration of the period of reduction of the exhaust air temperature after switching off the heating is 45 min.

The use of hydraulic cylinders for the automatic drive of the draft opening width control mechanism steadily maintains the air temperature inside the structure during heating, but is ineffective during cooling due to high thermal inertia [13].

It is possible to reduce the influence of thermal inertia by using a drafting opening width control system with an electric linear actuator. On the basis of the requirements to the variation interval of the opening width and the capabilities of standard electric actuators, a kinematic diagram of the drafting opening width control has been developed (see Fig. 1). It is controlled by means of an electric linear actuator and a flat lever mechanism. The size of the drafting opening depends on the output of the actuator rail.

In the position where the rail is inside the actuator body, the vent opening is closed (see Fig. 1, a). The maximum extension of the rail corresponds to the full opening of the vent (see Fig. 1, b). Determination of the size of the exhaust opening is performed by measuring the

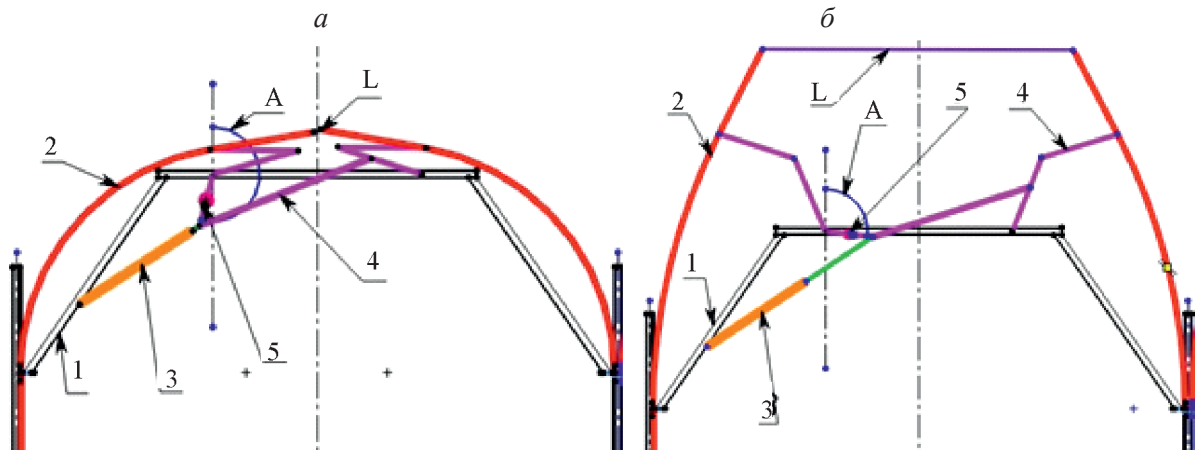

Рис. 1. Кинематическая схема управления вентиляцией:

а – вентиляция закрыта; *б* – вентиляция открыта; *1* – каркас укрытия; *2* – лист поликарбоната; *3* – электрический линейный актуатор; *4* – плоский рычажный механизм; *5* – датчик угла наклона рычага РТАМ 27; *A* – угол поворота рычага, *L* – ширина вытяжного проема

Fig. 1. Kinematic diagram of the ventilation control

a – ventilation closed, *б* – ventilation open; *1* – frame cover, *2* – polycarbonate sheet; *3* – electric linear actuator; *4* – flat lever mechanism; *5* – lever angle sensor RTAM 27; *A* – lever rotation angle; *L* – width of the exhaust opening.

[3]Panin B.G. Fundamentals of the theory of heat engineering, heating, ventilation, drying and cooling: monograph. Moscow: Light Industry, 1980. 380 p.

angle of rotation (A) of the leading link of the flat lever mechanism by means of the rotation angle sensor PTAM 27, the readings of which are transmitted to the data acquisition module MSD 200.

RESULTS AND DISCUSSION

Dependences of the tilt angle of the PTAM 27 sensor and the width of the draft opening on the stroke of the actuator rod were obtained graphically. The dependences graph is shown in Fig. 2, from which it follows that the dependences of the tilt angle of the PTAM 27 sensor and the width of the draft opening are linear and approximated by the equations of the first order. The width of the opening will be controlled by the logic controller. The maximum stroke of the actuator stem is 225 mm, which allows the drafting aperture width to be varied from 0 to 900 mm. At the same time, the inclination angle of the position sensor axis of the driving link of the mechanism changes from 0 to 90 deg.

The scheme of the aperture width control algorithm is shown in Fig. 3.

The algorithm for controlling the width of the opening has three options.

1. The air temperature in the cultivation facility is within the optimum zone. This is determined by the positive output of the logic operators comparing the measured temperature with the lower and upper limits of the optimum zone. In this case it is not necessary to change the opening width and the system is in the standby mode until the next temperature measurement after a time interval dt.

2. The measured air temperature is less than the lower limit (negative logical operator output). The controller turns on the opening closing actuator by the value of the lever angle dA, after which the system goes into the standby mode.

3. The temperature in the shelter is higher than the upper limit. The controller turns on the opening actuator by the angle of the lever dA, then the system goes into the standby mode.

The controlled parameters in the algorithm are dt - temperature measurement interval; dA - lever luffing step.

The temperature measurement interval is determined by the thermal inertia of the system. Thus, under the conditions of the laboratory experiment in 2018 significant changes in the width of the opening occurred in 5 min, in the

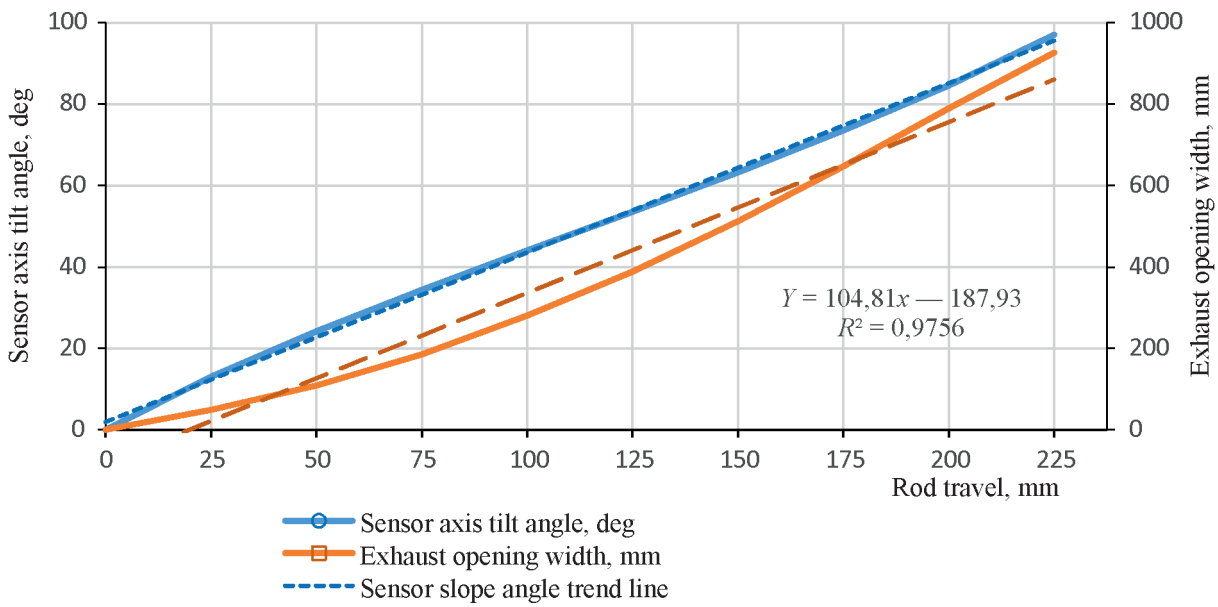

Рис. 2. Зависимости угла наклона оси датчика PTAM 27 и ширины вытяжного проема от хода штока актуатора

Fig. 2. Dependence of the angle of inclination of the axis of the sensor RTAM 27 and the width of the exhaust opening on the stroke of the electric drive rod

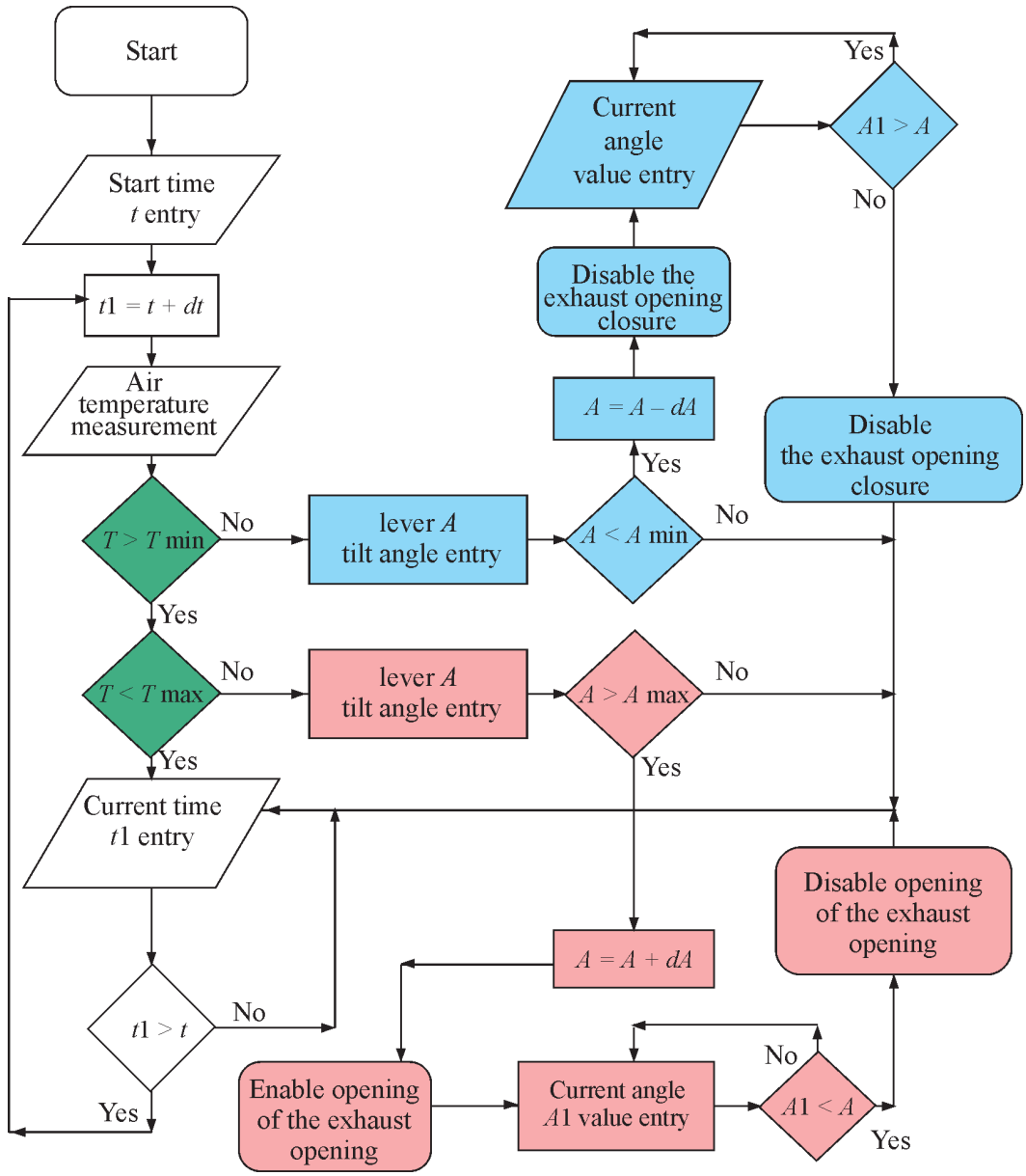

Рис. 3. Схема алгоритма управления шириной проема
Fig. 3. Diagram of the opening width control algorithm

open ground this parameter depends on the rate of change of external conditions and is on average 15 min. It follows from the construction of the scheme of the mechanism that $A_{max} = 90°$, $A_{min} = 0$.

CONCLUSION

Reducing the lack and excess of heat in the cultivation facility can be achieved by changing the width of the exhaust aperture from 0 to 900 mm. The kinematic scheme of the flat lever mechanism for controlling the width of the draft opening with the drive from the electric linear actuator with a stroke length of not less than 225 mm is developed. The algorithm of changing the draft aperture width depending on the air temperature inside the cultivation facility in real time mode is proposed. The obtained results can be used when designing a system of natural ventilation of a cultivation facility, ensuring consistent approximation of the air temperature to the biological requirements of plants.

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ЦИТОТОКСИЧЕСКОЕ ДЕЙСТВИЕ НАНОЧАСТИЦ ОКИСЛЕННОГО ГРАФЕНА НА БАКТЕРИАЛЬНЫЕ КЛЕТКИ

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Представлены результаты исследований внедрения нанотехнологий в различные сферы научной деятельности. В медицинской и ветеринарной практике перспективными считаются наночастицы различных форм углерода, так как они обладают широким арсеналом биомодулирующих эффектов на организм, проявляя незначительное экотоксическое и организмотоксическое воздействие. Большое значение для использования в медицине имеет их антибактериальное действие. Микроорганизмы являются одним из объектов изучения цитотоксических свойств новых лекарственных препаратов. Проведена оценка цитотоксического действия наночастиц окисленного графена на основные типы бактериальных клеток по результатам световой и атомно-силовой микроскопии. Световая микроскопия позволила установить, что действие субингибирующих концентраций наночастиц окисленного графена, достигнутое путем исследования колоний микроорганизмов на границе ингибиции их роста, может приводить к тинкториальной трансверсии у грамположительных микроорганизмов, в частности, золотистого стафилококка, в то время как у грамотрицательной кишечной палочки подобного феномена не отмечается. Методом атомно-силовой микроскопии установлено, что токсические концентрации наночастиц окисленного графена приводят к морфологической деградации, степень которой зависит от времени экспозиции наночастиц. При экспозиции в 30 мин наблюдали морфологическую деградацию клеток у основных типов бактерий (кокки, палочки), сопровождающуюся уменьшением контуров клеток. При увеличении экспозиции от 30 до 90 мин наблюдали полную морфологическую деструкцию бактериальных клеток и распад композиции бактериальной популяции. Цитотоксическая концентрация наночастиц окисленного графена составляет значение более 75 мкг·мл$^{-1}$, что установлено по результатам микроскопии образцов тестовых культур (*Escherichia coli* ATCC 25922 и *Staphylococcus aureus* ATCC 6538).

Ключевые слова: наночастицы, окисленный графен, световая микроскопия, атомно-силовая микроскопия, бактериальная морфология

THE CYTOTOXIC EFFECT OF GRAPHENE OXIDE NANOPARTICLES ON BACTERIAL CELLS

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The results of research on the introduction of nanotechnology in various fields of scientific activities are presented. In medical and veterinary practice, nanoparticles of various forms of carbon

are considered promising, because they have a wide arsenal of biomodulatory effects on the body, exhibiting little ecotoxic and organismotoxic effects. Their antibacterial effect is of great importance for the use in medicine. Microorganisms are one of the objects of study of the cytotoxic properties of new medicinal products. The cytotoxic effect of oxidized graphene nanoparticles on the main types of bacterial cells was evaluated by light and atomic force microscopy. Light microscopy allowed to establish that the effect of subinhibitory concentrations of nanoparticles of oxidized graphene, achieved by studying the colonies of microorganisms on the border of their growth inhibition, can lead to tinctorial transversion in Gram-positive microorganisms, in particular Staphylococcus aureus, while in Gram-negative E. coli such a phenomenon is not observed. Using the method of atomic force microscopy, it was found that toxic concentrations of oxidized graphene nanoparticles lead to morphological degradation, the degree of which depends on the exposure time of nanoparticles. Morphological degradation of cells in the main types of bacteria (cocci, bacilli), accompanied by a decrease in cell contours, was observed at 30 min exposure. When the exposure was increased from 30 to 90 min, complete morphological destruction of the bacterial cells and decay of the bacterial population composition were observed. The cytotoxic concentration of oxidized graphene nanoparticles is more than 75 $\mu g \cdot ml^{-1}$, as determined by the results of microscopy of test culture samples (*Escherichia coli* ATCC 25922 and *Staphylococcus aureus* ATCC 6538).

Keywords: nanoparticles, graphene oxide, light microscopy, atomic force microscopy, bacterial morphology

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INTRODUCTION

Rapid development of nanotechnology has led to the production of large quantities of nanoparticles and their further distribution in the environment. Due to their unique properties resulting from their nanoscale dimensionality, nanoparticles are of great interest in the veterinary and medical fields. However, there are opinions about their potential adverse effects both on the ecology and living organisms in general, and on individual cells in particular.

The main component of the biosphere is considered to be microorganisms, which ensure both the integrity of the entire biosphere and the well-being of its constituent macroorganisms, so the nature of the effects caused by nanoparticles on bacteria can be considered the primary indicator of ecotoxic effects on the biosphere.

Numerous works by researchers have established that cellular effects under the action of nanoparticles have a strong dependence on many parameters of the latter, such as their size, charge, shape and chemical nature, but also differ depending on the cell type and environmental conditions [1]. In this regard, it seems crucial to study the nature of nanoparticle-cell interactions in order to ensure the safe and innovative development of nanotechnology in medicine and ecology, including the possibility of using nanomaterials-based drugs as an alternative to antibiotics for specific and effective influence on bacteria [2].

The specific mechanism of the cytotoxic effect of nanoparticles on the bacterial cell is always multifaceted and can include the destruction of bacterial membranes [3], the production of reactive oxygen species [4], and other effects on metabolism [5]. In most of

the previous studies, the authors, including their own works [6-8], studied the physiological characteristics of bacterial viability and enzymatic activity to assess the cytotoxic effect of nanoparticles using available culturing techniques with colony forming units (CFU) counts or bacterial population densities. In all cases, the direct cytotoxic effects remained unobserved. In most of the works, researchers, including the authors of this article, used the most recognized cytotoxic nanomaterials, in particular, noble metal (silver) nanoparticles with a proven strong antibacterial effect.

However, whatever the mechanism of antibacterial action of nanoparticles, their initial effect is based on the contact between the outer cell membrane of the cell and the nanocomponent. All subsequent modifications of the morphological characteristics of bacterial cells and the composition of the whole bacterial population reflect the cytotoxic action of this nanomaterial. Recently, there has been considerable interest in carbon nanomaterials due to a number of unique properties, low cost and availability of their synthesis. Of these, oxidized graphene is a derivative of graphene, which is considered one of the most promising materials in biomedical research. In particular, it is known as an antimicrobial nanocomponent with satisfactory biocompatibility. On the other hand, this nanomaterial has acceptable physical parameters valuable for biomedical use. Thus, graphene oxide contains various functional groups, such as hydroxyl, epoxy and carboxylic groups, which ensure its good solubility in water. Although the stability of oxidized graphene colloids is not always sufficient, which limits their wide use, the authors' research in this field allowed the synthesis of nanosized colloidally stable forms of this material [9].

One of the modern methods of morphological evaluation of microorganisms is atomic force microscopy. Its use in microbiology makes it possible to obtain objective information on the physical parameters of the microobjects under study, assess their morphological characteristics and visualize the compositions of the entire bacterial population. In addition, traditional methods of assessing the tinctorial properties of bacteria, in particular, Gram staining, which makes it possible to determine the features of the chemical structure of the cell wall, which is considered to be the main barrier of interaction of a microorganism with the external environment, based on the gram identity of the studied microorganism culture, remain informative until now.

Previously, the antibacterial action of nanoparticles of different forms of carbon has been studied and evaluated [10], in which a different degree of bacterioinhibitory action was established. It depended largely on the nanomaterial shape, size and colloidal stability, i.e., it had a pronounced integral character. Early works of many researchers, including the authors of this article, evaluated the cytotoxic effect of nanoparticles on bacterial cells by atomic force microscopy, but in all cases they used little biocompatible materials, particularly silver or copper nanoparticles, which suggested a strong cytotoxic effect, but was also a strong obstacle to their wide use in medicine. The availability of nanomaterials based on the basic bioelement carbon offers great opportunities in biology, but the issue of their toxic effect on the cell remains understudied.

The purpose of the research is to study the effect of oxidized graphene nanoparticles on bacterial cells of the main representatives of opportunistic microbiota (*Escherichia coli* and *Staphylococcus aureus*) using atomic force and classical light microscopy.

MATERIAL AND METHODS

A sample of colloidal solution of oxidized graphene with stable physical and chemical parameters, prepared according to the method [9], was used as a test nanomaterial with the assumed cytotoxic effect. The initial concentration of nanoparticles in the sample was 600 μg-mL^{-1}, their average diameter was in the range of 100-120 nm. Different concentrations of the colloid test sample were used in the ex-

periments, which (after addition to the bacterial culture) had the following values: 300 μg-mL^{-1}, 150 μg-mL^{-1}, 75 μg-mL^{-1}, and 35 μg-mL^{-1}.

The microorganisms under study were 18-h bacterial cultures of two microorganisms (*Escherichia coli* ATCC 25922 and *Staphylococcus aureus* ATCC 6538) as representatives of the most widespread opportunistic microbiota belonging to different bacterial classes (Gram-negative bacilli and Gram-positive cocci). The test microorganisms were cultured in the Mueller-Hinton broth. After that, additional cultivation on the agar of the same name with the addition of oxidized graphene nanoparticles was performed. For this purpose, after the broth culture was distributed on the surface of the agar in a Petri dish, holes were made in its thickness with a sterile puncher 5 mm in diameter, into which 0.1 ml of the test sample of colloidal solution of oxidized graphene nanoparticles was introduced. Tinctorial properties of microorganisms were evaluated by the results of the Gram staining.

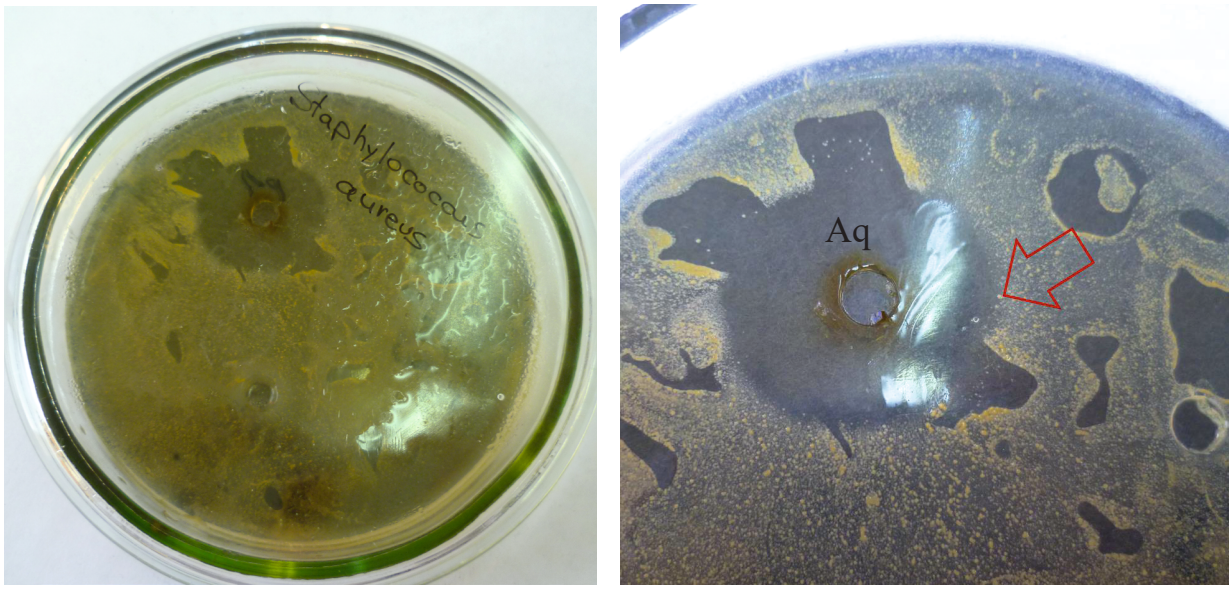
For atomic force microscopy (AFM), we performed fixation of broth bacterial cultures on mica, the thinnest layer of which was prepared by applying scotch tape. Before application to the substrate surface, the tested bacterial cultures were exposed to colloidal solutions of oxidized graphene for 30 and 90 min, after which they were deposited on mica by droplet precipitation in an amount of 5 μl by micropipetting. The sample under study was dried by natural evaporation. The prepared micropreparations were placed in an atomic force microscope connected through an interface to a functional computer with a working version of the AFM imaging software installed. Atomic force microscopy visually assessed the integrity of the bacterial cell, its surface composition, and the structure of the bacterial population.

RESULTS AND DISCUSSION

After the initial cultivation of test microorganisms on the Mueller-Hinton agar with a solution of oxidized graphene nanoparticles added to the cut well, colonies were selected at the border of the bacterial growth inhibition zone, where the subinhibitory concentration of nanoparticles was expected (see Fig. 1). As a control, microbial colonies were selected at the maximum distance from the place of nanoparticle application, where the minimum amount of nanoparticles was expected. After bacterial culture was selected, micro preparations were prepared, fixed chemically, and stained by the Gram method in the standard technique. The study of morpho- tinctorial characteristics of the test microorganism cultures made it possible to evaluate the cytotoxic effect of the oxidized graphene nanoparticles at a concentration close to the bacterioinhibitory (at the edge of the growth inhibition zone) in comparison with its minimum value (at the periphery of growth).

The preservation of typical morphological properties of *Escherichia coli* and *Staphylococcus aureus* (short sticks and cocci, respectively) was noted during light microscopy of micro preparations. However, an unusual phenomenon of tinctorial transversion of Staphylococcus aureus culture was noted during Gram staining, in which it changed its identity from Gram-positive partially to Gram-negative. This phenomenon had a clustered nondense character, which was noted only in the micropreparations of cultures sampled at the edge of the bacterial growth inhibition zone, where a paraletic concentration of nanoparticles was expected. No such phenomenon was observed in E. coli cultures, but this microorganism is among Gram-negative.

Fig. 2 shows microphotographs of preparations of Staphylococcus aureus colonies sampled at the edge of the growth inhibition zone, in which massive clusters of bacteria with altered tinctorial properties are evident. At the same time, such tinctorial dissociation was not noticeable in the control, and a typical morphological pattern characteristic of typical strains of *Staphylococcus aureus* ATCC 6538 was observed (see Fig. 3).



а *б*

Рис. 1. Ингибиция роста культуры *Staphylococcus aureus* ATCC 6538 на среде Мюллера-Хинтона:
а – колония культуры микроорганизма при локальном добавлении водного раствора наночастиц окисленного графена (лунка обозначена буквами Aq); *б* – колония культуры микроорганизма, отобранная для микроскопического исследования

Fig. 1. Growth inhibition of *Staphylococcus aureus* ATCC 6538 culture on Muller-Hinton agar:
a - microbial culture colony with local addition of an aqueous solution of oxidized graphene nanoparticles (the well is marked with the letters Aq); *б* - microbial culture colony, selected for microscopic study

It should be noted that such a phenomenon of changes in tinctorial properties in Gram-positive microorganisms under the action of cytolytic toxins has been little described in the literature, which reflects the lack of attention of researchers to light microscopy as a tool for assessing the biological properties of bacteria.

It is commonly known that, Gram staining is the basic method of examination in microbiology, in which microorganisms are divided into two groups depending on the composition of the cell wall and the content of peptidoglycan in it. Peptidoglycan is the main component of the bacterial cell wall in both Gram-positive and Gram-negative bacteria. This muropeptide can be modified under the action of bacterial glycolytic and peptidolytic enzymes (hydrolases) or cytotoxic substances called autolysins. Modifications or variations of the basic structure of peptidoglycan are found among all species of microorganisms, but are most obvious among Gram-positive bacteria, based on its much higher content. Many modifications are specific because of the action of unique modifying or lysing enzymes.

In addition, the peptidoglycan structure can also be disrupted in response to changes in cultivation conditions, in particular, in the presence of toxic substances, especially those whose mechanism of action targets the cell wall [11]. In any case, we did not set out to establish the true mechanism of tinctorial transversion in Staphylococcus aureus culture, but taking into account the fact that the bacterial grammars are determined by the cell wall composition, it can be concluded that oxidized graphene nanoparticles affect this cell structure, and its sublethal concentrations significantly disrupt its composition.

Atomic force microscopy allowed to visually assess the nature of morphological changes in the bacterial cells and the entire bacterial population, caused by the toxic effects of the oxidized graphene nanoparticles. Control samples of bacterial cultures under AFM visually corresponded to the typical morphology and size of cocci and bacilliform microorganisms (see Fig. 4).

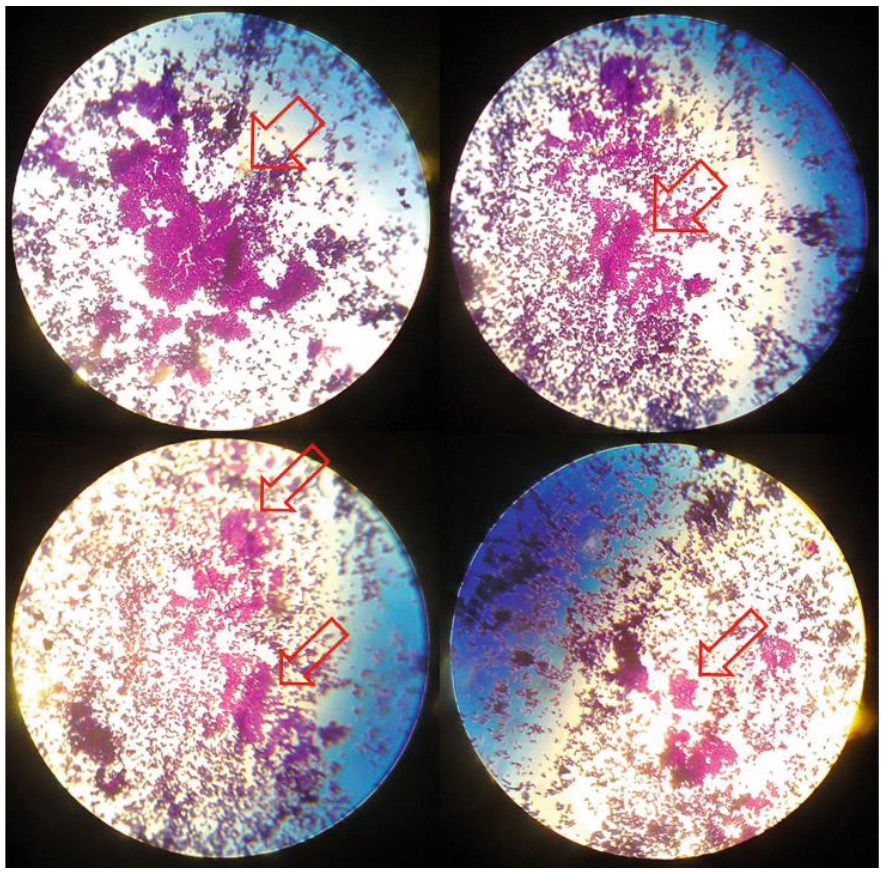


Рис. 2. Тинкториальная диссоциация культуры *Staphylococcus aureus* ATCC 6538 при действии паралетальных концентраций наночастиц окисленного графена (окраска по Граму, увеличение 800, кластерный эффект тинкториальной трансверсии бактериальных клеток с грамположительной окраски на грамотрицательную — отмечен стрелками)

Fig. 2. Tinctorial dissociation of *Staphylococcus aureus* ATCC 6538 culture in the presence of paralethal concentrations of graphene oxide nanoparticles (Gram stain, magnification 800, cluster effect of tinctorial transversion of bacterial cells from Gram-positive to Gram-negative staining is indicated by arrows)

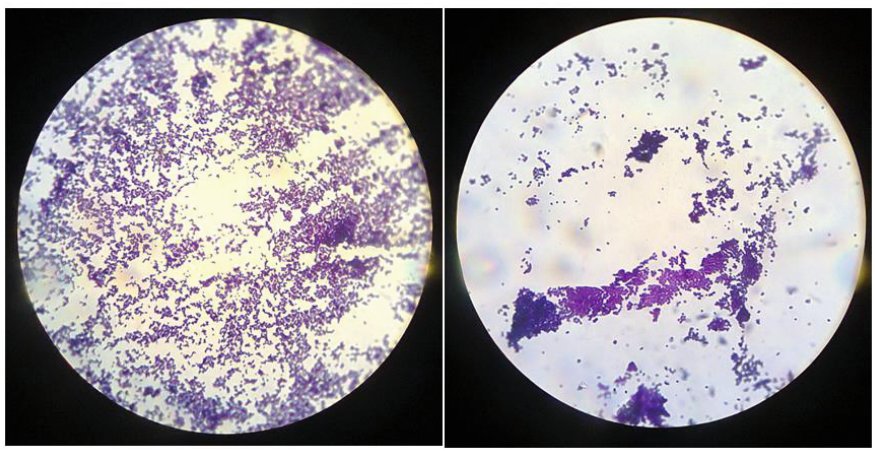
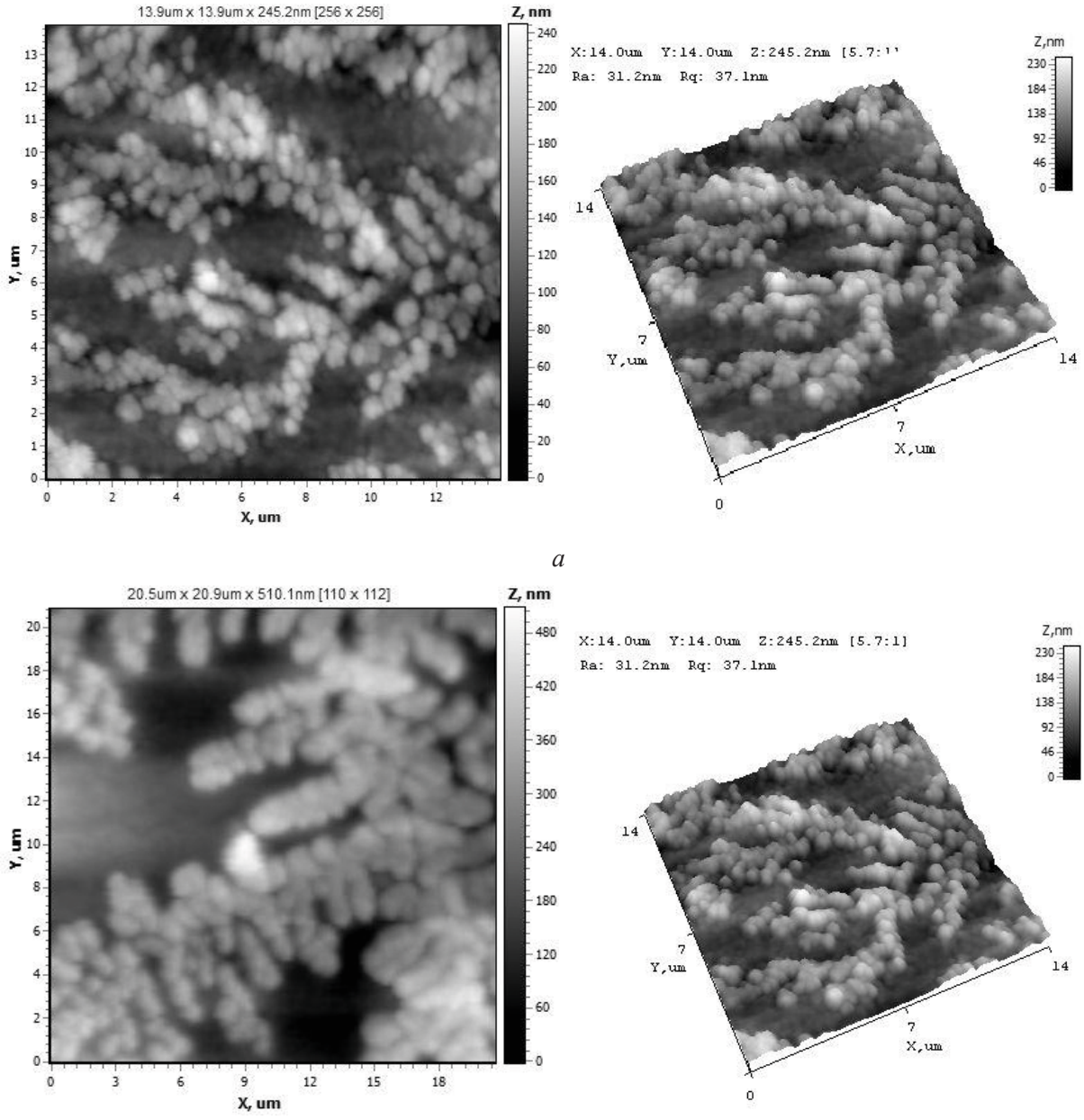


Рис. 3. Контрольные образцы *Staphylococcus aureus* ATCC 6538 при действии минимальных концентраций наночастиц окисленного графена (окраска по Граму, увеличение 800, сплошная грамположительная окраска клеток всей бактериальной культуры)

Fig. 3. Control samples of *Staphylococcus aureus* ATCC 6538 in the presence of minimal concentrations of graphene oxide nanoparticles (Gram stain, 800 magnification, continuous gram-positive staining of cells of the entire bacterial culture)

In the micropreparations of bacterial cultures treated with oxidized graphene nanoparticles there were morphological changes in the bacterial cells themselves, as well as in the composition of the entire microbial culture. The nature of the changes was generally the same, and their presence was detected 30 min after the treatment with oxidized graphene nanoparticles. The initial changes were characterized by the disturbance of the contours of the bacterial cells compared to the control samples. In particular, the expressiveness of the bacterial cells outlines was sharply reduced (see Fig. 5).

In spite of the preserved distinguishable isolation of individual bacterial cells, the intercellular space was reduced, the contours of the scanned objects lost their spatial contrast,



а

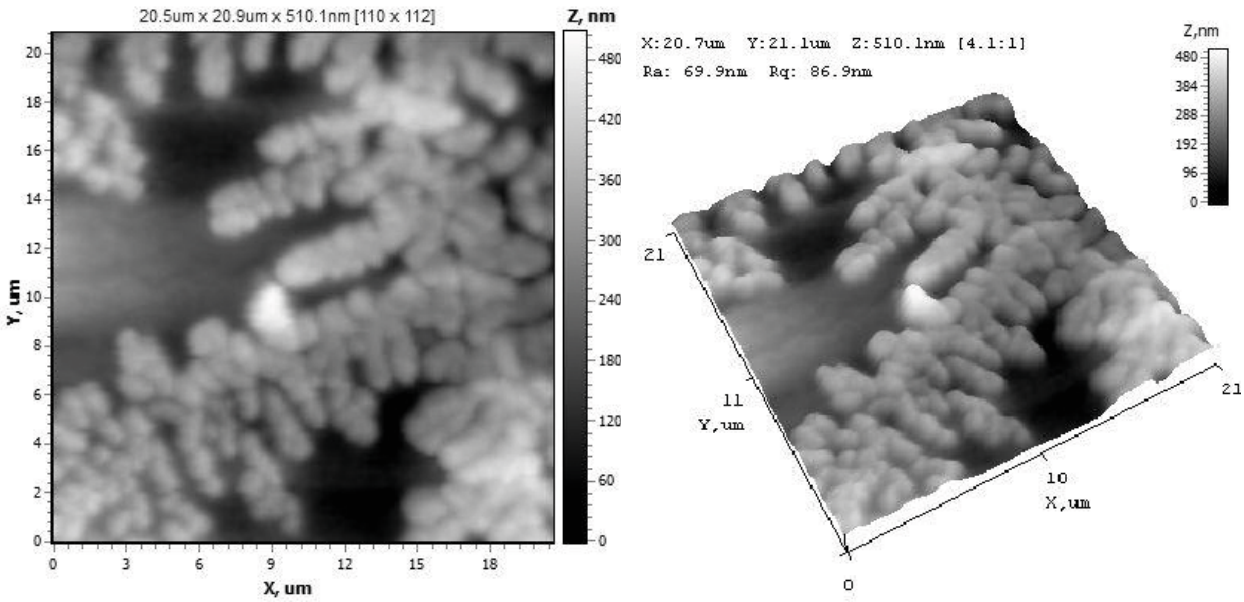
б

Рис. 4. Атомно-силовая микроскопия (контрольные образцы):
а – Staphylococcus aureus ATCC 6538; *б – Escherichia coli* ATCC 25922

Fig. 4. Atomic force microscopy (control samples):
a – Staphylococcus aureus ATCC 6538; *б – Escherichia coli* ATCC 25922

cell surface changes were evident (noticeable roughness), a partial exit of cytoplasm outside the bacterial cells was noted (see Fig. 6).

When the exposure of the oxidized graphene nanoparticles increased up to 90 min, the morphological destruction was noted not only at the level of individual cells, but also in the entire microbial population. In particular, the cell contours became almost indistinguishable, almost all the intercellular space was filled with the biomass of destructed cells, the height of the bacterial contours was sharply reduced compared to the control, the contrast between the maximum and minimum points



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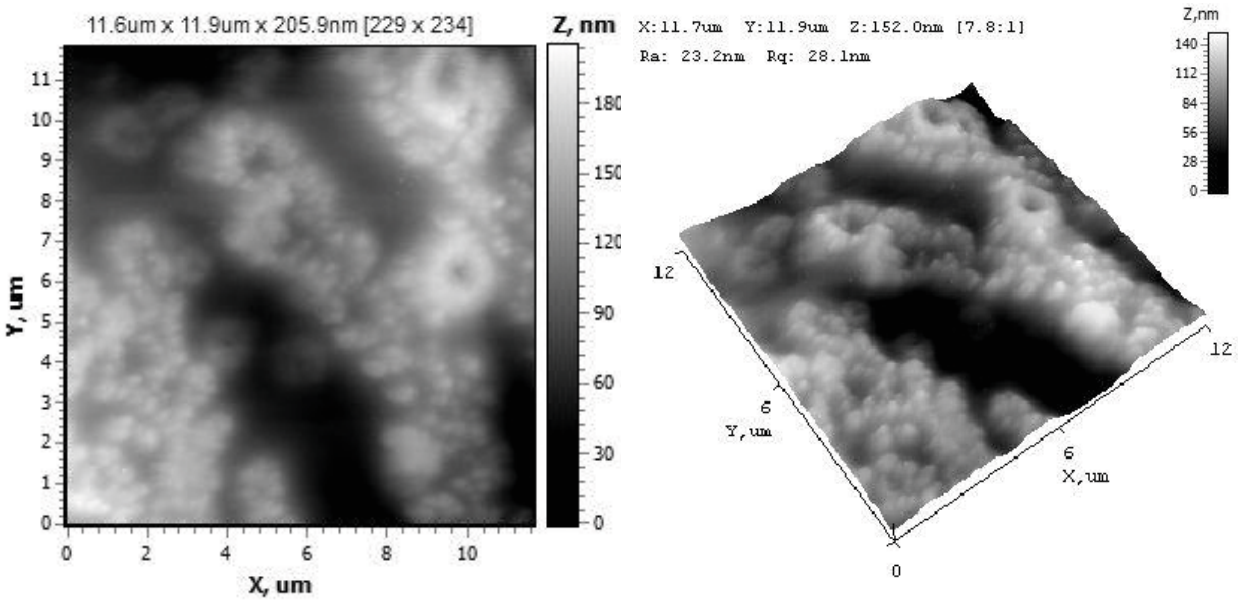

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Рис. 5. Морфологические изменения при действии супралетальных концентраций наночастиц окисленного графена в течение 30 мин:

а – S*taphylococcus aureus* ATCC 6538; *б* – *Escherichia coli* ATCC 25922

Fig. 5. Morphological changes under the action of supra-lethal concentrations of oxidized graphene nanoparticles for 30 min:

а – *Staphylococcus aureus* ATCC 6538; *б* – *Escherichia coli* ATCC 25922

of the scanned surface was sharply reduced (see Fig. 7).

It should be noted that the morphological degradation and subsequent destruction of the bacteria were noted only under the action of the oxidized graphene nanoparticles at concentrations of 75 μg-mL^{-1} and higher. In this case it can be argued that the cytotoxic concentration of this nanomaterial for the main types of bacteria lies in the range around the presented value, but its more precise elucidation was not the purpose of this study, because it is not identical to the concept of bacteriostatic or bactericidal concentration, as the latter is usually determined by the cultural methods of study.

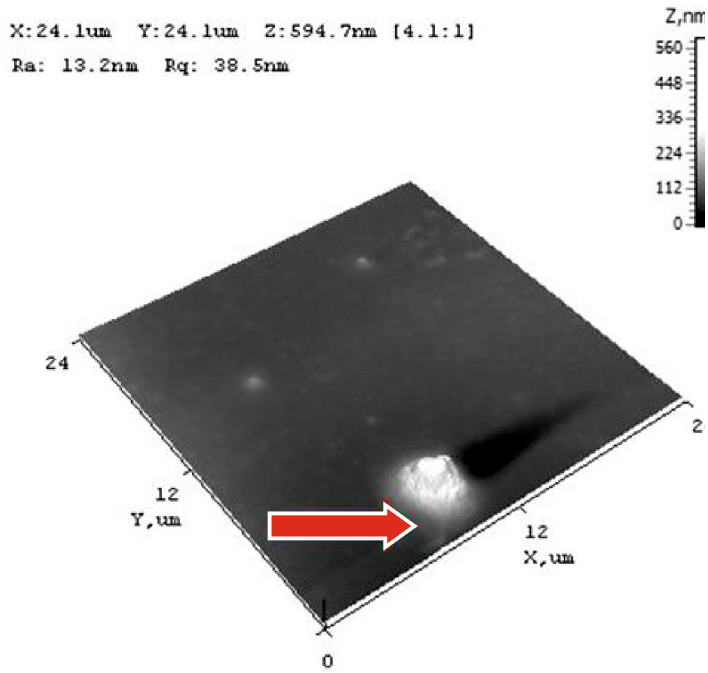
CONCLUSIONS

1. Oxidized graphene nanoparticles have antibacterial properties, which are manifested by obvious cytotoxic effects against prokaryotic cells.

2. Under the action of toxic concentrations of nanoparticles of oxidized graphene on individual Gram-positive bacteria (*Staphylococcus aureus* ATCC 6538) tinctorial transversion with a change in their gram-adhesion, indicating a possible toxic effect on the structure or composition of the bacterial cell wall is observed.

3. The action of toxic concentrations of the oxidized graphene nanoparticles for 30 minutes on the main types of bacteria (cocci, bacilli) is accompanied by morphological degradation of cells.

4. Increasing the exposure of toxic concentrations of the oxidized graphene nanoparticles up to 90 min leads to complete morphological destruction of bacterial cells and dis-



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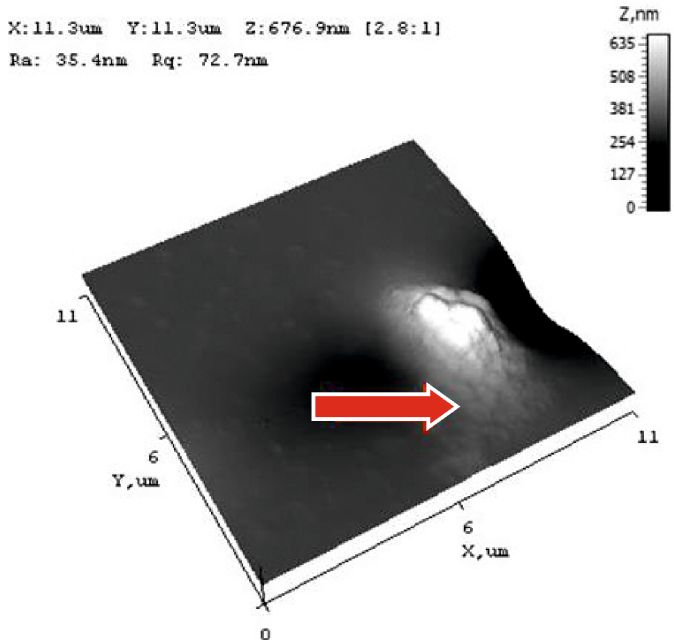

б

Рис. 6. Деградация морфологии бактериальных клеток при действии супралетальных концентраций наночастиц окисленного графена в течение 30 мин:

а – Staphylococcus aureus ATCC 6538, *б – Escherichia coli* ATCC 25922), частичный выход цитоплазмы (отмечены стрелкой)

Fig. 6. Degradation of bacterial cell morphology when exposed to supra-lethal concentrations of oxidized graphene nanoparticles for 30 min:

a – Staphylococcus aureus ATCC 6538, *б – Escherichia coli* ATCC 25922, partial exit of the cytoplasm (marked with an arrow)

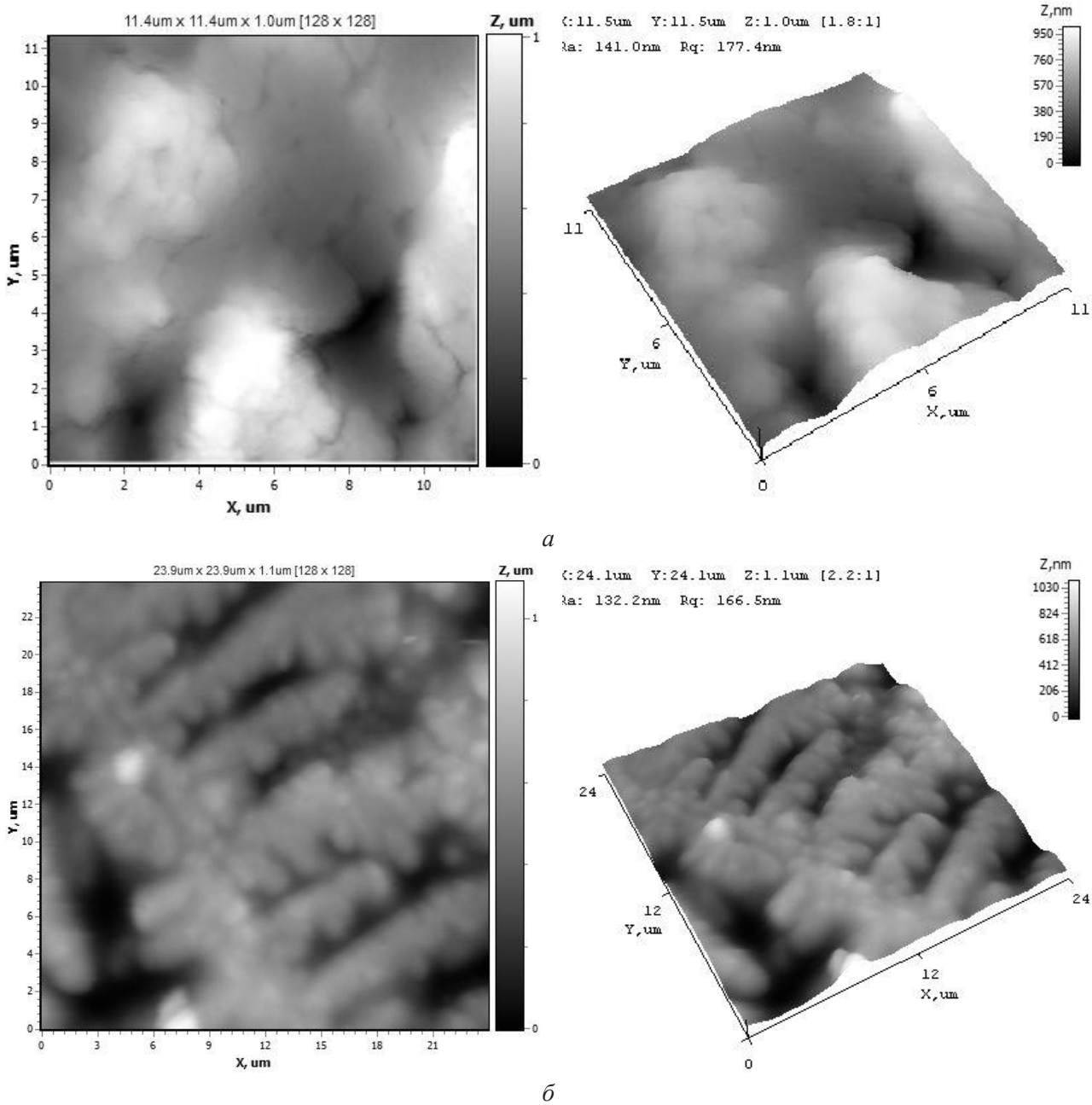

Рис. 7. Морфологическая деградация бактериальных клеток при действии супралетальных концентраций наночастиц окисленного графена в течение 90 мин:

а – Staphylococcus aureus ATCC 6538; *б – Escherichia coli* ATCC 25922

Fig. 7. Morphological degradation of bacterial cells under the action of supra-lethal concentrations of oxidized graphene nanoparticles for 90 min:

a – Staphylococcus aureus ATCC 6538; *б – Escherichia coli* ATCC 25922

integration of the composition of the bacterial population.

5. Cytotoxic concentration of the oxidized graphene nanoparticles lies in the value of more than 75 μg-mL^{-1} according to the results of test culture samples microscopy, but the bacterioinhibitory concentration requires further determination.

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К ЮБИЛЕЮ ВИКТОРА АЛЕКСЕЕВИЧА МАРЧЕНКО

Главному научному сотруднику, заведующему лабораторией ветеринарии Горно-Алтайского научно-исследовательского института сельского хозяйства – филиала Федерального Алтайского научного центра агробиотехнологий, доктору биологических наук, профессору Виктору Алексеевичу Марченко 14 августа 2022 г. исполняется 70 лет и 45 лет научной деятельности.

Виктор Алексеевич родился в г. Называевске Омской области. После окончания в 1974 г. Омского государственного ветеринарного института до 1977 г. работал начальником противоэпизоотического отряда Сладковской райветстанции Тюменской области. В этот период район имел лучшие показатели в РСФСР по оздоровлению сельскохозяйственных животных от хронических инфекций. В.А. Марченко в последующем продолжил трудовую деятельность на различных должностях в учреждениях Сибирского отделения Российской академии наук, Россельхозакадемии, ФАНО и Министерства науки и высшего образования Российской Федерации.

Научной деятельностью Виктор Алексеевич начал заниматься со студенческих лет. Его первая научная статья «Выявление причин гибели животных и изучение видового состава гельминтов овец Ставропольского края» опубликована в 1973 г. С апреля 1977 г. Виктор Алексеевич пришел в науку. Начинал он с младшего научного сотрудника Биологического института СО АН СССР. В 1985 г. успешно защитил кандидатскую диссертацию, в 1998 г. – докторскую, в 2007 г. ему присвоено ученое звание профессора. С октября 1993 г. В.А. Марченко возглавлял совместную лабораторию арахноэнтомозов животных Биологического института СО РАН и Горно-Алтайского научно-исследовательского института сельского хозяйства СО Россельхозакадемии. С 1995 г. работал заведующим отделом ветеринарии Горно-Алтайского научно-исследовательского института сельского хозяйства. В 1997–2003 гг. был директором Горно-Алтайского НИИСХа. С 2003 по 2010 г. работал заведующим лабораторией ветеринарной паразитологии Института экспериментальной ветеринарии Сибири и Дальнего Востока СО Россельхозакадемии, в 2010 г. перешел на работу в лабораторию экологии насекомых Института систематики и экологии животных СО РАН, одновременно возглавлял отдел ветеринарии Горно-Алтайского НИИСХа.

С 1999 г. Виктор Алексеевич активно совмещает научную и педагогическую деятельность, он профессор кафедры агротехнологий и ветеринарной медицины Горно-Алтайского государственного университета.

Круг научных интересов В.А. Марченко составляют вопросы экологии паразитических беспозвоночных и отработка методов ограничения их численности. Виктор Алексеевич проводил исследования в различных районах Сибири – Республике Алтай, Алтайском крае, Тыве, Хакасии, в Иркутской, Читинской и Новосибирской областях. За период научной деятельности Виктором Алексеевичем получен ряд новых, интересных как в теоретическом, так и в практическом отношении сведений по биологии и эпизоотологии паразитов сельскохозяйственных и диких животных, разработаны и внедрены в сельскохозяйственное производство новые технологические приемы контроля численности вредителей и системы ограничительных мероприятий. Он руководил исполнением заданий многих региональных и федеральных НТП, проектов РФФИ, договорными НИР с сельхозпредприятиями и научными учреждениями. На основе изучения экологии и эпизоотологии паразитических видов, испытания новых средств и методов терапии животных Виктором Алексеевичем разработаны рациональные отраслевые системы ограничительных мероприятий при ряде инвазионных заболеваний. Разработаны и утверждены соответствующими организациями более 30 методических рекомендаций и пособий по ветеринарной медицине и зоотехнии.

По результатам научной деятельности Виктором Алексеевичем в отечественных и зарубежных изданиях опубликовано более 260 научных работ, в том числе 7 монографий, получено 9 патентов Российской Федерации на изобретения. Материалы его исследований, проведенные самостоятельно, а также совместно с другими специалистами, были использованы в подготовке ряда нормативных документов ГУВ МСХ СССР и Департамента ветеринарии МСХ России. Научно-практические разработки Виктора Алексеевича были экспонированы на региональных сельскохозяйственных выставках, в Госплане СССР, выставках СО РАН и Россельхозакадемии, награждены дипломами СО РАН и СО РАСХН.

В Республике Алтай им организовано опытное производство противопаразитарных кормовых гранул для сельскохозяйственных животных. Виктор Алексеевич является ведущим специалистом страны в области биологии оводов, ведет активную научно-общественную деятельность, участвует в работе всероссийских координационных советов, является членом президиума СО ВЭО при РАН, заместителем председателя секции ветеринарной медицины научно-технического совета Министерства сельского хозяйства Республики Алтай, членом регионального экспертного совета РФФИ. Принимает участие в организации различного ранга конференций и научно-производственных совещаний. Им была организована аспирантура по ветеринарии в Горно-Алтайском государственном университете.

Виктор Алексеевич руководит научной работой студентов, аспирантов и докторантов, подготовил 6 кандидатов наук, принимает участие в оппонировании диссертаций, является членом диссертационных советов.

Научно-исследовательская деятельность Виктора Алексеевича отличается рациональным сочетанием фундаментальных и прикладных исследований, что в значительной мере способствует их успешному приложению в практику сельскохозяйственного производства.

За плодотворный труд Виктор Алексеевич награжден медалью ордена «За заслуги перед Отечеством» II степени, медалью Сибирского отделения Россельхозакадемии им. академика И.И. Синягина, почетной грамотой Российской академии сельскохозяйственных наук, благодарностью Министерства сельского хозяйства Российской Федерации, почетной грамотой Государственного Собрания – Эл Курултай Республики Алтай, почетными грамотами министерства сельского хозяйства, министерства образования и науки Республики Алтай. Ему присвоено почетное звание «Заслуженный деятель науки Республики Алтай».

Поздравляем Виктора Алексеевича с юбилеем и желаем осуществления всех творческих планов, дальнейших успехов в научно-педагогической деятельности, доброго здоровья и счастья!

Коллектив Горно-Алтайского научно-исследовательского
института сельского хозяйства – филиала
Федерального Алтайского научного центра агробиотехнологий,
коллектив Института экспериментальной ветеринарии Сибири и Дальнего Востока –
научного подразделения Сибирского федерального научного центра агробиотехнологий РАН

К 100-ЛЕТИЮ АКАДЕМИКА ВАСИЛИЯ РОМАНОВИЧА БОЕВА (1922–2004 гг.)

Василий Романович Боев прожил активную, яркую жизнь, которую условно можно разделить на четыре этапа.

Первый этап включает в себя детство и юность, прошедшие в Донецкой области. В годы Великой Отечественной войны Василий Романович воевал в составе 1-го Украинского фронта, принимал участие в освобождении восставшей Праги. Награжден 16 орденами и медалями, среди которых орден Красной Звезды, медаль «За взятие Берлина».

Послевоенный период Василия Романовича охватывает учебу на экономическом факультете Московской сельскохозяйственной академии им. К.А. Тимирязева, работу в Деминской МТС Волгоградской области с последующим переходом в Министерство сельского хозяйства СССР. Увлекшись научными исследованиями, в 1957 г. Василий Романович защитил диссертацию на соискание ученой степени кандидата экономических наук.

Второй этап жизни В.Р. Боева – руководство отделом цен и себестоимости сельскохозяйственной продукции Всесоюзного научно-исследовательского института экономики сельского хозяйства. В этот период состоялась его успешная защита диссертации на соискание доктора экономических наук, изданы авторские монографии «Закупочные цены и чистый доход колхозов», «Совершенствование закупочных цен на сельскохозяйственную продукцию (вопросы теории и практики)».

Третий этап – с 1971 по 1984 г. – связан с активной организационной и творческой деятельностью в Сибири. Академик В.Р. Боев возглавлял Сибирский научно-исследовательский институт экономики сельского хозяйства (СибНИИЭСХ), занимал должности профессора Новосибирского сельскохозяйственного института, первого заместителя председателя президиума Сибирского отделения ВАСХНИЛ. На институт была возложена координация исследований по экономике и организации сельскохозяйственного производства научных учреждений Сибири и Дальнего Востока. Ученые СибНИИЭСХа разрабатывали предложе-

ния и рекомендации по переводу сельского хозяйства Сибири на индустриальную основу, рациональному использованию производственных ресурсов, размещению и специализации сельского хозяйства, экономическому стимулированию сельскохозяйственного производства, созданию продовольственной базы в районах нового промышленного освоения. Под руководством В.Р. Боева ученые активно включились в исследование путей создания собственной продовольственной базы в новых районах промышленного освоения, в том числе Западно-Сибирского нефтегазового комплекса и Байкало-Амурской магистрали.

Институтом впервые в Сибири были проведены широкие научные исследования по вопросам межхозяйственной кооперации и агропромышленной интеграции. На их основе сформулированы принципы и организационные формы межхозяйственного кооперирования в регионе, создан ряд новых межхозяйственных формирований.

Были разработаны основные направления развития сельского хозяйства и создания продовольственной базы в районах нефтегазодобычи Западной Сибири, генеральная схема развития и размещения продовольственной базы в районах промышленного освоения Байкало-Амурской магистрали. На основе этих разработок Министерством сельского хозяйства и Госпланом РСФСР приняты важные решения по их практической реализации.

В эти годы СибНИИЭСХ занимался и вопросами эффективности использования основных фондов и капитальных вложений. Особое внимание уделялось разработке прогрессивных экономических нормативов с целью создания нормативной базы для текущего и перспективного планирования объемов, структуры, а также эффективности капитальных вложений и основных фондов, экономического обоснования распределения капитальных вложений по приоритетным направлениям, научно обоснованного определения потребности в основных производственных фондах на уровне субъекта РФ.

Четвертый этап жизни Василия Романовича связан с возвращением на должность директора Всесоюзного (ныне Всероссийского) научно-исследовательского института экономики сельского хозяйства. Новое время выдвинуло новые задачи перед аграрной наукой. Встал вопрос о совершенствовании ценообразования в условиях перехода сельскохозяйственных организаций на самофинансирование. В целом, осознавая необходимость развития рыночных методов хозяйствования, Василий Романович выступал против скоропалительных решений, дезорганизации производства, за использование принципа дополнительности, предотвращение негативных процессов в сельской жизни, сохранение системы государственной поддержки сельскохозяйственного производства, развитие крупных механизированных хозяйств, регулирование агропродовольственного рынка, достижение самообеспеченности продуктами питания населения страны.

Научное наследие академика Василия Романовича Боева – огромный вклад в аграрную экономику, позволяющий составить объективное представление о происходивших социально-экономических процессах на протяжении полувека нашей истории и одновременно востребованный новыми поколениями ученых при разработке перспективных направлений развития агропромышленного комплекса России и стран ЕАЭС.

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научного центра агробиотехнологий РАН

ВАСИЛИЙ ГЕРАСИМОВИЧ ЛУНИЦЫН

29 марта 2022 г. на 63-м году жизни после тяжелой продолжительной болезни ушел из жизни заслуженный деятель науки Российской Федерации, кавалер ордена Почета, доктор ветеринарных наук, профессор Василий Герасимович Луницын.

Василий Герасимович родился 17 июля 1959 г. в с. Колыванское (Алтайский край, Павловский район). В 1981 г. с отличием окончил ветеринарный факультет Алтайского сельскохозяйственного института и поступил на работу в Центральную научно-исследовательскую лабораторию пантового оленеводства, где прошел путь от младшего научного сотрудника до директора единственного в России научного учреждения СО РАСХН, занимающегося пантовым оленеводством. С 2017 г. работал заместителем директора по научной работе Федерального Алтайского научного центра агробиотехнологий (Алтайский край, Барнаул).

Василий Герасимович был ведущим ученым в области пантового оленеводства в Российской Федерации и стран СНГ. В 1985 г. ему присуждена степень кандидата ветеринарных наук, в 1993 г. – доктора ветеринарных наук, в 2000 г. – ученое звание профессора, в 2006 г. – почетное звание «Заслуженный деятель науки Российской Федерации», в 2010 г. он награжден орденом Почета.

Благодаря многолетней научно-исследовательской работе, которая имела не только фундаментальное значение, но несла и научно-практическую значимость, а также природной трудовой напористости, высокому трудолюбию и целеустремленности В.Г. Луницын опубликовал более 760 научных работ, в том числе 29 монографий и книг, 50 научно-методических разработок и рекомендаций, 23 технических условия, новизна которых подтверждена 99 патентами и авторскими свидетельствами. Он соавтор алтае-саянской породы маралов и двух ее породных типов (шебалинский, теньгинский), алтае-уссурийской породы пятнистых оленей.

Научная работа Василия Герасимовича в области ветеринарии была посвящена изучению новых методов диагностики, профилактики и мерам борьбы с инфекционными (туберкулез, пастереллез, бруцеллез) и инвазионными болезнями пантовых оленей; схемам специфической профилактики заразных болезней маралов и пятнистых оленей; методам фиксации при массовых обработках животных; ветеринарно-санитарным правилам для ферм пантового оленеводства и заготовки, консервированию и переработке продукции пантового оленеводства.

В зоотехнической практике разработана и внедрена современная система племенной работы в пантовом оленеводстве, итогом которой стали регистрация двух пород и двух по-

родных типов, разработки норм кормления маралов в виде типовых рационов, испытание новых кормовых добавок для пантовых оленей, изучение мясной продуктивности и качества мяса представителей семейства оленевых, разработки способов повышения выхода приплода в пантовом оленеводстве.

В области хранения и переработки усовершенствованы существующие и разработаны новые, с применением современного оборудования технологии заготовки, консервирования и глубокой переработки продукции пантового оленеводства, методы оценки ее качества.

Являясь ведущим специалистом по вопросам пантового оленеводства, В.Г. Луницын постоянно оказывал научно-методическую помощь хозяйствам. Результаты его научных работ получили широкое практическое применение, они освоены во многих мараловодческих и оленеводческих хозяйствах Сибири и России. Опубликованные научные работы в настоящее время используются специалистами и учеными России и стран СНГ при производстве и переработке продукции пантового оленеводства, борьбе с заразными болезнями пантовых оленей, а также в учебном процессе сельскохозяйственных вузов.

Под научным руководством Василия Герасимовича подготовлены и защищены 2 докторских и 28 кандидатских диссертаций. В.Г. Луницын – один из организаторов 7-го Международного конгресса по пантовому оленеводству, проходившего на Алтае в 2018 г., был членом редакционной коллегии журнала «Вестник Алтайского ГАУ», а также членом двух диссертационных советов Алтайского государственного аграрного университета по защите докторских и кандидатских диссертаций.

Работы В.Г. Луницына удостоены 33 дипломов президиума СО РАСХН и РАСХН. За добросовестный труд он неоднократно награжден почетными грамотами СО РАСХН, Министерства образования и науки, администрациями Алтайского края и Республики Алтай, являлся лауреатом премии Алтайского края в области науки и техники (2013, 2019 гг.), профессором года в номинации сельскохозяйственные (2010 г.) и естественные науки (2014 г.).

Жизненный путь, пройденный Василием Герасимовичем – яркий пример беззаветного служения избранному делу. Он ценил в людях профессионализм, честность и порядочность.

Скорбим в связи с кончиной Василия Герасимовича Луницына и выражаем глубокие соболезнования родным и близким.

Коллективы СФНЦА РАН и ФГБНУ ФАНЦА,
академики РАН *А.С. Донченко*, *В.А. Солошенко*,
В.В. Альт, *Н.И. Кашеваров*,
члены-корреспонденты РАН *К.Я. Мотовилов*, *Н.А. Донченко*,
доктора ветеринарных наук *Н.А. Шкиль*, *Ю.И. Смолянинов*

ПРАВИЛА ДЛЯ АВТОРОВ

Правила для авторов составлены на основе этических принципов, общих для членов научного сообщества, и правил публикации в международных и отечественных научных периодических изданиях, а также в соответствии с требованиями ВАК для периодических изданий, включенных в Перечень российских рецензируемых научных журналов, в которых должны быть опубликованы основные научные результаты диссертаций на соискание ученой степени доктора и кандидата наук.

Журнал публикует оригинальные статьи по фундаментальным и прикладным проблемам по направлениям:

- общее земледелие и растениеводство;
- селекция, семеноводство и биотехнология растений;
- агрохимия, агропочвоведение, защита и карантин растений;
- кормопроизводство;
- инфекционные болезни и иммунология животных;
- частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства;
- разведение, селекция, генетика и биотехнология животных;
- технологии, машины и оборудование для агропромышленного комплекса;
- пищевые системы.

Статья, направляемая в редакцию, должна соответствовать тематическим разделам журнала «Сибирский вестник сельскохозяйственной науки»:

Наименование рубрики	**Шифр и наименование научной специальности в соответствии с Номенклатурой научных специальностей, по которым присуждаются ученые степени**
Земледелие и химизация	4.1.1. Общее земледелие и растениеводство 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Растениеводство и селекция	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений
Защита растений	4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Кормопроизводство	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Зоотехния и ветеринария	4.2.3. Инфекционные болезни и иммунология животных 4.2.4. Частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства 4.2.5. Разведение, селекция, генетика и биотехнология животных
Механизация, автоматизация, моделирование и информационное обеспечение	4.3.1. Технологии, машины и оборудование для агропромышленного комплекса
Переработка сельскохозяйственной продукции	4.3.3. Пищевые системы
Проблемы. Суждения Научные связи Из истории сельскохозяйственной науки Краткие сообщения Из диссертационных работ	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений 4.2.3. Инфекционные болезни и иммунология животных 4.2.4. Частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства 4.2.5. Разведение, селекция, генетика и биотехнология животных 4.3.1. Технологии, машины и оборудование для агропромышленного комплекса 4.3.3. Пищевые системы

В журнале также публикуются обзоры, краткие сообщения, хроника, рецензии, книжные обозрения, материалы по истории сельскохозяйственной науки и деятельности учреждений и ученых.

Число публикаций одного автора в номере журнала не должно превышать двух, при этом вторая статья допустима лишь в соавторстве.

К рассмотрению принимаются материалы от различных категорий исследователей, аспирантов, докторантов, специалистов и экспертов в соответствующих областях знаний.

Все статьи рецензируются и имеют зарегистрированный в системе CrossRef индекс DOI.

Публикации для авторов **бесплатны**.

При направлении статьи в редакцию журнала «Сибирский вестник сельскохозяйственной науки» рекомендуем руководствоваться следующими правилами.

РЕКОМЕНДАЦИИ АВТОРУ ДО ПОДАЧИ СТАТЬИ

Представление статьи в журнал «Сибирский вестник сельскохозяйственной науки» подразумевает, что:

- статья ранее не была опубликована в другом журнале;
- статья не находится на рассмотрении в другом журнале;
- все соавторы согласны с публикацией текущей версии статьи.

Перед отправкой статьи на рассмотрение необходимо убедиться, что в файле (файлах) содержится вся необходимая информация на русском и английском языках, указаны источники информации, размещенной на рисунках и в таблицах, все ссылки оформлены корректно.

ПОРЯДОК НАПРАВЛЕНИЯ РУКОПИСЕЙ СТАТЕЙ

1. Отправка статьи осуществляется через электронную редакцию на сайте журнала **https://sibvest.elpub.ru/jour/index.** После предварительной регистрации автора, в правом верхнем углу страницы выбрать опцию «Отправить рукопись». Затем загрузить рукопись статьи (в формате *.doc или *.docx) и сопроводительные документы к ней. После завершения загрузки материалов обязательно выбрать опцию «Отправить письмо», в этом случае редакция автоматически будет уведомлена о получении новой рукописи.

Сопроводительные документы к рукописи статьи:

- скан-копия письма от организации с подтверждением авторства и разрешением на публикацию (образец на **http://sibvest.elpub.ru/**);
- скан-копия авторской справки по представленной форме (образец на **http://sibvest.elpub.ru/**), в которой должно быть выражено согласие на открытое опубликование статьи в печатном варианте журнала и его электронной копии в сети Интернет;
- скан-копия рукописи с подписями авторов. Автор, подписывая рукопись и направляя ее в редакцию, тем самым передает авторские права на издание этой статьи СФНЦА РАН;
- анкеты авторов на русском и английском языках (образец на **http://sibvest.elpub.ru/**);
- скан-копия справки из аспирантуры (для очных аспирантов).

2. Все поступающие в редакцию рукописи статей регистрируются через систему электронной редакции. В личном кабинете автора отражается текущий статус рукописи.

3. Нерецензируемые материалы (материалы научной хроники, рецензии, книжные обозрения, материалы по истории сельскохозяйственной науки и деятельности учреждений и ученых) направляются на e-mail: **sibvestnik@sfsca.ru** и регистрируются ответственным секретарем.

ПОРЯДОК ОФОРМЛЕНИЯ СТАТЬИ

Текст рукописи оформляется шрифтом Times New Roman, кеглем 14 с интервалом 1,5, все поля 2,0 см, нумерация страниц внизу. Объем статьи не более 15 страниц (включая таблицы, иллюстрации и библиографию); статей, размещаемых в рубриках «Из диссертационных работ» и «Краткие сообщения», – не более 7 страниц.

Структура оформления статьи:

1. **УДК**
2. **Заголовок статьи на русском и английском языках (не более 70 знаков).**
3. **Фамилии и инициалы авторов, полное официальное название научного учреждения, в котором проведены исследования на русском и английском языках.**

Если в подготовке статьи принимали участие авторы из разных учреждений, необходимо указать принадлежность каждого автора к конкретному учреждению с помощью надстрочного индекса.

4. **Реферат на русском и английском языках.** Объем реферата не менее 200–250 слов. Реферат является кратким и последовательным изложением материала статьи по основным разделам и должен отражать основное содержание, следовать логике изложения материала и описания результатов в статье с приведением конкретных данных. Не следует включать впервые введенные термины, аббревиатуры (за исключением общеизвестных), ссылки на литературу. В реферате не следует подчеркивать новизну, актуальность и личный вклад автора; место исследования необходимо указывать до области (края), не упоминать конкретные организации.
5. **Ключевые слова на русском и английском языках.** 5–7 слов по теме статьи. Желательно, чтобы ключевые слова дополняли реферат и название статьи.
6. **Информация о конфликте интересов либо его отсутствии.** Автор обязан уведомить редактора о реальном или потенциальном конфликте интересов, включив информацию о конфликте интересов в соответствующий раздел статьи. Если конфликта интересов нет, автор должен также сообщить об этом.

Пример формулировки: «Автор заявляет об отсутствии конфликта интересов».

7. **Благодарности на русском и английском языках.** В этом разделе указываются все источники финансирования исследования, а также благодарности людям, которые участвовали в работе над статьей, но не являются ее авторами.
8. **Основной текст статьи.** При изложении оригинальных экспериментальных данных рекомендуется использовать подзаголовки:

ВВЕДЕНИЕ (постановка проблемы, цели, задачи исследования)

МАТЕРИАЛ И МЕТОДЫ (условия, методы (методика) исследований, описание объекта, место и время проведения)

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

ЗАКЛЮЧЕНИЕ или **ВЫВОДЫ**

СПИСОК ЛИТЕРАТУРЫ. Количество источников не менее 15. В список литературы включаются только рецензируемые источники: статьи из научных журналов и монографии. Самоцитирование не более 10% от общего количества. Библиографический список должен быть оформлен в виде общего списка в порядке упоминания в тексте, желательны ссылки на источники 2–3-летнего срока давности. Правила оформления списка литературы – в соответствии с ГОСТ Р 7.05–2008 (требования и правила составления библиографической ссылки). В тексте ссылка на источник отмечается порядковой цифрой в квадратных скобках, например [1]. Литература в списке дается на тех языках, на которых она издана. В библиографическое описание публикации необходимо вносить всех авторов, не сокращая их одним, тремя и т.п. Недопустимо сокращение названий статей, журналов, издательств.

Если необходимо сослаться на авторефераты, диссертации, сборники статей, учебники, рекомендации, учебные пособия, ГОСТы, информацию с сайтов, статистические отчеты, статьи в общественно-политических газетах и прочее, то такую информацию следует оформить в *сноску* в конце страницы. Сноски нумеруются арабскими цифрами, размещаются постранично сквозной нумерацией.

Внимание! Теоретические, обзорные и проблемные статьи могут иметь произвольную структуру, но обязательно должны содержать реферат, ключевые слова, список литературы.

ПРИМЕРЫ ОФОРМЛЕНИЯ СПИСКА ЛИТЕРАТУРЫ, REFERENCES И СНОСОК

СПИСОК ЛИТЕРАТУРЫ:

Монография

Климова Э.В. Полевые культуры Забайкалья: монография. Чита: Поиск, 2001. 392 с.

Часть книги

Холмов В.Г. Минимальная обработка кулисного пара под яровую пшеницу при интенсификации земледелия в южной лесостепи Западной Сибири // Ресурсосберегающие системы обработки почвы. М.: Агропромиздат, 1990. С. 230–235.

Периодическое издание

Пакуль А.Л., Лапшинов Н.А., Божанова Г.В., Пакуль В.Н. Технологические качества зерна мягкой яровой пшеницы в зависимости от системы обработки почвы // Сибирский вестник сельскохозяйственной науки. 2018. Т. 48. № 4. С. 27–35. DOI: 10.26898/0370-8799-2018-4-4.

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Составляется в том же порядке, что и русскоязычный вариант, по следующим правилам:

Фамилии И.О. авторов в устоявшемся способе транслитерации, англоязычное название статьи, *транслитерация названия русскоязычного источника (например через сайт: https://antropophob.ru/translit-bsi) = англоязычное название источника.* Далее оформление для монографии: город, англоязычное название издательства, год, количество страниц; для журнала: год, номер, страницы). (In Russian).

Пример: Avtor A.A., Avtor B.B., Avtor C.C. Title of article.

Транслитерация авторов. Англоязычное название статьи

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

Транслитерация источника = Англоязычное название источника

Монография

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

Часть книги

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).

Периодическое издание

Pakul A.L., Lapshinov N.A., Bozhanova G.V., Pakul V.N. Technological grain qualities of spring common wheat depending on the system of soil tillage. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2018, vol. 48, no. 4, pp. 27–35. (In Russian). DOI: 10.26898/0370-8799-2018-4-4.

СНОСКИ:

Цитируемый текст[1].

[1]*Климова Э.В., Андреева О.Т., Темникова Г.П.* Пути стабилизации кормопроизводства Забайкалья // Проблемы и перспективы совершенствования зональных систем земледелия в современных условиях: материалы науч.-практ. конф. (Чита, 16–17 октября 2008 г.). Чита, 2009. С. 36–39.

Цифровой идентификатор Digital Object Identifier – DOI (когда он есть у цитируемого материала) необходимо указывать в конце библиографической ссылки.

Пример:

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

Наличие DOI статьи следует проверять на сайте http://search.crossref.org/ или https://www.citethisforme.com. Для этого нужно ввести в поисковую строку название статьи на английском языке.

РИСУНКИ, ТАБЛИЦЫ, СКРИНШОТЫ И ФОТОГРАФИИ

Рисунки должны быть хорошего качества, пригодные для печати. Все рисунки должны иметь подрисуночные подписи. Подрисуночную подпись необходимо перевести на английский язык. Рисунки нумеруются арабскими цифрами по порядку следования в тексте. Если рисунок в тексте один, то он не нумеруется. Отсылки на рисунки оформляются следующим образом: «На рис. 3 указано, что …» или «Указано, что … (см. рис. 3)». Подрисуночная

подпись включает порядковый номер рисунка и его название. «Рис. 2. Описание жизненно важных процессов». Перевод подрисуночной подписи следует располагать после подрисуночной подписи на русском языке.

Таблицы должны быть хорошего качества, пригодные для печати. Предпочтительны таблицы, пригодные для редактирования, а не отсканированные или в виде рисунков. Все таблицы должны иметь заголовки. Название таблицы должно быть переведено на английский язык. Таблицы нумеруются арабскими цифрами по порядку следования в тексте. Если таблица в тексте одна, то она не нумеруется. Отсылки на таблицы оформляются следующим образом: «В табл. 3 указано, что …» или «Указано, что … (см. табл. 3)». Заголовок таблицы включает порядковый номер таблицы и ее название: «Табл. 2. Описание жизненно важных процессов». Перевод заголовка таблицы следует располагать после заголовка таблицы на русском языке.

Фотографии, скриншоты и другие нерисованные иллюстрации необходимо загружать отдельно в виде файлов формата *.jpeg (*.doc и *.docx – в случае, если на изображение нанесены дополнительные пометки). Разрешение изображения должно быть >300 dpi. Файлам изображений необходимо присвоить название, соответствующее номеру рисунка в тексте. В описании файла следует отдельно привести подрисуночную подпись, которая должна соответствовать названию фотографии, помещаемой в текст.

Следует обратить внимание на написание формул в статье. Во избежание путаницы необходимо греческие (α, β, π и др.), русские (А, а, Б, б и др.) буквы и цифры писать прямым шрифтом, латинские – курсивным (*W*, *Z*, *m*, *n* и др.). Математические знаки и символы нужно писать также прямым шрифтом. Необходимо четко указывать верхние и нижние надстрочные символы (W^1, F_1 и др.).

ВЗАИМОДЕЙСТВИЕ МЕЖДУ ЖУРНАЛОМ И АВТОРОМ

Редакция просит авторов при подготовке статей руководствоваться изложенными выше правилами.

Все поступающие в журнал «Сибирский вестник сельскохозяйственной науки» статьи проходят предварительную проверку на соответствие формальным требованиям. На этом этапе редакция оставляет за собой право:

- принять статью к рассмотрению;
- вернуть статью автору (авторам) на доработку с просьбой устранить ошибки или добавить недостающие данные;
- вернуть статью автору (авторам) без рассмотрения, оформленную не по требованиям журнала;
- отклонить статью из-за несоответствия ее целям журнала, отсутствия оригинальности, малой научной ценности.

Переписка с авторами рукописи ведется через контактное лицо, указанное в рукописи.

Все научные статьи, поступившие в редакцию журнала «Сибирский вестник сельскохозяйственной науки», проходят обязательное двухстороннее «слепое» рецензирование (double-blind – автор и рецензент не знают друг о друге). Рукописи направляются по профилю научного исследования на рецензию членам редакционной коллегии.

В спорных случаях редактор может привлечь к процессу рецензирования нескольких специалистов, а также главного редактора. При положительном заключении рецензента статья передается редактору для подготовки к печати.

При принятии решения о доработке статьи замечания и комментарии рецензента передаются автору. Автору дается 2 месяца на устранения замечаний. Если в течение этого срока автор не уведомил редакцию о планируемых действиях, статья снимается с очереди публикации.

При принятии решения об отказе в публикации статьи автору отправляется соответствующее решение редакции.

Ответственному (контактному) автору принятой к публикации статьи направляется финальная версия верстки, которую он обязан проверить.

ПОРЯДОК ПЕРЕСМОТРА РЕШЕНИЙ РЕДАКТОРА/РЕЦЕНЗЕНТА

Если автор не согласен с заключением рецензента и/или редактора или отдельными замечаниями, он может оспорить принятое решение. Для этого автору необходимо:

- исправить рукопись статьи согласно обоснованным комментариям рецензентов и редакторов;
- ясно изложить свою позицию по рассматриваемому вопросу.

Редакторы содействуют повторной подаче рукописей, которые потенциально могли бы быть приняты, однако были отклонены из-за необходимости внесения существенных изменений или сбора дополнительных данных, и готовы подробно объяснить, что требуется исправить в рукописи для того, чтобы она была принята к публикации.

ДЕЙСТВИЯ РЕДАКЦИИ В СЛУЧАЕ ОБНАРУЖЕНИЯ ПЛАГИАТА, ФАБРИКАЦИИ ИЛИ ФАЛЬСИФИКАЦИИ ДАННЫХ

Редакция научного журнала «Сибирский вестник сельскохозяйственной науки» в своей работе руководствуется традиционными этическими принципами научной периодики и сводом принципов «Кодекса этики научных публикаций», разработанным и утвержденным Комитетом по этике научных публикаций, требуя соблюдения этих правил от всех участников издательского процесса.

ИСПРАВЛЕНИЕ ОШИБОК И ОТЗЫВ СТАТЬИ

В случае обнаружения в тексте статьи ошибок, влияющих на ее восприятие, но не искажающих изложенные результаты исследования, они могут быть исправлены путем замены pdf-файла статьи. В случае обнаружения в тексте статьи ошибок, искажающих результаты исследования, либо в случае плагиата, обнаружения недобросовестного поведения автора (авторов), связанного с фальсификацией и/или фабрикацией данных, статья может быть отозвана. Инициатором отзыва статьи может быть редакция, автор, организация, частное лицо. Отозванная статья помечается знаком «Статья отозвана», на странице статьи размещается информация о причине отзыва статьи. Информация об отзыве статьи направляется в базы данных, в которых индексируется журнал.

УВАЖАЕМЫЕ ПОДПИСЧИКИ!

Подписку на журнал «Сибирский вестник сельскохозяйственной науки»
(как на годовой комплект, так и на отдельные номера)
можно оформить одним из следующих способов:

- на сайте Почта России. Зайти в раздел «Онлайн-сервисы», затем – «Подписаться на газету или журнал». Подписной индекс издания ПМ401;
- в агентстве подписки ГК «Урал-Пресс» по индексу 46808. Ссылка на издание http://ural-press.ru/catalog/97210/8656935/?sphrase_id=319094. В разделе контакты зайти по ссылке http://ural-press.ru/contact/, где можно выбрать филиал по месту жительства;
- в редакции журнала (телефон 7-383-348-37-62; e-mail: sibvestnik@sfsca.ru).

Полнотекстовая версия журнала
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