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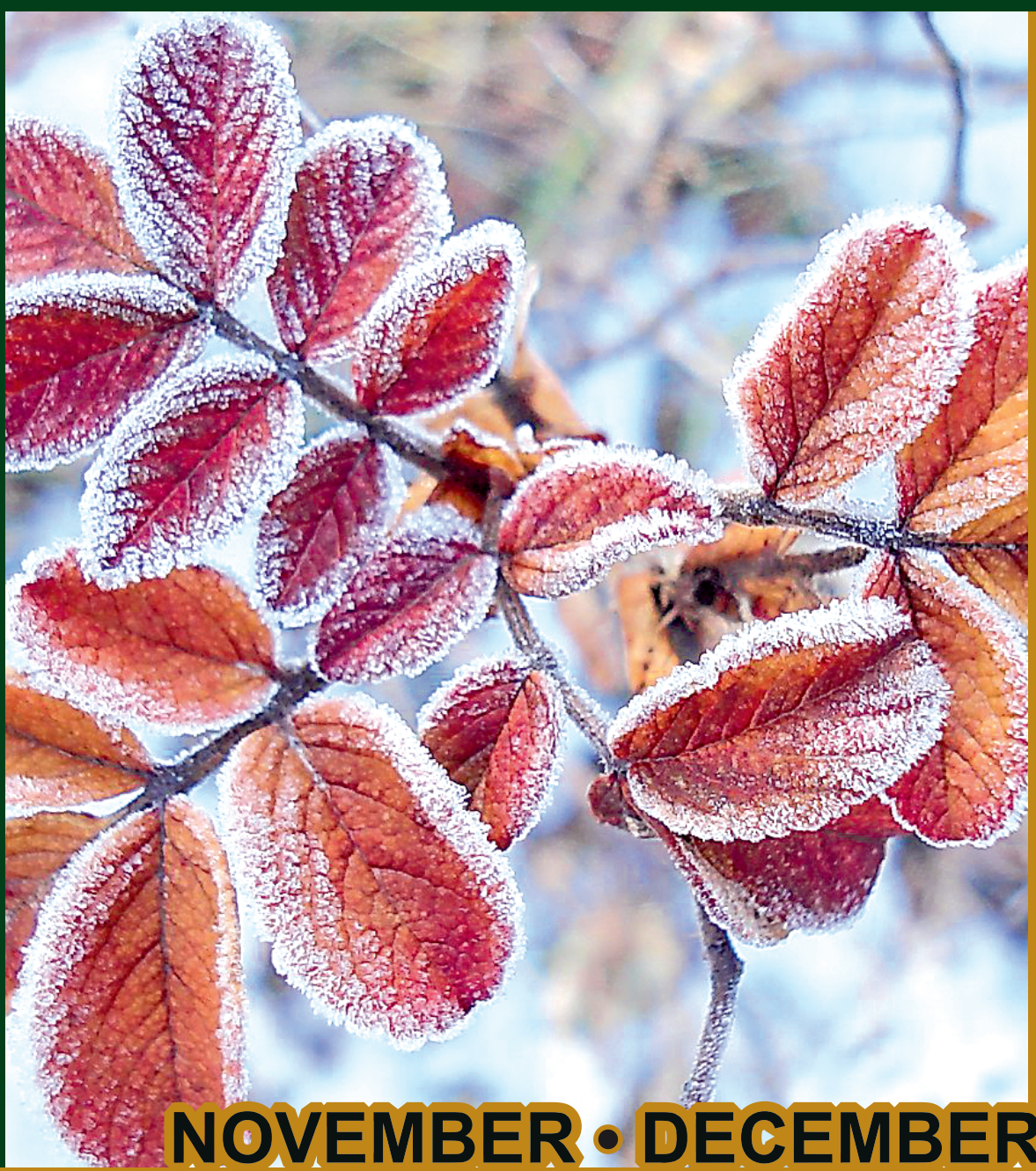

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СИБИРСКИЙ ВЕСТНИК СЕЛЬСКОХОЗЯЙСТВЕННОЙ НАУКИ

SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

УЧРЕДИТЕЛИ: СИБИРСКИЙ ФЕДЕРАЛЬНЫЙ НАУЧНЫЙ ЦЕНТР АГРОБИОТЕХНОЛОГИЙ РОССИЙСКОЙ АКАДЕМИИ НАУК
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МИНЕРАЛЬНЫЕ УДОБРЕНИЯ, ИЗВЕСТЬ И СИДЕРАЦИЯ В ПЛОДОСМЕННОМ СЕВООБОРОТЕ В УСЛОВИЯХ ПРИБАЙКАЛЬЯ

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Представлены результаты исследований по влиянию длительного применения минеральных удобрений, извести и сидерации на кислотность почвы и продуктивность сельскохозяйственных культур. Эксперимент проведен в длительном (2017–2020 гг.) стационарном полевом опыте в пятой ротации четырехпольного плодосменного севооборота: кукуруза, ячмень + клевер, клевер, яровая пшеница. Почва опытного участка – серая лесная тяжелосуглинистая. Изучали следующие варианты: без удобрений, $N_{90}P_{60}$, $P_{60}K_{90}$, $N_{90}K_{90}$, $N_{90}P_{60}K_{90}$ на двух фонах – без известкования и с внесением извести по 0,5 Нг (5,7 т/га). Установлено, что пятикратное применение мелиоранта способствовало снижению кислотности серой лесной почвы: pH_{KCl} по сравнению с исходным показателем (4,5–4,9) увеличился на 0,9–1,5, гидролитическая кислотность снизилась на 6,1–8,3 мг-экв./100 г почвы, степень насыщенности основаниями увеличилась на 20,0–25,5%. За счет применения сидерации в севообороте pH_{KCl} возрос на 0,4–0,6, гидролитическая кислотность снизилась на 2,3–4,1 мг-экв./100 г почвы, степень насыщенности основаниями увеличилась на 9,2–13,3%. Минеральные удобрения в применяемых дозах не оказывали влияния на изменение кислотности почвы, как на непроизвесткованном, так и на произвесткованном фонах. Продуктивность севооборота по вариантам опыта увеличилась на 0,23–0,69 т зерновых единиц/га (т з. ед./га) (7–21%) и была наибольшей при совместном действии полного минерального удобрения ($N_{90}P_{60}K_{90}$) и извести. Окупаемость 1 кг д.в. минеральных удобрений сельскохозяйственной продукцией составила 6,1–11,5 кг зерна, 1 т извести – 2,5–3,2 ц зерна.

Ключевые слова: серая лесная почва, кислотность, плодосменный севооборот, известкование, минеральные удобрения, сидерация

MINERAL FERTILIZERS, LIME AND GREEN MANURING IN CROP ROTATION UNDER CONDITIONS OF THE BAIKAL REGION

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The results of research on the effect of long-term application of mineral fertilizers, lime and green manuring on soil acidity and crop productivity are presented. The experiment was conducted in a long-term (2017-2020) stationary field experiment in the fifth rotation of a four-field crop rotation: corn, barley + clover, clover, spring wheat. The soil of the experimental plot is gray forest heavy loam. The following variants were studied: without fertilizers, $N_{90}P_{60}$, $P_{60}K_{90}$, $N_{90}K_{90}$, $N_{90}P_{60}K_{90}$ on two backgrounds - without liming and with the introduction of 0.5 Ng of lime (5.7 t/ha). It was found that 5 times use of ameliorant helped to decrease acidity of gray forest soil: pH_{KCl} increased by 0,9-1,5 in comparison with the initial indicator (4,5-4,9), hydrolytic acidity decreased by 6,1-

8,3 mg-eq./100 g, the degree of base saturation increased by 20,0-25,5%. Due to the use of green manuring in the crop rotation, pH_{KCl} grew by 0.4-0.6; hydrolytic acidity fell by 2.3-4.1 mg-eq./100 g of soil, the degree of base saturation raised by 9.2-13.3%. The mineral fertilizers at the applied rates had no effect on changing the soil acidity, both on non-lime- and lime-fertilized backgrounds. The productivity of crop rotations by experiment variants increased by 0.23-0.69 tons of grain units per hectare (tgru/ha) (7-21%) and was the greatest with the combined effect of total mineral fertilizer ($N_{90}P_{60}K_{90}$) and lime. The recoupment of 1 kg rate of application of mineral fertilizers to agricultural products was 6.1-11.5 kg of grain, 1 ton of lime - 2.5-3.2 kg of grain.

Keywords: gray forest soil, acidity, crop rotation, liming, mineral fertilizers, green manuring

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INTRODUCTION

The degradation of soils and land resources is a global problem that has a negative impact on the income and food security of the population around the world [1, 2]. In the Russian Federation, a widespread decrease in the soil fertility of agricultural lands has been observed since the late 20th century, which is accompanied by a negative balance of nutrition elements [3] and a general deterioration of the agrochemical characteristics of all soil types and varieties [4, 5], including gray forest subtypes [6]. Strongly acidic and moderately acidic soils prevail among these soils, which are characterized by a low content of humus and mobile forms of nutrition elements.

After eliminating excessive acidity by applying lime and making up for the lack of nutrients with mineral and organic fertilizers, it is possible to improve the agrochemical properties of gray forest soil to create favorable conditions for the cultivation of crops [7, 8].

Liming and systematic use of mineral fertilizers contribute to their effective use and stable yields[1] [9-10]. The complex effect of the systematic use of mineral fertilizers, lime and sideration on the reduction of soil acidity is currently not enough studied. The results of the studies for four rotations of fruit and vegetable rotation showed a positive effect of liming on reducing the acidity of gray forest soils and crop productivity [11, 12].

The aim of the study was to study the change in the acidity of gray forest soils with long-term use of lime, mineral fertilizers and sideration at the end of five rotations of fruit-and-vegetable crop rotation.

MATERIAL AND METHODS

Field studies were conducted in 2020 on the experimental field of the Irkutsk Research Institute of Agriculture (NIISKh) in the Irkutsk district of the Irkutsk region at the end of the fifth rotation of the fruit and vegetable rotation,

[1]Gladysheva O.V., Svirina V.A., Artyukhova O.A. Changes in soil fertility and crop rotation productivity with long-term use of mineral fertilizers with liming. Plodorodie. 2021. № 1. pp. 27–29. DOI: 10.25680/S9948603.2021.118.08.

laid in 2001. Crop rotation included the following crops: corn (for silage) - barley + clover - clover (for green manure) - spring wheat. The experiment was conducted on two backgrounds - without lime and with lime applied at 0.5 Hr (5.7 t/ha). Soil of the experimental station was gray forest heavy loamy, humus content 4,5-4,8%, total nitrogen 0,17-0,21%, pH_{salt} 3,9-4,4; hydrolytic acidity (Hr) - 9,1-10,6 mg-eq./100 g, the degree of base saturation (V) - 68,4-72,1%, P_2O_5 - 100-120, K_2O - 80-100 mg/kg soil (by Kirsanov). The following fertilizer application systems were studied: 1) without fertilizer, 2) NP, 3) PK, 4) NK, 5) NPK. Mineral fertilizers (ammonium nitrate, double superphosphate, potassium chloride) were applied to corn (hybrid Katerina SV) in the first and second rotations at a dose of $N_{90}P_{40}K_{90}$, for barley (variety Biom) with undersowing clover (variety Rodnik Sibiri) - $N_{40}P_{40}K_{40}$. Given the positive effect of green-manuring on the yield of crops for two rotations of crop rotation, starting with the third rotation (2009), the doses of mineral fertilizers were reduced by 30%, they resulted in $N_{60}P_{30}K_{60}$ (for corn) and $N_{30}P_{30}K_{30}$ (for barley).

Limestone meal ($CaCO_3$ content - 85%) was applied in spring before sowing corn (seeding rate - 200 thousand grains/ha, or 60 kg/ha) on the surface with subsequent embedding with a disc harrow in two trails at a depth of 12-15 cm. Barley and clover were sown after early spring harrowing followed by rolling (sowing rate: barley - 6.5 million germinated grains/ha, clover - 4 million germinated grains/ha). In the second year of its life clover was used as a green manure. Spring wheat (Buryatskaya ostistaya variety) was sown as the closing crop in the rotation with a seeding rate of 7 million germinated grains/ha. The area of the cultivated plot was 122.5 m^2, the area of the record plot was 96.3 m^2. Repeatability is 4 times, arrangement of plots is single-row, consecutive.

Grain crops were counted on a plot by direct harvester "Sampo-500", fodder crops - manually. The research consisted of phenological observations, soil sampling, recording of crop yields, and agrochemical analyses in the laboratory. The samples were taken from 0-20 cm layer in the first field of the crop rotation to study the soil acidity dynamics in autumn, in which pHKCl was determined by the potentiometric method (GOST 26483-85)[2], the hydrolytic acidity - by the Kappen method, and the degree of base saturation - by the computational method[3]. Statistical processing of the results was performed using the application software package Snedecor[4].

RESULTS AND DISCUSSION

Prolonged use of lime in fruit and vegetable rotation had a significant impact on the reduction of acidity of gray forest soils. The pH_{KCl} of the fertilized varieties increased by 1,1-1,5 and the hydrolytic acidity decreased by 7,1-8,3 mg equivalent per 100 grams of soil in comparison with the initial value (4,5-4,9) by the end of the fifth rotation, the degree of base saturation increased by 22,8-25,5%. In the variant without fertilizers these indicators were 0,9 and 6,1 mg-eq./100 g of soil and 20% respectively (See Table 1).

There was a decrease in the soil acidity on the background without lime application. In the variant without fertilization pH_{KCl} increased by 0,4, the hydrolytic acidity decreased by 2,3 mg-eq./100 g of soil, the degree of base saturation increased by 9,2%. In the variants with the use of mineral fertilizers the value of pH_{KCl} increased in comparison with the initial one (3,8-3,9) by 0,4-0,6, the hydrolytic acidity decreased by 3,4-4,1, the degree of base saturation increased by 9,9-13,3%. We believe that the reduction of the soil acidity on the unlimed background was influenced by the use of green mass of clover for green manure. Similar results were obtained in the studies of other scientists [13]. The neutralizing effect of green legume crop on the soil acidity was established by V.N. Prokoshev [14]. L.P. Galeeva notes the reduction of

[2]GOST 26483–85. Preparation of salt extract and determination of its pH by the CINAO method. M., 1985. 7 p.
[3]Arinushkina E.V. Guidance on chemical analysis of soils. M.: Kolos, 1979. 416 p.
[4]Sorokin O.D. Applied Statistics on the Computer. 2nd ed. Novosibirsk, 2012. 282 p.

Табл. 1. Влияние извести и минеральных удобрений на показатели кислотности серой лесной почвы в слое 0–20 см

Table 1. The effect of lime and mineral fertilizers on acidity parameters of gray forest soil in a layer of 0-20 cm

Option	pH_{KCl}		Hg, mg-eq./100 g		V, %	
	2001	2020	2001	2020	2001	2020
Without fertilizers	4,0	4,4	10,1	7,8	68,7	77,9
$N_{90}P_{60}$	3,9	4,3	11,1	7,7	68,2	78,1
$P_{60}K_{90}$	3,8	4,4	11,4	7,6	65,7	78,6
$N_{90}K_{90}$	3,9	4,5	11,4	7,3	66,3	79,6
$N_{90}P_{60}K_{90}$	3,8	4,3	11,9	8,4	65,9	76,5
Without fertilizers + lime 0,5 Hg	4,8	5,7	8,8	2,7	73,2	93,2
$N_{90}P_{60}$ + lime 0,5 Hg	4,6	6,1	8,7	1,6	73,1	95,9
$P_{60}K_{90}$ + lime 0,5 Hg	4,9	6,0	9,8	1,5	70,5	96,0
$N_{90}K_{90}$ + lime 0,5 Hg	4,5	6,0	9,8	1,7	70,8	95,2
$N_{90}P_{60}K_{90}$ + lime 0,5 Hg	4,9	6,1	8,8	1,6	72,7	95,7
$LSD_{05\ total}$	0,2	0,2	0,5	0,4	0,7	1,1
$LSD_{05\ lime}$	0,3	0,3	0,9	0,8	1,2	2,0
$LSD_{05\ fertilizers}$	0,5	0,4	0,4	1,2	0,9	3,2

hydrolytic acidity of leached chernozems when green manure is used [15]. The studies of Sh.K. Khusnidinov in our region have established that the use of Eastern galega as a greenhouse crop reduces the value of hydrolytic acidity of the soil [16]. Studies have shown that the application of mineral fertilizers in the applied doses had no significant effect on the change in the soil acidity.

Agronomic efficiency of fertilizers and ameliorants is determined by yield increase, recoupment of fertilizers unit by grain or in grain units and the share of fertilizers in yield formation. In the fruitful crop rotation for the four years on average reliable yield increase was obtained in all variants of the experience in both backgrounds. The crop capacity of the crop rotation in the fifth rotation by the variants of the experiment was increased by 0,25 - 0,61 t grain units/ha (9-21%) for the unlimed background and by 0,23 - 0,69 t grain units/ha (7-21%) for the limed one (see table 2).

The most productive was the variant with the application of $N_{90}P_{60}K_{90}$. Yield increase on the unlimed background was 0,61 t grain units/ha, or 21%, on the calcified one - 0,69 t grain units/ha, or 21%, and was the highest in the experiment with the highest payback of 1 kg rate of fertilizer application - 10,2 and 11,5 kg grain units correspondingly. In the variant with a double combination of nitrogen and phosphorus on a limed background was the lowest increase in productivity, which was 0.23 t grain units/ha with the lowest payback of 1 kg rate of fertilizer application (6.1 kg grain units).

Application of lime allowed to increase productivity of crop rotation by 0.36-0.46 tons of grain units/ha (12-14%). Recoupment of 1 t of lime by agricultural production depending on the experiment variant was 2,5-3,2 centners and was the highest at joint application of complex mineral fertilizer and ameliorant. The results of analysis of variance showed a fairly high degree of influence of the studied factors in the formation of arable productivity. The influence of lime was 0.589, mineral fertilizers - 0.405.

CONCLUSION

On the basis of nineteen-year research in the fifth rotation of the fruit and vegetable rotation it was found that the use of lime at a dose of 0.5 Ng and clover fallow ensured the reduction

Табл. 2. Влияние удобрений и извести на продуктивность севооборота и их окупаемость сельскохозяйственной продукцией (в среднем за 2017–2020 гг.)

Table 2. The effect of fertilizers and lime on crop rotation productivity and their payback by agricultural products (averaged for 2017-2020)

Fertilizers applied per crop rotation, kg a.p./ha	Crop rotation productivity, t g.u./ha	Productivity increase, t g.u./ha		Product payback	
		fertilizers	lime	1 kg a.p. of fertilizers, kg of grain	1 t of lime, centners of grain
Without fertilizers	2,84	–	–	–	–
$N_{90}P_{60}$	3,09	0,25	–	6,6	–
$P_{60}K_{90}$	3,12	0,28	–	7,4	–
$N_{90}K_{90}$	3,27	0,43	–	9,5	–
$N_{90}P_{60}K_{90}$	3,45	0,61	–	10,2	–
Without fertilizers + lime 0,5 Hg	3,22	–	0,38	–	2,7
$N_{90}P_{60}$ + lime 0,5 Hg	3,45	0,23	0,36	6,1	2,5
$P_{60}K_{90}$ + lime 0,5 Hg	3,55	0,33	0,43	8,8	3,0
$N_{90}K_{90}$ + lime 0,5 Hg	3,71	0,49	0,44	10,9	3,1
$N_{90}P_{60}K_{90}$ + lime 0,5 Hg	3,91	0,69	0,46	11,5	3,2
$LSD_{05\ total}$	0,15				
$LSD_{05\ lime}$	0,07				
$LSD_{05\ fertilizers}$	0,11				

Note. Proportion of influence: lime - 0.589, fertilizers - 0.405.

of acidity in the gray forest soil. After five rotations of the fruit-planting crop rotation and fivefold addition of lime, the grey forest soil can be classified as close to the neutral and neutral (pH_{KCl} 5,7-6,1, Hr - 1,5- 2,7 mg-eq./100 g of soil, V - 93,2-96,0%). The use of mineral fertilizers contributed to an increase in the productivity of the crop rotation by 0.23-0.69 t grain unit / ha, lime - by 0.36-0.46 t grain unit / ha. Payback of 1 kg rate of fertilizer application for the rotation averaged 6.1-11.5 kg of grain, 1 ton of lime - 2.7-3.2 kg of grain.

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ФЛУОРЕСЦЕНЦИЯ ХЛОРОФИЛЛА ЛИСТЬЕВ ПШЕНИЦЫ ПРИ ИНФИЦИРОВАНИИ *BIPOLARIS SOROKINIANA*, ХЛОРИДНОМ ЗАСОЛЕНИИ И ГИПЕРТЕРМИИ СЕМЯН

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Представлены результаты измерения и сравнение информативности параметров флуоресценции хлорофилла (ФлХ) 10-суточных проростков яровой пшеницы в лабораторных условиях при раздельном и совместном действии стрессоров. Исследования проводили в 2020, 2021 гг. Установлено, что раздельное и совместное действие хлоридного засоления (1,3%), инфицирования возбудителем корневой гнили злаков *Bipolaris sorokiniana* Shoem. (5000 конидий на зерно) подавляло световые и темновые реакции фотосинтеза. Обнаружено достоверное снижение эффективного квантового выхода *Y*(II), коэффициента фотохимического тушения *qP* и скорости электронного транспорта *ETR* у обоих сортов, наибольшее – в варианте совместного действия стрессоров (до 62,7%). Максимальный фотохимический квантовый выход ФС II *Fv / Fm* оказался менее информативным, достоверных изменений параметра не обнаружено. Ингибирование светозависимых реакций сопровождалось достоверным увеличением значений параметров нефотохимического тушения ФлХ – коэффициента *qN* и квантового выхода регулируемого нефотохимического тушения ФлХ *Y*(*NPQ*) от 24,1 до 72,1% у обоих сортов, наиболее выраженным у сорта Сибирская 12. Параметр *Y*(*NO*) – квантовый выход нерегулируемого нефотохимического тушения ФлХ – изменялся недостоверно относительно контроля у обоих сортов. Выявлен положительный эффект предварительной гипертермии семян (43 °С) на функциональную активность фотосинтетического аппарата проростков – достоверное ($p \leq 0,05$) увеличение значений параметров *Y*(II), *qP, ETR* (на 18,0–59,0%) и снижение значений параметров *Y*(*NPQ*), *Y*(*NO*) и *qN* (на 18,8–35,1%) при последующем действии инфицирования и хлоридного засоления у обоих сортов, преимущественно у сорта Омская 18. Установлена информативность параметров ФлХ для оценки стрессоустойчивости сортов. Достоверные межсортовые различия (от 1,2–6,2 раза) выявлены практически по всем параметрам (кроме *Fv / Fm, Y*(*NO*), *Fv*) по всем вариантам опыта. Установлена сортоспецифичность – наименьшие изменения параметров ФлХ относительно контроля были у устойчивого сорта Омская 18 во всех вариантах опыта. Предложенный подход позволит разработать неинвазивный метод ранней диагностики стрессоустойчивости (фенотипирования) новых генотипов пшеницы к действию биотических и абиотических стрессоров.

Ключевые слова: пшеница, сорт, устойчивость, стрессоры, фотосинтез, параметры флуоресценции хлорофилла

CHLOROPHYLL FLUORESCENCE OF WHEAT LEAVES WHEN INFECTED WITH *BIPOLARIS SOROKINIANA*, CHLORIDE SALINITY AND SEED HYPERTHERMIA

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Results of chlorophyll fluorescence parameters (ChlF) informativity measurement and comparison of 10-d-old spring wheat seedlings under laboratory conditions under separate and combined stressors action are presented. It was found that separate and combined action of chloride salinity (1,3%), infection with cereal root rot pathogen *Bipolaris sorokiniana* Shoem. (5000 conidia per grain) suppressed light and dark reactions of photosynthesis. The effective quantum yield *Y*(II), photochemical quenching *qP* and electron transport *ETR* decreased significantly in both cultivars, most significantly in the co-activated version (up to 62,7%). The maximum photochemical quantum yield of FS II *Fv / Fm* was less informative, no significant changes in the parameter were found. Inhibition of light-dependent reactions was accompanied by a significant increase in the values of the parameters of non-photochemical quenching ChlF - coefficient qN and quantum yield of regulated non-photochemical quenching ChlF *Y* (*NPQ*) from 24.1 to 72.1% in both varieties, most pronounced in the variety Sibirskaya 12. The parameter *Y*(*NO*), the quantum yield of unregulated non-photochemical quenching of ChlF, changed insignificantly relative to the control in both varieties. The positive effect of seed pre-heating (43 °C) on the functional activity of photosynthetic apparatus of seedlings - the reliable ($p \leq 0,05$) increase of the parameter *Y(II)*, *qP*, *ETR* (by 18,0-59,0%) and decrease of the parameter *Y*(*NPQ*), *Y*(*NO*) and *qN* (by 18,8-35,1%) at further infection and chloride salinization in both sorts, mainly in the variety Omskaya 18 was revealed. The informativeness of the parameters ChlF for assessment of varieties stress tolerance was established. Significant inter-variety differences (from 1.2-6.2 times) were revealed for almost all parameters (except for *Fv / Fm, Y(NO), Fv*) for all variants of experiment. The varietal specificity was established - the least changes in ChlF parameters relative to the control were in the stable variety Omskaya 18 in all variants of the experiment. The proposed approach will make it possible to develop a non-invasive method for early diagnosis of stress tolerance (phenotyping) of new wheat genotypes to biotic and abiotic stressors.

Keywords: wheat, variety, resistance, stressors, photosynthesis, chlorophyll fluorescence parameters

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INTRODUCTION

Adverse environmental conditions, soil salinity, pathogens lead to stressful conditions of plants, which limits the agricultural production of wheat worldwide. According to current projections, stress interactions between abiotic and biotic environmental factors will become even more prevalent due to observed and projected climate change [1, 2]. One of the ways to reduce the negative effects of the complex of stressors and to obtain high and stable yields of spring wheat grain is a reasonable choice of stress-resistant varieties [3, 4]. In this regard, the development of selection methods to accelerate the screening of stress-resistant genotypes at the early stages of plant development plays an important role in the programs to develop stress-resistant crop varieties. Biophysical diagnostic methods meet such requirements. In this case, integral indices of plant organism state, such as energy status (photosynthesis intensity, oxidative phosphorylation), cell membrane stability (permeability), electrical parameters (action potential), spectral characteristics, etc., are used as diagnostic indicators. [5-7].

Photosynthesis is one of the stress-sensitive processes of plant cells [8, 9]. During photosynthesis, all the light energy absorbed by chlorophyll molecules is spent on photochemical reactions (photochemical quenching), thermal dissipation (non-photochemical quenching) and fluorescence, processes competing in the deactivation of excited states of photosystem II (PS II) pigments [10]. A change in the efficiency of one of them leads to an oppositely directed change in the other two. Disruption of photosynthetic activity of plants can be assessed by chlorophyll fluorescence registration (ChlF), which allows to determine the overall bioenergetic status of a plant organism, i.e. its ability to photosynthetically transform energy [11, 12]. ChlF is a secondary emission of light energy absorbed by a chlorophyll molecule, a measure of the energy of light quanta that were not used in photosynthesis. ChlF is emitted mainly by chlorophyll α molecules in FS II antenna complexes and is associated not only with processes in the pigment matrix and reaction centers (RC) of photosystem II (PS II), but also with redox reactions on the donor and acceptor sides and even in the entire electron transfer chain. It is determined in the mode of recording dark induction curves with pulse time saturation analysis [13]. By measuring the characteristics of ChlF, it is possible to estimate the photosynthetic apparatus performance, including the fraction of energy used in photochemistry [14].

The use of ChlF measurements in the study of photosynthetic characteristics and stress in plants is currently widespread in physiological and ecophysiological studies. This is due to the development of understanding of the relationship between the parameters of ChlF and the processes of photosynthetic electron transport in the electron transport chain (ETC), which determine the change in fluorescence intensity, as well as the commercial availability of a number of fluorimeters [15, 16].

The method is non-destructive, highly sensitive and allows us to obtain information on photosynthetic efficiency and integrity of photosynthetic apparatus at the earliest stages of stress development [13, 17]. In particular, it is used to assess the resistance of wheat to temperature stress, drought, increased acidity, salinity and herbicides [7, 18- 20], apple varieties and forms to pesticides [21], garden strawberry to diseases and pests [22, 23], and for diagnostics of mineral nutrition [24, 25].

ChlF is registered by means of sensitive photodiodes used separately or as a part of fluorimeters. The most promising and widespread are PAM fluorimeters, which measure ChlF by pulse-amplitude-modulation method (Pulse-Amplitude-Modulation). By modulating the amplitude of the measuring light beam (microsecond pulse range) and parallel detection of the excited ChlF, the relative photochemical yield can be determined[1] [14]. Registration of ChlF is performed *in vivo*, does not require sample preparation of the objects under study, and takes place in the presence of light with any spectral composition, as well as sunlight under field conditions [16].

[1]Product catalog of the German company "Heinz Walz GmbH". http://www.heinzwalz.ru/

Our study was aimed at evaluation of photosynthetic activity of wheat seedlings under separate and combined action of salt stress, infection with cereal root rot pathogen *Bipolaris sorokiniana* Shoem. and elevated temperature (seed heating). These stressors are among the factors negatively affecting the growth and development of wheat in the major grain-growing areas of the world, including the West Siberian region[2] [26, 27]. These factors can disrupt normal metabolism of wheat plants, negatively affecting key physiological processes, including photosynthesis [6, 28].

The purpose of the work is to study the effect of separate and combined action of chloride salinity, common root rot and elevated temperature (seed heating) on ChlF parameters of soft spring wheat seedlings to identify informative parameters for assessing stress tolerance of varieties.

MATERIAL AND METHODS

Experimental work was carried out in the laboratory for the study of physical processes in agrophytocenoses of the Siberia Physical and Engineering Institute of Agrarian Issues, SFSCA RAS.

To identify informative parameters of ChlF, greenhouse experiments (water cultures) under laboratory conditions were carried out under separate and combined effects of sodium chloride, the causative agent of common root rot of cereals and elevated temperature (seed heating) on the seedlings of released varieties of spring wheat: Sibirskaya 12 (relatively unstable) selected by Siberian Research Institute of Plant Industry and Breeding - branch of the Institute of Cytology and Genetics, SB RAS, and Omskaya 18 (relatively stable) selected by Omsk Agrarian Scientific Center.

Experiment options:

- Control (seeds without heating) and elevated temperature (seed heating at 43 °C);
- seeds without heating + infection with *B. sorokiniana* (5000 conidia per grain);
- seeds without heating + chloride salinity 1,3%;
- seeds without heating + infection with *B. sorokiniana* (5000 conidia per grain) + chloride salination 1.3%;
- seed heating at 43°C + infection with *B. sorokiniana* (5000 conidia per grain);
- seed heating at 43°C + chloride salination 1.3%;
- seed heating at 43 °C + infection with *B. sorokiniana* (5000 conidia per grain + chloride salination 1.3%.

The levels of stress loads - conidial suspension of *B. sorokiniana* 5000 conidia per grain and concentration of sodium chloride (NaCl) 1.3% - were determined by us in specially conducted greenhouse experiments as allowing to differentiate wheat varieties of Siberian breeding in evaluation of their resistance to these stress factors by biometric indices and cell membrane permeability [3, 4] [29].

Wheat seeds were presterilized with 96% ethyl alcohol for 2 min followed by three-fold rinsing with distilled water. The seeds were heated for 20 min in hot water in a water bath according to VIR method[5]. After cooling, the seeds were placed in Petri dishes with moistened filter paper and germinated in the thermostat at 22 ºC for three days. Simultaneously, soaked seed samples were germinated without heating. On the third day of cultivation, the seeds were infected with a conidial suspension of a mixture of medium pathogenic *B. sorokiniana* isolates prepared on 0.1% aqueous agar (one drop per grain).

[2]Goltyapin V.Y., Mishurov N.P., Fedorenko V.F., Golubev I.G., Balabanov V.I., Petukhov D.A. Digital technologies for surveying agricultural land by drones: analytical review. Moscow: Rosinformagrotech, 2020. 88 p.

[3]Patent RU 2446671 IPC A01G7/00, A01H1/04. Method of determination of relative resistance of varieties of soft spring wheat to chloride salinity. T.A. Gurova, V.Y. Berezina, N.S. Kutserubova. Published on 10.04.2012.

[4]Patent RU 2625027 IPC A01C12N 1/14, A01H 5/12. Method for determining the relative resistance of varieties of soft spring wheat to the pathogen of common root rot of cereals. T.A. Gurova, V.V. Alt, O.S. Lugovskaya. Published on 11.07.2017.

[5]Diagnostics of plant resistance to stresses: method recommendations, edited by G.V. Udovenko. Л., 1988. 228 p.

Then the seedlings were grown in the climatic chamber Biotron-7 in a roll culture with tap water (variants - control and infection with *B. sorokiniana*) and sodium chloride at the photoperiod "day-night" 16 and 8 h, respectively, illumination 20 000 and 0 lux (day-night), temperature 22 and 18 ºC (day-night), humidity 60%.

The kinetics and parameters of ChlF PS II were recorded using a Dual- PAM-100/F fluorimeter (Heinz Walz GmbH, Germany) using amplitude-pulse modulation in the mode of recording the slow kinetics of dark induction curves with saturation pulse analysis (Slow Kinetics). The delay time for recording the induction curves after determining the minimum and maximum ChlF α is 40 s, which is sufficient for complete re-oxidation of acceptors ("opening" of reaction centers). The interval between saturation pulses during recording of induction curves is 20 s, the data recording time is 4 min. Excitation of chlorophyll α molecules was performed by a "blue" light-emitting diode with a wavelength of 460 nm, detection of the ChlF was performed by a "red" photodiode with a wavelength of 680 nm. The fluorimeter was controlled by specialized software. Before measuring the ChlF, 10-day-old wheat seedlings were adapted to darkness in a sample chamber for 30 min to reach completely oxidized state of PS II acceptors (all PS II reaction centers were "open"). To record the ChlF parameters, a seedling sheet was fixed on a rack with an optical holder and a program for recording ChlF induction curves was run.

The following fluorescence parameters were obtained: *Fo, Fm* - minimum and maximum levels of ChlF induced by the light pulse after leaf adaptation to darkness; *Fo', Fm'* - minimum and maximum levels of ChlF induced by the light pulse after leaf adaptation to light; *Fv / Fm* - maximum photochemical quantum yield of PS II; *Y*(II) - effective photochemical quantum yield of PS II after leaf adaptation to light; *Y*(*NPQ*) - quantum yield of regulated non-photochemical quenching of ChlF; *Y*(*NO*) - quantum yield of unregulated non-photochemical quenching of ChlF; *qP* - photochemical quenching factor of ChlF; *qN* - non-photochemical quenching factor of ChlF; *ETR* - electron transport rate. The variable (variable) ChlF was calculated: $Fv = Fm - Fo$.

Variety response was determined by the relative change in the measured parameters of seedlings after exposure of plants to stressors. The smaller changes in parameters, the higher the resistance in the studied group of varieties. Repetition of the experiments were analytical and biological - 6-fold and 3-fold. Statistical processing of data was performed in Microsoft Excel 2000 program using a standard data analysis package. The parameters of ChlF recorded for 4 min were analyzed. Error of mean did not exceed 3-5%. Three series of experiments were performed. Student's t-test was used to determine the significance of differences in mean values.

RESULTS AND DISCUSSION

ChlF parameters, the changes of which reflect structural and functional characteristics of the photosynthetic apparatus of plants, were evaluated in seedlings of two wheat varieties under infection with common rot pathogen, chloride salinity and seed pre-heating with the possibility of diagnosing stress tolerance of varieties. PAM measurements of the ChlF generate different parameters, which are mainly derived from five mutually independent levels of ChlF: minimum (background) *Fo* and maximum fluorescence yields *Fm* in the dark-adapted state; steady-state *Fs*; minimum (background) *Fo*' and maximum fluorescence yields *Fm*' in the light adapted state of samples, respectively.

The variable ChlF after dark leaf adaptation is Fv. The parameter depends on the maximum quantum yield of PS II. The decrease in the value of this parameter indicates the weakening of photosynthetic activity and energy dissipation in the form of heat. The value of *Fv* decreases under stresses which cause damage to thylakoids [13]. Stress factors in the conditions of our experiment slowed down the activity of photosynthetic apparatus of the seedlings of both varieties, which was expressed in reliable ($p \leq 0.05$) decrease of *Fv* parameter values in all variants of the experiment (from 14.0 to

42.4%), the highest in the variant of combined stressors compared with the control (see the table).

We found that seed pre-heating increased seedling resistance (by cross-adaptation) to the subsequent action of the pathogen and salinity [30]. Cross-adaptation is the process of increasing the resistance of an organism to a particular stress factor as a result of adaptation to a factor of another nature. It can be assumed that in our experiment, pre-warming of seeds activates the protective mechanisms of plants and keeps them active for a long time. Subsequent action of pathogen and salinity increases the level of signaling molecules and the already activated defense systems try to prevent stress development.

The protective effect of hyperthermia was noted in the variant of infection in the variety Sibirskaya 12: reliable ($p \leq 0,05$) decrease of *Fv* inhibition by 13,3%, and also in the variants of combined action of the stressors in the variety Sibirskaya 12 by 34,6% and in the variety Omskaya 18 by 41,7%. In the variant of salinity after seed heating, the increase of inhibitory effect of the stressor - 2-fold reduction of *Fv* parameter, most pronounced in the variety Sibirskaya 12 - was observed.

The parameter of ChlF variable can be considered as informative in the study of the influence of stress factors (infection with common rot pathogen, chloride salinity and pre-heating of seeds) on photosynthetic activity of wheat seedlings. However, reliable inter-variety differences in this parameter were not revealed in the conditions of our experiment.

Maximum photochemical quantum yield of PS II – Fv / Fm. This parameter is one of the basic characteristics of photosystems work. It evaluates the maximum photochemical activity of PS II and is defined as the ratio of the number of light quanta used in the charge separation of PS II to the total number of quanta absorbed by the antenna complex of this photosystem [16]. The parameter is registered immediately after dark adaptation of plant tissues. Significant influence of stress factors and associated with them slowing down the activity of photosynthetic apparatus of seedlings of both varieties in the conditions of our experiment expressed by changes in the parameter *Fv / Fm* in all the experimental variants was not found (see the table). At the same time, the values of the background *Fo* and maximum *Fm* ChlF under the conditions of our experiment significantly decreased in both varieties almost in all the variants. Stress factors influenced the antennal complex, i.e. there were losses of energy during its migration, and fluorescence was excited. At the same time, unreliable changes of *Fo* were established in the variety Sibirskaya 12 in the variant of infection with seed heating and in the variety Omskaya 18 in the variants of combined stress and salinization with and without seed heating. *Fm* indicator did not change significantly in both varieties in the variants of infection without heating and with heating of seeds. The maximum photochemical quantum yield is a frequently used parameter in assessing the effect of environmental stressors on the photosynthetic apparatus of plants, but in the studies on the assessment of phytotoxic states of duckweed, insufficient sensitivity and uninformativeness of this parameter are also noted [31].

Effective photochemical quantum yield of PS II in the light – Y(II). Y(II) = (*Fm′ – Fs*)/*Fm′*. The parameter reflects the part of light energy that can potentially be used in photochemical reactions. It is measured after adaptation of plant tissues to the light at "closed" RC PS II, when the primary acceptors plastoquinones are in reduced state. We found that infection of wheat seedlings with *B. sorokiniana*, chloride salinity and their combined effect have a negative effect on the efficiency of photochemical quenching of ChlF, which leads to a decrease in the intensity of photosynthesis. The effect of stressors is associated with the disturbance of electron acceptance by RC PS II [14]. Under the conditions of our experiments, *Y*(II) decreased significantly ($p \leq 0.05$) from 18.6 to 56.6% in the seedlings of both varieties in all experimental variants compared to the control, most significantly in the variant of combined action of stressors (see the table).

Pre-heating of seeds with subsequent overlapping of infection and chloride salinity influ-

Изменение значений параметров флуоресценции хлорофилла проростков пшеницы при раздельном и совместном действии стрессоров (отн. ед.)
Changing values of chlorophyll fluorescence parameters of wheat seedlings under separate and combined stressors (relative units)

Variety	Option	Indicator									
		Y(II)	*Y*(*NPQ*)	*Y*(*NO*)	*qP*	*qN*	*ETR*	*Fo*	*Fm*	*Fv*	*Fv*/ *Fm*
Without seed heating											
Sibirskaya 12	Control	4,1 ± 0,2	2,9 ± 0,1	3,0 ± 0,1	6,3 ± 0,3	5,3 ± 0,2	204,7 ± 9,1	7,6 ± 0,4	22,9 ± 1,4	15,3 ± 0,2	0,67 ± 0,02
	B. sorokiniana	3,3 ± 0,1*	3,6 ± 0,2*	3,1 ± 0,1	5,1 ± 0,2*	5,9 ± 0,2	159,9 ± 7,3*	6,8 ± 0,3	20,0 ± 1,3*	13,2 ± 0,2*	0,66 ± 0,02
	NaCl	2,8 ± 0,1*	3,8 ± 0,1*	3,4 ± 0,2	4,3 ± 0,1*	5,8 ± 0,1	133,5 ± 4,0*	6,2 ± 0,2*	19,4 ± 0,3*	13,2 ± 0,2*	0,68 ± 0,02
	B. sorokiniana+ NaCl	1,8 ± 0,1*	4,8 ± 0,2*	3,4 ± 0,1	3,0 ± 0,1*	6,7 ± 0,3*	77,5 ± 1,7*	6,1 ± 0,2*	16,2 ± 0,2*	10,1 ± 0,1*	0,63 ± 0,03
Omskaya 18	Control	3,3 ± 0,1	3,2 ± 0,1	3,5 ± 0,2	4,9 ± 0,2	5,4 ± 0,1	161,0 ± 7,8	6,3 ± 0,2	20,7 ± 0,5	14,4 ± 0,3	0,70 ± 0,03
	B. sorokiniana	3,0 ± 0,1	4,1 ± 0,2	2,9 ± 0,1	4,7 ± 0,1	6,5 ± 0,3*	155,4 ± 5,1	7,5 ± 0,3*	22,6 ± 0,6	15,1 ± 0,3	0,67 ± 0,02
	NaCl	2,0 ± 0,1*	4,7 ± 0,2	3,3 ± 0,1	3,2 ± 0,1*	6,5 ± 0,3*	87,6 ± 1,9*	6,2 ± 0,2	18,1 ± 0,3	11,9 ± 0,2*	0,66 ± 0,02
	B. sorokiniana + NaCl	1,8 ± 0,1*	5,1 ± 0,3	3,1 ± 0,1	3,1 ± 0,1*	7,0 ± 0,3*	80,9 ± 1,6*	4,9 ± 0,1*	13,2 ± 0,2*	8,3 ± 0,1*	0,63 ± 0,01
Seed heating 43°C											
Sibirskaya 12	Control	4,3 ± 0,2	2,2 ± 0,1	3,5 ± 0,2	6,2 ± 0,3	4,3 ± 0,2	214,5 ± 10,5	7,9 ± 0,4	26,4 ± 0,9	18,5 ± 0,5	0,70 ± 0,06
	B.sorokiniana	3,5 ± 0,1*	2,9 ± 0,1*	3,3 ± 0,1	5,2 ± 0,2*	5,0 ± 0,2*	171,3 ± 8,1*	7,6 ± 0,4	23,9 ± 0,5	16,3 ± 0,3	0,68 ± 0,05
	NaCl	2,7 ± 0,1*	3,8 ± 0,2*	3,5 ± 0,2	4,2 ± 0,2*	5,8 ± 0,2*	127,9 ± 3,2*	6,6 ± 0,3*	19,9 ± 0,4*	13,3 ± 0,2*	0,67 ± 0,04
	B. sorokiniana+ NaCl	2,3 ± 0,1*	3,6 ± 0,2*	4,1 ± 0,2*	3,7 ± 0,1*	5,4 ± 0,2*	107,9 ± 2,1*	6,7 ± 0,2*	21,1 ± 0,6*	14,4 ± 0,2 *	0,68 ± 0,02
Omskaya 18	Control	3,5 ± 0,2	2,9 ± 0,1	3,6 ± 0,1	4,4 ± 0,2	4,7 ± 0,1	173,3 ± 5,4	7,3 ± 0,4	23,9 ± 0,7	16,6 ± 0,3	0,69 ± 0,03
	B. sorokiniana	2,8 ± 0,1*	4,1 ± 0,2*	3,1 ± 0,1*	4,6 ± 0,2	6,4 ± 0,3*	147,2 ± 2,9*	6,5 ± 0,3	19,4 ± 0,5*	12,9 ± 0,2*	0,67 ± 0,03
	NaCl	2,3 ± 0,1*	3,8 ± 0,1*	3,9 ± 0,2	3,6 ± 0,1*	6,0 ± 0,3*	106,6 ± 1,9*	5,9 ± 0,2*	18,4 ± 0,5*	12,5 ± 0,1*	0,68 ± 0,04
	B. sorokiniana+ NaCl	1,9 ± 0,1*	4,0 ± 0,2*	4,1 ± 0,2*	3,0 ± 0,1*	5,7 ± 0,2*	85,2 ± 1,4*	6,9 ± 0,3	19,4 ± 0,6*	12,5 ± 0,2*	0,65 ± 0,02

* Differences with the control are significant at the significance level $p \leq 0.05$.

enced the parameter *Y*(II) in different degree. Significant ($p \leq 0,05$) increase of the parameter was observed in the variety Omskaya 18 under salinization by 28,0%, and in the variety Sibirskaya 12 under combined action of stressors and infection by 18,0 and 59,6%, respectively, which means that the positive effect of seed pre-heating on the functional activity of PS II was revealed. Similar results on the protective role of the temperature factor in maintaining the stability of photosynthetic membranes were obtained in hyperthermia and infection with *B. sorokiniana* of barley seedlings [32]. The parameter *Y*(II) changed to the least extent relative to the control in the seedlings of the variety Omskaya 18. Inter-variety differences in all the variants of experiments were 1.2-2.0 times with reliability of differences at the level of $p \leq 0.05$. The greatest differences in the variant of infection with and without seed heating were 1.7-2.0 times. Fig. 1 shows the changes of *Y*(II) parameter under the action of *B. sorokiniana* and chloride salinity without seed pre-heating.

Quantum yield of regulated non-photochemical quenching of ChlF – Y(NPQ). Y(*NPQ*) = 1 – *Y*(II) – 1 / (*NPQ* + 1 + *qL* (*Fm/ Fo* – 1)). The parameter reflects the energy-dependent thermal dissipation of excited chlorophyll PS II energy [13]. Regulated non-photochemical quenching of ChlF acts as a protective mechanism against excess excitation energy, i.e., it dissipates it into safe heat. This avoids damage to the RC of PS II by light, the intensity of which exceeds the electron transport capabilities [33]. Regulated heat dissipation is stimulated by the xanthophyll cycle [14, 34]. We found that under the action of *B. sorokiniana*, chloride salinity and hyperthermia of seeds there is an activation of the dissipation of part of the excitation energy of chlorophyll PS II into heat. Parameter *Y(NPQ)* was reliably ($p \leq 0,05$) increased in both cultivars in all the experimental variants from 24,1 to 72,7%, and more in the variety Sibirskaya 12, especially in the variants of salinity and combined action of stressors with seed pre-heating - 72,7 and 63,6%, respectively (see the table).

Protective effect of hyperthermia was observed only in the variety Omskaya 18 under the combined effect of stressors and chloride salinity - reliable ($p \leq 0.05$) reduction of the parameter by 35.1 and 18.8%. In the variety Sibirskaya 12 we observed a 24.1% decrease in the parameter in the control variant compared to the control without seed heating.

Inter-variety differences in all the variants of experiments ranged 1.2-1.7 times with reliability of differences at the level of $p \leq 0.05$. The greatest differences in the variant of salinity without heating and with seed heating were 1,5-1,7 times.

Fig. 2 shows changes in the Y(NPQ) parameter under the action of B. sorokiniana and chloride salinity without seed pre-heating.

Quantum yield of unregulated non-photochemical quenching of ChlF – Y(*NO*). *Y*(*NO*) = 1 / (*NPQ* + 1 + *qL* (*Fm/Fo*–1)). The parameter is related to the thermal losses resulting from the "closure" of the RC of PS II as a result of blocking the electron transfer along the electron-transport chain [14]. Side reactions in this case are associated with the formation of active oxygen radicals. An increase in the index means that photochemical energy conversion and protective regulatory mechanisms are ineffective. Very high value of the index indicates not only blocking of RC PS II, but also violation of proton gradient of thylakoid membranes [35]. Under the conditions of our experiments, unreliable changes of the index in the variety Sibirskaya 12 in all the experimental variants were established (see the table). In the variant of infection with *B. sorokiniana*, the stimulating effect of seed hyperthermia was observed in the variety Omskaya 18; the index decreased by 13,9% relative to the control with unreliable changes in all the test variants, except for the variant of combined action of stressors with seed heating - *Y(NO)* increase by 13,8%. The results obtained indicate the effectiveness of protective regulatory mechanisms of photosynthetic reactions in the seedlings of these varieties with the advantage of the variety Omskaya 18. Fig. 3 shows changes in the *Y(NQ)* parameter under the action of *B. sorokiniana* and chloride salinity without seed pre-heating.

Photochemical quenching coefficient of ChlF – qP. qP = (*Fm'*– *Fs*) / (*Fm'* – *Fo'*). The

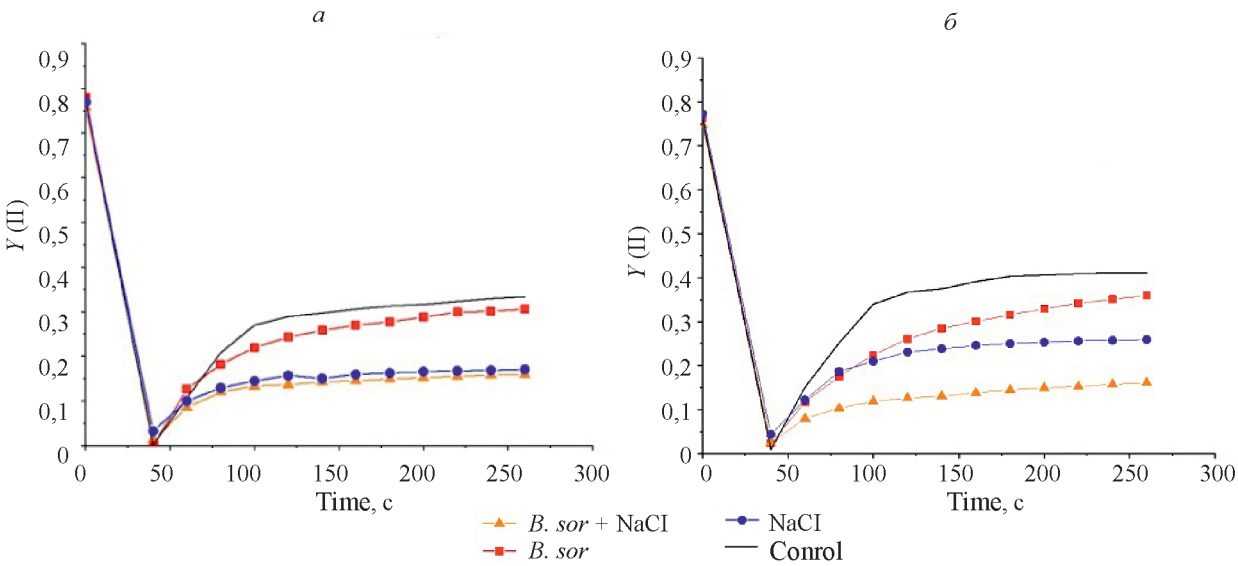

Рис. 1. Усредненные значения эффективного квантового выхода фотохимического превращения световой энергии *Y*(II) проростков яровой пшеницы при действии *B. sorokiniana* и хлоридного засоления:
а – сорт Омская 18; *б* – сорт Сибирская 12

Fig. 1. Average values of effective quantum yield of photochemical conversion of light energy *Y*(II) of spring wheat seedlings under the action of *B. sorokiniana* and chloride salinity:
а - variety Omskaya 18; *б* - variety Sibirskaya 12

parameter estimates the fraction of complexes of PS II with the oxidized primary acceptor QA at the time before the application of saturating light flash. Indicates the fraction of light energy consumed by the "open" RCs of FS II. We found reliable ($p \leq 0,05$) decrease of *qP* parameter in all the experimental variants for both cultivars in the range from 16,1 to 52,4%, more so for the variety Sibirskaya 12 (see the table). In the variety Omskaya 18 in the variant of infection reliable changes in the parameter were not found. All stress factors reduced the number of complexes of FS II with oxidized primary acceptor QA, which led to a violation of photochemical quenching of ChlF.

The protective effect of hyperthermia was established in the variant of combined action of stressors in the variety Sibirskaya 12 and in the variants of salinization and combined action of stressors in the variety Omskaya 18 - reliable ($p \leq 0.05$) increase of *qP* parameter by 23.1; 47.6 and 13.6%, respectively. Analysis of the experimental data shows the coincidence of the dynamics of the photochemical quenching coefficient *qP* with the dynamics of the effective photochemical quantum yield of PS II in the light *Y*(II). Inter-variety differences in all the variants of experiments were 1.3-4.7 times with the reliability of differences at the levels of $p \leq 0.05$ and $p \leq 0.01$. The greatest differences in the variants of infection with and without heating of seeds were 3.4-4.7 times.

Fig. 4 shows changes in *qP* parameter under the action of *B. sorokiniana* and chloride salinity without seed pre-heating.

Non-photochemical quenching coefficient of ChlF – qN. qN = (Fm – Fm′) / (Fm – Fo′). The parameter is related to the processes of conversion of a part of the energy absorbed in the light phase of photosynthesis into heat. It increases in stressed plants [11, 12]. Under our conditions, *qN* increased significantly ($p \leq 0.05$) in all the experimental variants from 16.3 to 36.2% in both varieties, to a lesser extent in the variety Sibirskaya 12 in infection and chloride salinity variants without seed warming (see the table). However, pre-heating of seeds led to an increase in thermal dispersion in both varieties, most pronounced in the variety Sibirskaya 12 (up to 3.5 times in the variant of salinity). At the same time, the protective effect of hyperthermia was also observed. Thus, the variety Omskaya

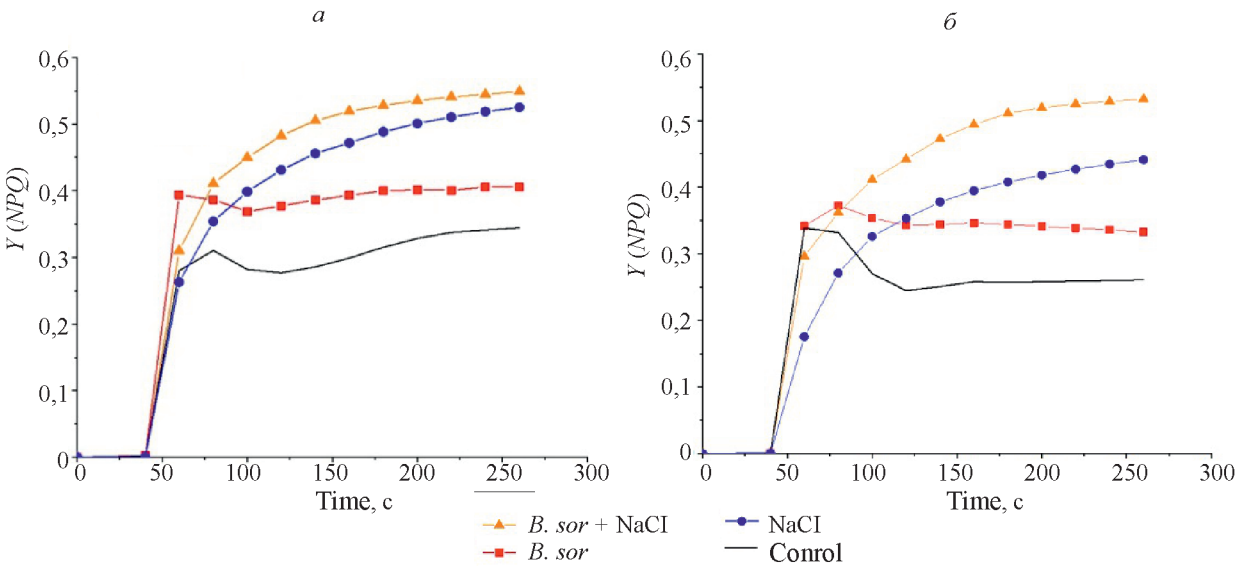

Рис. 2. Усредненные значения квантового выхода регулируемого нефотохимического тушения ФлХ – *Y*(*NPQ*) проростков яровой пшеницы при действии *B. sorokiniana* и хлоридного засоления: *а* – сорт Омская 18; *б* – сорт Сибирская 12

Fig. 2. Average values of quantum yield of regulated non-photochemical quenching ChlF - *Y(NPQ)* of spring wheat seedlings under the action of *B. sorokiniana* and chloride salinity: *а* – variety Omskaya 18; *б* – variety Sibirskaya 12

18 showed a decrease of *qN* parameter values in the variant of combined stressors and control by 28.1 and 27.7%, respectively. In the Sibirskaya 12 variety *qN* parameter decreased only in the control variant by 23.3%. Since photochemical and non-photochemical quenching of chlorophyll fluorescence are competitive, the higher *qP*, the lower *qN*. Analysis of the obtained data confirmed this fact (see Fig. 5, 6). Intersectional differences in all the variants of the experiments were 1,2-2,3 times with the reliability of differences at the level of $p \leq 0{,}05$ and $p \leq 0{,}01$. The greatest differences in the variant of salinity without heating and infection with seed heating were 2.2-2.3 times.

The speed of electronic transport through photosystems – ETR. ETR = Y(II) × 0,84 × 0,50 × *PPFD*. The parameter shows the rate of charge separation in RC PS II. The electron transport rate decreases under stress [12, 13]. We found that *B. sorokiniana* stress factors, chloride salinity and seed hyperthermia significantly ($p \leq 0.05$) reduced the electron transport rate in wheat seedlings of both varieties in all the test variants in the range from 15.2 to 62.7%, especially in the Sibirskaya 12 variety (see the table). The greatest decrease of *ETR* values in comparison with the control was observed in the variant of joint action of stressors - 62,1% (Sibirskaya 12) and 49,8% (Omskaya 18). The pathogen had less effect on the electron transport rate. The *ETR* parameter decreased by 21.9% in the Sibirskaya 12 variety, while the Omskaya 18 variety showed insignificant changes compared to the control (see Fig. 6).

The protective effect of seed hyperthermia was observed in the variety Sibirskaya 21 - reliable ($p \leq 0.05$) increase of *ETR* by 20.7% in the variant of combined effect of stressors and in the variety Omskaya 18 in the variant of salinity by 36.7%. Inter-variety differences in all the variants of the experiments were 1.2-6.2 times with reliability of differences at the levels of $p \leq 0.05$ and $p \leq 0.01$. The greatest differences in the variant of infection without seed heating were 6,2 times.

Thus, the varietal specificity and informativeness of all the applied parameters of ChlF in the study of the combined effect of the causative agent of common root rot, chloride salinity and seed hyperthermia on the seedlings of spring wheat varieties was established.

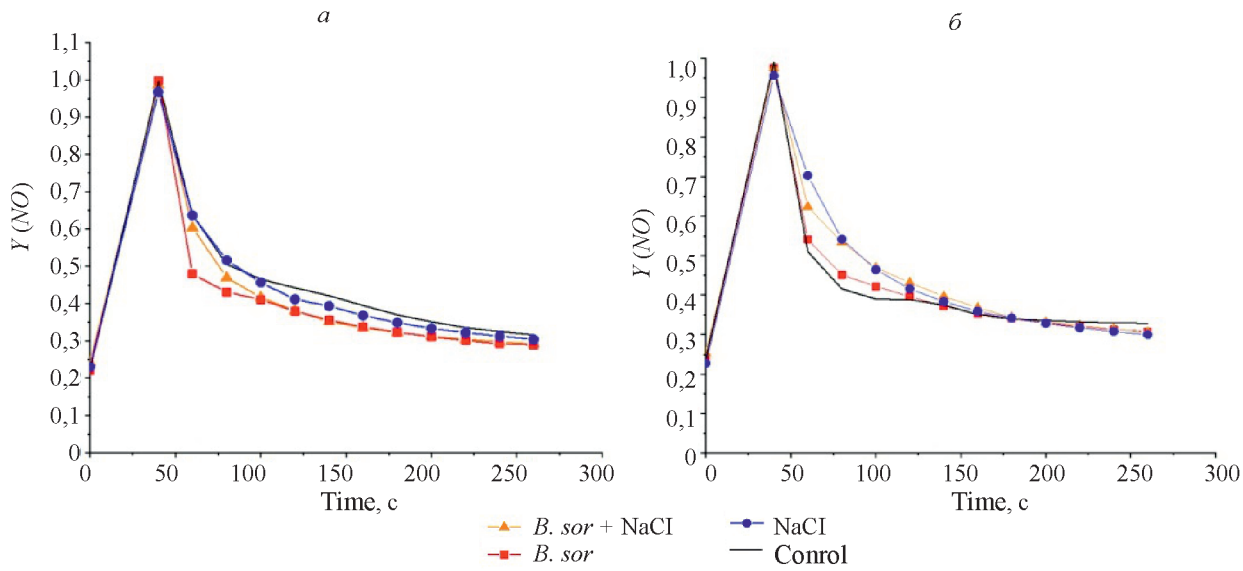

Рис. 3. Усредненные значения квантового выхода нерегулируемого нефотохимического тушения ФлХ – *Y*(*NQ*) проростков яровой пшеницы при действии *B. sorokiniana* и хлоридного засоления:
а – сорт Омская 18; *б* – сорт Сибирская 12

Fig. 3. Average values of quantum yield of unregulated non-photochemical quenching ChlF - *Y(NQ)* of spring wheat seedlings under the action of *B. sorokiniana* and chloride salinity:
а - variety Omskaya 18; *б* - variety Sibirskaya 12

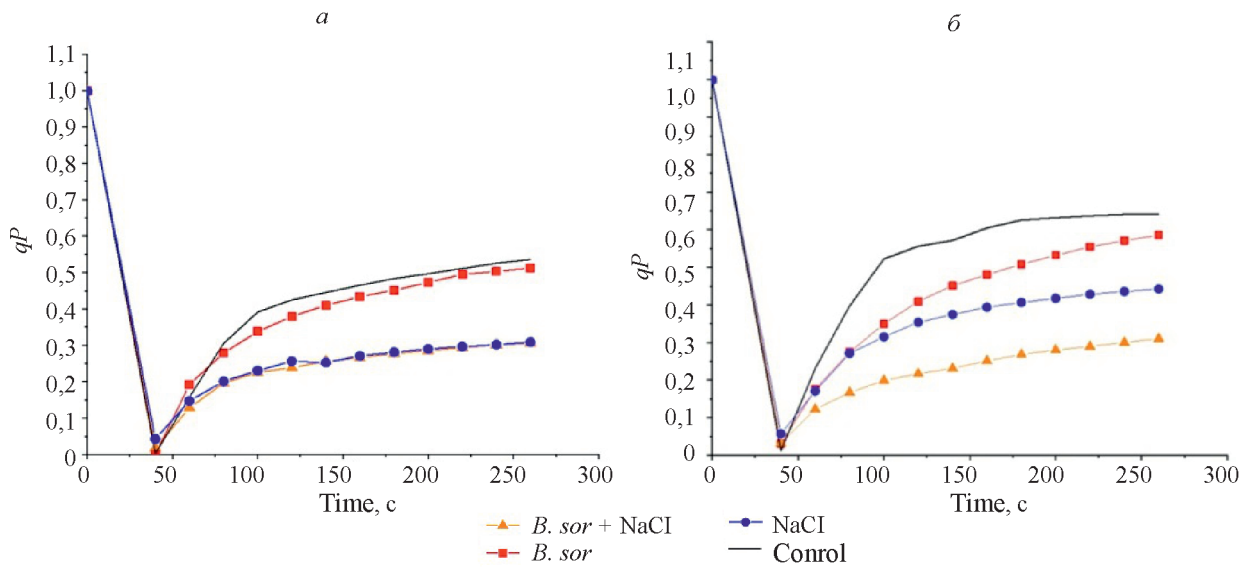

Рис. 4. Усредненные значения коэффициента фотохимического тушения флуоресценции хлорофилла – *qP* проростков яровой пшеницы при действии *B. sorokiniana* и хлоридного засоления:
а – сорт Омская 18; *б* – сорт Сибирская 12

Fig. 4. Average values of photochemical quenching coefficient of chlorophyll fluorescence - *qP* of spring wheat seedlings under the action of *B. sorokiniana* and chloride salinity:
а – variety Omskaya 18; *б* – variety Sibirskaya 12

CONCLUSIONS

1. Separate and combined effects of chloride salinity (1.3%), infection with the cereal root rot pathogen *B. sorokiniana* (5000 conidia per grain) suppressed light and dark reactions of photosynthesis. Reliable ($p \leq 0,05$) decrease of effective quantum yield *Y*(II), photochemical quenching coefficient *qP* and electron transport rate *ETR* was found in both varieties, the greatest - in the variant of combined stressors (up to 62,7%). The maximum photochemical

quantum yield of PS II *Fv / Fm* was less informative, no significant changes in the parameter were found.

2. Inhibition of light-dependent reactions was accompanied by a significant ($p \leq 0.05$) increase in the values of non-photochemical quenching parameters of ChlF - coefficient *qN* and quantum yield of regulated non-photochemical quenching of ChlF Y(NPQ) from 24.1 to 72.1% in both varieties, most pronounced it was in the variety Sibirskaya 12, especially in the variants with salinity and combined stress-

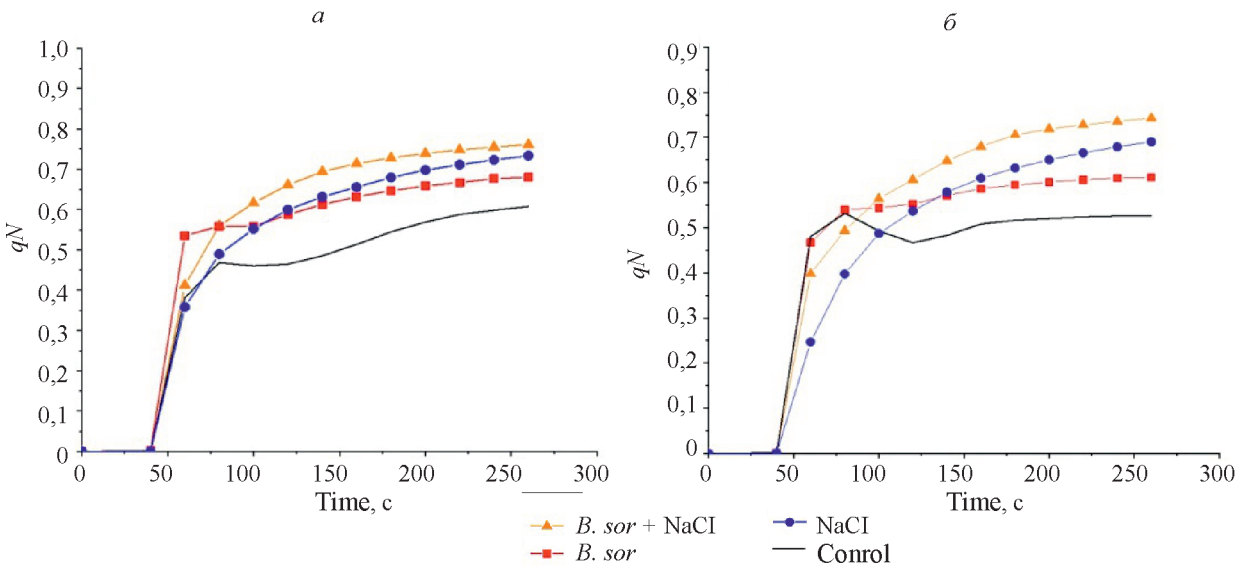

Рис. 5. Усредненные значения коэффициента нефотохимического тушения ФлХ – *qN* проростков яровой пшеницы при действии *B. sorokiniana* и хлоридного засоления:
а – сорт Омская 18; *б* – сорт Сибирская 12

Fig. 5. Averaged values of non-photochemical quenching coefficient ChlF - *qN* of spring wheat seedlings under the action of *B. sorokiniana* and chloride salinity:
а – variety Omskaya 18; *б* – variety Sibirskaya 12

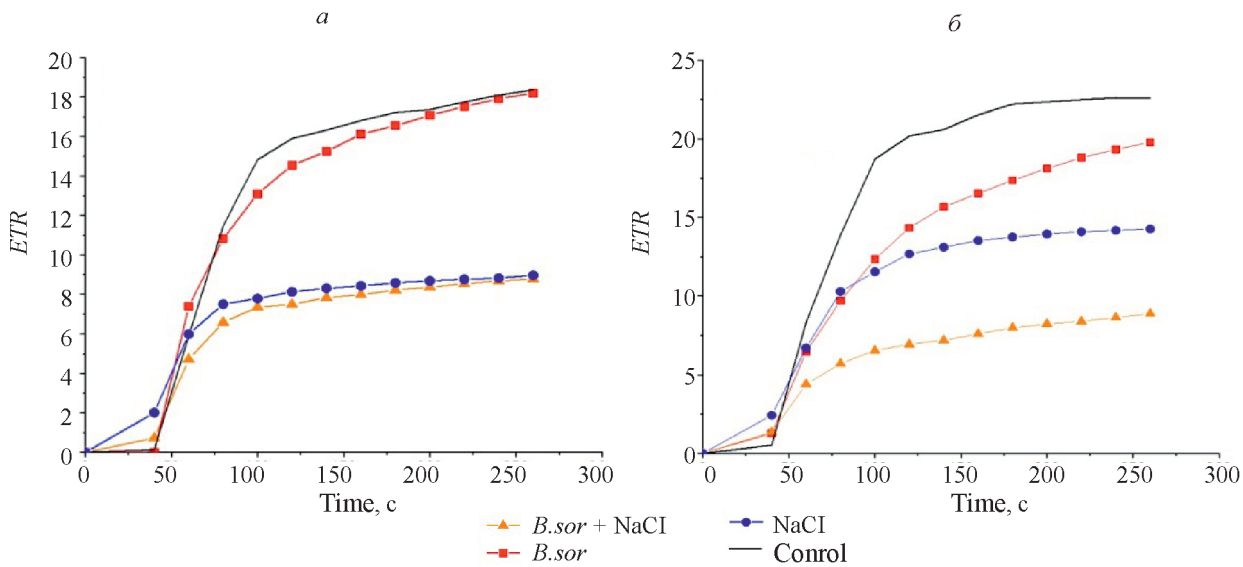

Рис. 6. Усредненные значения скорости электронного транспорта через фотосистемы – *ETR* проростков яровой пшеницы при действии *B. sorokiniana* и хлоридного засоления:
а – сорт Омская 18; *б* – сорт Сибирская 12

Fig. 6. Average values of electron transport rate through photosystems - *ETR* of spring wheat seedlings under the action of *B. sorokiniana* and chloride salinity:
а - variety Omskaya 18; *б* - variety Sibirskaya 12

ors. The parameter *Y(NO)* - quantum yield of unregulated non-photochemical quenching of ChlF changed insignificantly relative to the control in both varieties.

3. The positive effect of preliminary hyperthermia of seeds on the functional activity of photosynthetic apparatus of seedlings was revealed - a significant ($p \leq 0.05$) increase of values of *Y(II), qP, ETR* parameters (by 18.0-59.0%) and decrease of values of *Y(NPQ), Y (NO)* and *qN* parameters (by 18.8-35.1%) under the subsequent action of infection and chloride salinity in both varieties, mainly in the variety Omskaya 18.

4. The informativeness of ChlF parameters for assessment of varieties stress tolerance was established. Significant inter-variety differences (from 1.2-6.2 times) were revealed for almost all parameters (except *Fv / Fm, Y(NO*), *Fv*) for all the variants of the experiment. Variety specificity was established - the smallest changes of parameters relative to the control were in the stable variety Omskaya 18 in all the variants of the experiment.

5. The studied parameters of photochemical and non-photochemical quenching of ChlF can be used as informative parameters for diagnostics of photosynthetic activity and evaluation of wheat varieties resistance to chloride salinity, infection and seed hyperthermia. The proposed approach will allow to develop a non-invasive method for early diagnosis of stress tolerance (phenotyping) of new genotypes to biotic and abiotic stressors.

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ОЦЕНКА НОВЫХ ГИБРИДОВ КУКУРУЗЫ В УСЛОВИЯХ ПРЕДГОРНОЙ ЗОНЫ КАБАРДИНО-БАЛКАРИИ

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Представлены результаты создания гибридов кукурузы с урожайностью не ниже 8–11 т/га, обладающих хорошей влагоотдачей в период созревания, с достаточно хорошей полегаемостью и устойчивостью к биотическим и абиотическим факторам среды. Научно-практическая работа выполнена в 2020, 2021 гг. на опытном поле лаборатории селекции и семеноводства раннеспелой кукурузы в предгорной зоне Кабардино-Балкарской Республики. Проведена оценка гибридных комбинаций различных групп спелости: раннеспелые с индексом скороспелости ФАО 170–220 и среднеспелые – ФАО 220–300. Закладку опытов в контрольным питомнике и изучение экспериментальных гибридных комбинаций по основным хозяйственным значениям проводили согласно общепринятым методическим рекомендациям. Гибриды изучены по основным хозяйственно ценным признакам: уборочная влажность зерна, выход зерна, урожайность зерна при 14%-й влажности. В группе спелости ФАО 170–220 по уборочной влажности отмечено 8 гибридов, по выходу зерна – 6, по урожаю зерна – 7 комбинаций. В варианте ФАО 220–300 выделены по уборочной влажности 5 гибридных комбинаций, по выходу зерна – 7, по урожаю зерна – 3 гибридные комбинации. Данная работа по оценке гибридов кукурузы в контрольном питомнике проведена в соответствии с планом научно-исследовательской работы. Все выделенные в научно-практической работе гибриды превышали достоверно (по оцененным показателям) стандартные значения в своих группах спелости.

Ключевые слова: кукуруза, гибриды, группа спелости, уборочная влажность, урожай зерна, контрольный питомник, результаты испытаний

EVALUATION OF NEW CORN HYBRIDS IN THE CONDITIONS OF THE FOOTHILL ZONE OF KABARDINO-BALKARIA

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The results of creating corn hybrids with yields no lower than 8-11 t/ha, with good water-yielding capacity during ripening, with good enough lodging and resistance to biotic and abiotic environmental factors are presented. Scientific and practical work was carried out in 2020, 2021 in the experimental field of the Laboratory of Breeding and Seed Production of Early-Maturing Corn in the Foothill Zone of the Kabardino-Balkarian Republic. Evaluation of hybrid combinations of different ripeness groups: early-ripening with an index of early maturity FAO 170-220 and medium-ripening - FAO 220-300 was conducted. Planting experiments in the control nursery and the study of experimental hybrid combinations on the main economic values were carried out according to generally accepted methodological recommendations. The hybrids were studied for the main economically valuable traits: harvest grain moisture, grain yield, grain yield at 14% moisture. In the ripeness group FAO 170-220 by harvesting moisture 8 hybrids were noted, by grain yield - 6, by grain yield - 7 combinations. In the variant FAO 220-300, 5 hybrid combinations were selected for harvesting moisture content, 7 hybrid combinations for grain output, 3 hybrid combinations for grain yield. This work on the evaluation of corn hybrids in the control nursery was carried out in accordance with the plan of research work. All hybrids selected in the scientific and practical work exceeded reliably (according to the evaluated indicators) the standard values in their ripeness groups.

Keywords: corn, hybrids, ripeness group, harvesting humidity, grain yield, control nursery, test results

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INTRODUCTION

Ensuring the growth of grain production, including corn, and the creation on this basis of a balanced fodder base is one of the main priorities of food security of the Russian Federation [1]. Corn is an important grain and fodder crop. It is widely spread because of its high potential yielding capacity. Gross yield of this crop reaches 800 million tons, which makes 34% of total world production. In Russia corn production is about 5 million tons, and there is a tendency of its growth. In almost all corn-growing countries corn is grown for grain, which is used for food, fodder and technical purposes. For the food industry corn grain is a raw material for the production of cereals, flour, oil, starch, alcohol (ethanol), and syrup [2, 3].

Due to its properties corn in Russia is used as a grain and fodder crop, which is mainly used to feed livestock and poultry. Green mass of corn is used for making silage and grain is added to mixed fodder as an obligatory component. Corn grain has high fodder value - 1 kg contains 1.34 fodder units (f.u.), while barley grain - 1.2 f.u., oats - 1 f.u. It contains 65-70% nitrogen-free extractive substances, 9-12% protein, 4-5% fat, 2% sugar, and very little fiber [4]. According to scientists, corn is of great importance in the economy and increasing food security [5].

Expansion of corn crops is an obvious need, it should be given special attention as a crop that gives high yields and allows you to quickly solve the issues of complete supply of livestock nutritious and concentrated fodder, and industry - raw materials for processing [6]. The need to increase grain production is the reason for growing corn outside the traditional cultivation zones, in the areas with less favorable conditions - lack or excess of light, heat, water and other factors. In the Russian Federation corn is cultivated in very contrasting climatic zones. In recent years, a wide range of new high-yielding corn hybrids, the potential yields of which are much higher than the standards, have been grown in production [7]. The most important factor in the intensification of corn grain production is the creation of highly productive hybrids adapted to local soil and climatic conditions [8].

In Kabardino-Balkaria the main priority in crop production is seed production and commercial production of corn, since agroclimatic conditions in the republic are the most optimal in comparison with other regions and the regions of the Russian Federation that produce corn. Cereal crop yields have been showing an upward trend since 2005. Therefore, the creation of a solid base of corn seed breeding requires the study of the breeding material in terms of yield and resistance to extreme environmental factors, the chemical composition of grain and green mass[1]. Because of the increasing competition in the grain market, properly organized breeding and seed breeding research are important areas that determine the further generation of promising varieties and hybrids of agricultural crops [9].

The Kabardino-Balkarian Republic has a well-defined vertical zonality. On a small territory in one climatic zone there are three sharply different agricultural zones: mountain, foothill and steppe (flatland). Corn is cultivated in all zones, but for each zone it is necessary to select

[1]Khatefov E.B. Seed productivity of tetraploid maize and ways to increase it in the conditions of Kabardino-Balkaria: Doctor of Biology thesis: 06.01.05. SPb, 2012, 45 p.

specifically those or other hybrids of different ripeness groups, depending on the purposes for which corn is produced (grain, silage, seeds) [1].

The purpose of the work is to evaluate corn hybrids of different ripeness groups in the control nursery by economically useful traits for further use in the breeding and seed production program of the Institute of Agriculture - Branch of the Federal Scientific Center "Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences" (IA KBSC RAS).

MATERIAL AND METHODS

Scientific and practical work was carried out in 2020, 2021 on the experimental field of the Laboratory of Breeding and Seed Production of Early-Maturing Corn of the Institute of Agriculture - branch of the Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences (IA KBSC RAS) at the Scientific and Production Site No. 1 (piedmont zone).

The soil of the experimental plot is common chernozem. Soil form - carbonate soil. Soil variant - heavy loamy. Agrochemical characteristics of the soil of the experimental plot (according to Chirikov): pH - 7.2; P_2O_5 mobile - 9.8 mg/100 g soil; K_2O exchangeable -7.2 mg/100 g soil; humus (according to Tyurin) - 4.4%. The arable horizon contains 3.9-4.2% humus, 18-27 mg of nitrogen, 27-34 mg of labile phosphorus, and 230-250 mg of exchangeable potassium [10]. Agrometeorological conditions for the years of study are presented in Table 1 (data of the Kabardino-Balkarian Central Hydrometeorological Service).

Weather conditions were generally favorable for good growth and development of the crop.

The material and technical part of the experiment consisted of the following elements: corn seeds of own selection, except for standard values, hand planters, journal of phenological observations, polyethylene bags, scales, moisture meter.

The control nursery included 72 hybrid combinations (FAO 170-220 and 220- 300), (FAO 170-220, standard Mashuk 171, and FAO 220-300, standard Krasnodar 291 AMV). The precursor in the 2020, 2021 trials was winter wheat. Nitro-ammonium phosphate in the amount of 150 kg/ha with inter-row cultivation was applied annually to the experimental plot, and top dressing with ammonium nitrate at the rate of 150 kg/ha was carried out. In the phase of 3-6 leaves the plot was treated with postemergence herbicide Elumis, MD at a rate of 2 l/ha.

Monitoring of corn plants development was carried out throughout the study period, and harvest grain moisture, yield, and grain yield were determined when converted to 14% moisture. Establishment of the experiments and the study of experimental hybrid combinations on the main economic values were carried out according to the methodical recommendations [2-4]. Plots were double-row, in double repetition, the area of one plot was 7.84 m^2, the placement was randomized. Sowing and harvesting of the crop during the years of study were carried out manually. Harvesting was carried out with determination of harvesting moisture content by a Wille 68 moisture meter with 3-fold measurement of each number.

RESULTS AND DISCUSSION

The results of hybrids evaluation in the control nursery by the main economically valuable traits for 2020, 2021 are presented in Table 2.

The data obtained indicate that in the FAO 170-220 group the following hybrids are distinguished by harvesting moisture Malvina C × 1/99-1-1 5014-1-2, Malvina C × 1/99-1-1 5014-1-4, Malvina C × 92c 5428-2-3-3-1, Malvina C × 92c 5195-3-3- 2-1-1, Malvina C × 92c 5195-3-3-2-2-1, Malvina C × 1/99-4-1-1, Milena M × 1/66- 1-4-1, Milena M × 92c 5261-2-1-1-3. On average, the values were in the range

[2]Filev D.S., Tsikov V.S., Zolotov V.I., Logachev N.I., Telyatnikov N.Y., Ponomarenko A.K. Methodological recommendations for field experiments with corn. Dnepropetrovsk: All-Russian Research Institute of Corn, 1980. 54 p.

[3]Methodology of State Variety Testing of Agricultural Crops. 1989. Issue. 2. Moscow, 197 p.

[4]Dospekhov B.A. Methodology of field experience (with the basics of statistical processing of research findings). Moscow: Agropromizdat, 1985. 351 p.

Табл. 1. Метеоданные вегетационных периодов в предгорной зоне Кабардино-Балкарской Республики за 2020, 2021 гг.

Table 1. Meteorological data of vegetation periods in the foothill zone of the Kabardino-Balkarian Republic, for 2020, 2021

Month	Indicator						
	Air temperature, °C			Amount of precipitation		Air humidity, %	
	Average	Maximum	Minimum	Absolute index, mm	% of the norm	Average	Minimum
2020							
April	10,2	16,2	3,2	37,7	61,0	57	36
May	16,1	22,3	11,1	114,1	124,7	68	51
June	21,9	28,8	15,4	71,4	73,0	60	41
July	25,0	31,9	19,5	20,0	33,4	55	33
August	22,1	28,8	15,6	86,3	94,3	54	33
September	19,2	25,9	13,1	20,2	37,1	64	43
2021							
April	11,6	17,8	7,1	35,1	55,1	69	50
May	18,1	24,8	11,8	83,8	98,6	61	42
June	22,3	26,3	15,6	127,1	144,8	69	55
July	24,1	30,8	17,6	112,4	103,4	58	40
August	24,6	34,6	16,2	34,2	34,5	54	33
September	15,3	31,2	5,8	103,5	125,6	79	22

of 14,4–17,2%. In terms of grain yield, the best are Malvina C × 1/99-1-1 5014-1-2, Malvina × 1/99-1-1 5014-1-4, Malvina C × 1/99-4-1-1, Milena M × 1/66-1-4-1, Milena M × 92c 5261-2-1-1-3, Malvina C × КБ 630-2-3-3-2-2-2-4-2-9-1-4, Malvina C × 92c 5195-3-3-2-1-3, this indicator was 82,1–84,3%. In terms of grain yield (at 14% moisture content) – Malvina C × 1/99-1-1 5014-1-2, Malvina C × 1/99-1- 1 5014-1-4, Malvina C × 92c 5428-2-3-3-1, Malvina C × 92c 5195-3-3-2-2-1, Milena M × 1/66-1-4-1, Malvina C × КВ 630-2-3- 3-2-2-2-4-2-9-1-4, Malvina C × 92c 5195-3- 3-2-1-3, hybrid combinations exceeded the standard variant by 0.17-0.60 t/ha. In the variant FAO 220-300 such hybrids can be distinguished by harvesting moisture, as RG 1 C × 92c 5280-2-2-2-2-3, RG 4 M × 92c 5253-1-1-1-3, Madonna M × 92c 5520-1-1-1- 1, OL 3104 M × 6207-1, OL 273 M × 92c 6195- 5-1-1-1 (the values for this attribute were as follows 16,1–18,1%); in terms of grain yield – RG 1 C × 92c 5280-2-2-2-2-3, (В 52м × GK 26 zm) × 633MB, RG 4 M × 92c 5253-1-1-1-3, Madonna M × 92c 5195-3-3-2-2-1, Madonna M × 92c 5520-1-1-1-1, OL 3104 M × 6207- 1, OL 273 M × 92c 6195-5-1-1-1 (at the level of 81,2–84,3%); by grain yield – RG 1 C92c 5280-2-2-2-2-3, (B 52m × GK 26 zm) × 633MB, OL 3104 M × 6207-1, Kr. 704 UM × 633MB (the selected hybrids outperformed the standard value by 0,24–0,62 t/ha).

CONCLUSION

Analysis of corn hybrids in the control nursery is important because it allows us to identify the most valuable hybrids according to the main economically valuable indicators.

In the course of research on evaluation of corn hybrids for economically useful characteristics 6 hybrids were identified in the group FAO 170-220 and 4 hybrids in the group FAO 220-300, which exceeded the standard values on all main indicators of productivity. The selected early- ripening and medium-early corn hybrids are of great breeding interest, therefore, they will be transferred for ecological variety testing to scientific institutions belonging to the Corn Coordinating Council.

Табл. 2. Результаты испытания выделившихся гибридов кукурузы в контрольном питомнике за 2020, 2021 гг. в НПУ № 1 (предгорная зона)
Table 2. Results of testing of isolated corn hybrids in a control nursery for 2020, 2021 in NPU No. 1 (foothill zone)

Item No.	Hybrid	Grain yield at 14% moisture, t/ha			Harvest moisture of grain (average), %			Grain output (average), %		
		2020	2021	Average	2020	2021	Average	2020	2021	Average
	FAO 170–220									
1	Mashuk 171 (standard)	5,47	5,58	5,53	16,8	18,0	17,4	79,9	80,3	80,1
2	Malvina C × 1/99-1-1 5014-1-2	5,96	5,98	5,7	17,0	17,4	17,2	82,8	83,3	83,1
3	Malvina C × 1/99-1-1 5014-1-4	5,95	6,3	6,13	17,4	15,2	16,3	81,6	82,6	82,1
4	Malvina C × 92c 5428-2-3-3-1	6,07	5,98	6,01	14,2	14,8	14,5	82,3	80,1	81,2
5	Malvina C × 92c 5195-3-3-2-1-1	5,8	5,53	5,51	14,9	15,7	15,3	80,2	80,0	80,1
6	Malvina C × 92c 5195-3-3-2-2-1	5,81	5,87	5,84	15,6	14,8	15,2	80,1	79,3	79,7
7	Malvina C × 1/99-4-1-1	5,37	5,45	5,41	15,0	14,4	14.7	83,6	85,0	84.3
8	Milena M × 1/66-1-4-1	5,85	5,81	5,83	17,3	15,1	16,2	82,6	82,2	82,4
9	Milena M × 92c 5261-2-1-1-3	5,32	5,28	5,26	15,9	16,7	16,3	82,9	83,4	83,2
10	Malvina C × K 630-2-3-3-2-2-2-4-2-9-1-4Б 630-2-3-3-2-2-2-4-2-9-1-4	5,90	5,98	5,94	18,0	17,4	17,7	81,6	81,8	81,7
11	Malvina C × 92c 5195-3-3-2-1-3	6,01	6,04	6,02	16,9	18,7	17,8	82,7	81,5	82,1
	LSD_{05}	0,31	0,41							
	FAO 220–300									
12	Krasnodarsky 291 (standard)	7,06	7,88	7,47	18,7	19,5	19,1	80,1	18,3	79,2
13	RG 1 C × 92c 5280-2-2-2-2-3	7,51	8,48	8,0	17,2	17,0	17,1	83,9	84,7	84,3
14	(B 52м × Г 26) K 26 зм) × 633MB	7,72	8,45	8,09	20,3	17,7	19,0	84,1	83,1	83,6
15	RG 4 M × 92c 5253-1-1-1-3	7,35	7,41	7,38	15,8	16,4	16,1	81,5	80,9	81,2
16	Madonna M × 92c 5195-3-3-2-2-1	6,41	6,50	6,46	19,0	19,8	19,4	83,5	84,9	84,2
17	Madonna M × 92c 5520-1-1-1-1	6,61	6,73	6,67	18,1	17,7	17,9	84,3	83,9	84,1
18	OL 3104 M × 6207-1	7,78	7,77	7,78	18,7	16,8	17,8	83,0	84,0	83,5
19	OL 273 M × 92c 6195-5-1-1-1	6,78	7,36	7,07	17,8	18,3	18,1	81,2	81,8	81,5
20	Кр. 704 УМ × 633MB	7,69	7,73	7,71	20,1	20,5	20,3	79,0	79,2	79,1
	LSD_{05}	0,42	0,54							

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ИЗУЧЕНИЕ МЯГКОЙ ПШЕНИЦЫ ПО СНИЖЕНИЮ ТЕМПЕРАТУРЫ ПОЛОГА В УСЛОВИЯХ АЛТАЙСКОГО КРАЯ

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Представлены результаты исследований в области селекции на засухоустойчивость пшеницы по методу инфракрасной термометрии. Отмечено, что в России данный метод до сих пор не получил распространения. Изучен параметр снижения температуры полога (Canopy temperature depression CTD) среди коллекционных образцов яровой мягкой пшеницы. Эксперимент проведен в Алтайском крае в 2019–2021 гг. У 55 сортов яровой мягкой пшеницы исследованы урожайность, элементы ее структуры и длительность периода всходы – колошение. Температуру полога измеряли при помощи портативного инфракрасного термометра. Определяли CTD как разность между температурой воздуха и температурой полога. Средняя по сортам величина CTD составила 6,1, –0,8 и 2,6 °С в 2019, в 2020 и 2021 гг. соответственно. Достоверное влияние на изменчивость данного признака оказал как фактор год, так и генотип. На протяжении трех лет исследования CTD имел стабильную достоверную взаимосвязь с длительностью периода всходы – колошение (r = 0,27–0,37), а в два года из трех – с урожайностью r = 0,32 и 0,60. В самом засушливом году (2020) CTD положительно коррелировал не только с элементами структуры урожая (r = 0,17–0,48), но и с высотой растения (r = 0,55). Наибольшая величина CTD в среднем за три года отмечена у Алтайской жницы (3,5 °С), Степной нивы (3,6), Бурлака (3,8), Обской 2 (3,9 °С), Лютесценс 360/96, Мерцаны, Александра (4,0 °С) и Лютесценс 208/08-4 (4,4 °С).

Ключевые слова: инфракрасный термометр, пшеница, снижение температуры полога, засухоустойчивость, период всходы – колошение, урожайность

STUDY OF SOFT WHEAT BY THE CANOPY TEMPERATURE DEPRESSION UNDER ALTAI TERRITORY CONDITIONS

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Results of research in the field of wheat drought tolerance breeding by infrared thermometry method are presented. It is noted that in Russia this method is still not widespread. The parameter Canopy temperature depression (CTD) among collection samples of spring wheat was studied. The experiment was conducted in the Altai Territory in 2019-2021. Yield, elements of its structure and the duration of seedling – heading period were studied in 55 varieties of spring soft wheat. The canopy temperature was measured with a portable infrared thermometer. CTD was defined as the difference between the air temperature and the canopy temperature. The average CTD across the varieties was 6.1,-0.8, and 2.6 °C in 2019, 2020, and 2021, respectively. Significant influence on the variability of this trait had both the factor of year and genotype. During the three years of the study CTD had a stable reliable relationship with the duration of the seedling - heading period (r = 0.27-0.37), and in two of the three years - with the yield (r = 0.32 and 0.60). In the driest year (2020), CTD was positively correlated not only with the yield structure elements (r = 0.17-0.48), but also with the plant height (r = 0.55). The highest average CTD value for three years was recorded for Altayskaya zhnica (3.5 °C), Stepnaya niva (3.6 °C), Burlak (3.8 °C), Obskaya 2 (3.9 °C), Lutescens 360/96, Merzana, Alexander (4.0 °C) and Lutescens 208/08-4 (4.4 °C) cultivars.

Keywords: infrared thermometer, wheat, canopy temperature depression, drought tolerance, period seedling – heading, yield

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INTRODUCTION

Climate change models predict an increase in the air temperature and drought frequency in the future [1]. One way to adapt to a changing climate is to breed drought-tolerant varieties. Selection for tolerance of crops to moisture deficit and heat tolerance is complicated due to the following reasons. Firstly, the complexity of the drought phenomenon itself, which can vary in type, time of occurrence, duration and intensity [2]. Secondly, the complexity of plant resistance mechanisms, which include morphological, physiological, biochemical and anatomical features [3]. The drought tolerance of breeding material is traditionally evaluated by the yield under drought conditions [4]. However, selection based solely on yield complicates selection for drought tolerance, since yield is a very complex trait with low heritability under stress [5]. In this regard, it is important to find new criteria for assessing drought tolerance.

Since the late 1970s infrared thermometry method began to be used to estimate the canopy temperature of various wheat varieties [6]. Canopy temperature reveals the water status of plants, i.e. the balance between water consumption by the roots and transpiration by the leaves. This trait is measured with a portable infrared thermometer or an infrared camera. Most often, it is not the canopy temperature that is measured, but the difference between the air temperature and the canopy temperature (Canopy temperature depression – CTD).

Currently, the method of infrared thermometry is widespread in the world due to its simplicity, speed of evaluation of an individual sample and cost-effectiveness. The relationship between the canopy temperature and the yield has been determined [7] with other morphological and physiological traits [8]. However, this method, despite its advantages, is not widespread in Russia.

The purpose of the research is to study the collection of spring wheat varieties by the trait "canopy temperature reduction", to analyze its variability and relationship with other traits.

MATERIAL AND METHODS

The experiment was conducted in the Altai Territory in 2019- 2021. The material of the study were 55 varieties of spring wheat of different ecological and geographical origin of three groups of ripeness. The sowing was carried out in the first ten-day period of May by SSFK-7 seeder on fallow forecrop in the plots of 10 m^2. The seeding rate was 500 grains/m^2. Harvesting was carried out by Wintersteiger classic harvester. During the vegetation period the date of earing was marked. Yield structure elements were determined according to conventional methods. Vegetation canopy temperature was measured in the phase of milk ripeness in triplicate using an infrared thermometer (UT300C). Measurements were taken on a hot sunny cloudless and windless day at 50 cm above the canopy at an angle of 30º to the plane of the plot. Canopy temperature reduction (CTD) was calculated by the formula:

$$CTD = Ta – Tc,$$

where Ta – air temperature, Tc – canopy temperature.

Statistical processing of the results was carried out by methods of variance and correlation analysis.

The weather conditions of the growing seasons 2019-2021 differed in the amount and distribution of precipitation and average daily tem-

peratures. However, in all three years there was drought during the periods from flowering to full ripeness. The average monthly temperature of July 2019-2021 was almost the same as the average annual value, and the average monthly temperature of August exceeded the average annual value by 1.3-2.4 °C. Precipitation deficit in 2019-2021 was recorded in May (-11 to -23 mm to the norm), in 2019 and 2021 - in July (-22 and -29 mm to the norm, respectively). In 2020, the earing was preceded by precipitation deficit in June (-22 mm to the norm).

RESULTS AND DISCUSSION

Positive CTD value averaged across varieties was observed in 2019 and 2021 (6.1 and 2.6 °C) at air temperatures of 27 and 26 °C, respectively. In 2020, at an air temperature of 31 °C, the CTD value averaged -0.8 °C for the varieties. Thus, in 2019 and 2021 at the time of canopy temperature measurement it was cooler than the air, and in 2020 it was warmer.

The trait "canopy temperature decrease" is largely influenced by weather conditions of the years of the study. At the same time, a significant influence of genotype on variation of this trait was established (see Table 1). The interaction of the factors year × genotype was statistically insignificant.

The following varieties were characterized by the coolest canopy on average for three years: Altayskaya zhnica (3,5 ° C), Stepnaya Niva (3,6), Burlak (3,8), Obskaya 2 (3,9), Lutescens 360/96-6, Mertsana, Alexander (4,0), Lutescens 208/08-4 (4,4 ° C). Significantly less ability to canopy cooling compared to the above genotypes had: Omskaya 41 (0,2 °C), Libertina (1,0), Novosibirskaya 41, Izera (1,5), Ershovskaya 34 (1,6), Grenada (1,7), Ershovskaya 33 (1,8), Stolypinskaya 2 and Quintus (1,9 °C) (see Table 2).

Correlation analysis showed a significant positive relationship between CTD and the yield in 2020 (r = 0.60) and 2021 (r = 0.32). Over three years, CTD was consistently positively correlated with the duration of the sprouting - earing period (r = 0.27-0.37). To the greatest extent, the CTD indicator was associated with morphobiological traits in 2020 (see Table 3).

The first researchers paid attention to a large number of environmental factors affecting CTD. Among these factors soil moisture supply, wind, evapotranspiration, cloud cover, air temperature, relative air humidity, and solar radiation should be listed [9]. In this connection, CTD varies more strongly than other traits [10, 11]. This feature of the trait complicates its evaluation and selection of genotypes with cool canopy under drought and heat conditions.

The positive correlation between CTD and productivity traits is indicated by B. Bahar et al. [12]. Significant correlation between CTD and plant height, between CTD and sprouting - earing period, found in our study, is consistent with previously known patterns [13, 14]. Consequently, high-growing and medium-late varieties have a better ability to cool down and bring the canopy temperature to a more optimal for photosynthesis than low-growing and medium-early varieties.

Since in many studies CTD shows a close positive correlation with yield under drought and heat conditions, this parameter is proposed as a breeding criterion for drought tolerance of varieties [15]. Probably insignificant and average correlation of CTD with yield in 2019

Табл. 1. Результат двухфакторного дисперсионного анализа 55 сортов яровой мягкой пшеницы по CTD (2019–2021 гг.)

Table 1. Result of ANOVA for CTD of 55 spring soft wheat cultivars in 2019-2021

Source of variation	*SS*	*df*	*ms*	*F*	$F_{st\,0,05}$
Year	3923,0	2	1961,5	595,93	3,00
Genotype	321,6	54	6,0	1,81	1,40
Year × genotype interaction	388,0	108	3,6	1,09	1,30
Residual dispersion	1086,2	330	3,3		

Табл. 2. Генотипы яровой мягкой пшеницы с наименьшими и наибольшими значениями CTD (°C) в 2019–2021 гг.

Table 2. Genotypes of spring soft wheat with the highest and lowest CTD (°C) in 2019-2021

Genotype	2019	2020	2021	On average
Omskaya 41	2,0	–3,4	1,9	0,2
Libertina	3,5	–2,8	2,4	1,0
Novosibirskaya 41	5,0	–2,1	1,6	1,5
Izera	3,7	–1,4	2,1	1,5
Ershovskaya 34	4,3	–1,5	2,0	1,6
Grenada	3,7	–1,5	2,8	1,7
Ershovskaya 33	5,2	–1,3	1,5	1,8
Stolypinskaya 2	5,0	–1,8	2,5	1,9
Quintus	5,2	–2,6	3,0	1,9
Altaiskaya zhnitsa	6,0	1,5	3,0	3,5
Stepnaya Niva	7,4	1,1	3,6	3,6
Burlak	6,3	1,9	3,3	3,8
Obskaya 2	7,4	1,8	2,6	3,9
Lutescens 360/96–6	7,0	0,5	3,3	4,0
Merzana	7,1	1,5	3,5	4,0
Alexandr	8,4	0,7	2,7	4,0
Lutescens 208/08-4	7,4	0,8	4,9	4,4
LSD_{05}	2,4	3,1	1,3	–

Табл. 3. Парные коэффициенты корреляции между CTD и другими морфобиологическими признаками яровой мягкой пшеницы (2019–2021 гг.)

Table 3. Coefficients of correlation for CTD and other morphological traits of spring soft wheat in 2019-2021

Trait	2019	2020	2021
Duration of sprouting - earing period	0,30*	0,37*	0,27*
Plant height	0,26	0,55*	0,24
Productive bushiness coefficient	–0,04	0,17	–0,19
Ear length	0,00	0,48*	–0,13
Number of spikelets in an ear	–0,13	0,42*	–0,12
Main ear grain content	–0,04	0,23	–0,03
Main ear grain weight	0,08	0,30*	0,10
Thousand-kernel weight	0,21	0,20	0,25
Yield	0,05	0,60*	0,32*

* $r > r_{table}$ at $p > 0,95$.

and 2021 can be explained by mild character of drought. Thus, the average yields from 2019 to 2021 were 4.12; 2.66 and 4.60 t/ha, respectively.

CONCLUSION

As a result of studying the collection of spring wheat varieties according to the CTD parameter, the varieties characterized by a cool canopy were identified. These include: Altayskaya zhnica, Stepnaya Niva, Burlak, Obskaya 2, Lutescens 360/96-6, Mertsana, Alexander, Lutescens 208/08-4. A significant stable correlation of the studied parameter with the duration of the sprouting - earing period (r = 0.27-0.37), as well as a positive correlation with the yield in two years out of three (r = 0.32 and 0.60) was established. However, instability of the studied trait by years makes it difficult to use in practical wheat breeding.

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ЧУВСТВИТЕЛЬНОСТЬ СЕВЕРОКАВКАЗСКОЙ И БЕЛОРУССКОЙ ПОПУЛЯЦИЙ *MICRODOCHIUM NIVALE* (FR.) SAMUELS & HALLET К ФУНГИЦИДАМ

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Розовая снежная плесень (возбудитель *Microdochium nivale*) – наиболее распространенный во всем мире низкотемпературный патоген. Изучена чувствительность двух географически отдаленных популяций возбудителя розовой снежной плесени (юга России и Республики Беларусь) к девяти современным фунгицидам. Для исследования отобраны фунгициды, включенные в Государственный каталог пестицидов и агрохимикатов, разрешенных к применению на территории Российской Федерации и рекомендуемые для обработки против снежной плесени. Материалом для изучения служила чистая культура гриба *M. nivale*. В исследовании использован метод агаровых блоков. Внесение растворов фунгицидов в питательную среду осуществляли двумя стандартными методами – вмешиванием в среду и растиранием препарата по поверхности среды шпателем. Выявлены препараты, обладающие 100%-м фунгицидным действием против обеих изучаемых популяций: Поларис, МЭ, Кинто Дуо, КС и Баритон Супер, КС. Препараты Оплот Трио, ВСК, Вайбранс Трио, ТКС, Максим Форте, КС показали 100%-ю эффективность только против белорусской популяции патогена. Определено, что применение двух методов внесения препарата в питательную среду (вмешивание и растирание по поверхности агара) имеет высокий коэффициент корреляции (для белорусской популяции – r_{xy}= 1,0, для северокавказской – r_{xy}= 0,99). Однако вмешивание меньше ингибирует рост колоний, поэтому является более предпочтительным в исследованиях по изучению чувствительности к препаратам чистой культуры гриба *M. nivale*. Выявлена статистически достоверная разница между чувствительностью к фунгицидам популяций географически отдаленных регионов (при использовании метода вмешивания F_t 5,32 < F_f 23,2, метода растирания – F_t 5,32 < F_f 37,7). Данные свидетельствуют о гетерогенности возбудителя снежной плесени по чувствительности к современному ассортименту протравителей семян.

Ключевые слова: снежная плесень, выпревание, *Microdochium nivale*, озимые зерновые культуры

SENSITIVITY OF THE NORTH CAUCASIAN AND BELARUSIAN POPULATIONS OF *MICRODOCHIUM NIVALE* (FR.) SAMUELS & HALLET TO FUNGICIDES

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Pink snow rot (pathogen *Microdochium nivale*) is the most common low-temperature pathogen worldwide. Sensitivity of two geographically distant populations of the pink snow rot pathogen (southern Russia and the Republic of Belarus) to nine modern fungicides was studied. The fungicides

included in the State Catalogue of pesticides and agrochemicals permitted for use in the Russian Federation and recommended for treatment against snow rot were selected for the study. The material for the study was a pure culture of the fungus *M. nivale*. The agar block method was used in this study. The fungicide solutions were introduced into the nutrient medium using two standard methods: by interfering with the medium and by rubbing the preparation on the medium surface with a spatula. The preparations with 100% fungicidal effect against both studied populations were identified: Polaris, OE, Quinto Duo, SC and Bariton Super, SC. Oplot Trio, WS, Vybrance Trio, FC, Maxim Forte, SC showed 100% efficacy only against the Belarusian population of the pathogen. It was determined that the use of two methods of introducing the preparation into the nutrient medium (intervention and rubbing on the agar surface) has a high correlation coefficient (for the Belarusian population - $r_{xy} = 1.0$, for the North Caucasian population - $r_{xy} = 0.99$). However, intervention is less likely to inhibit colony growth and is therefore preferable in drug sensitivity studies of pure culture of the fungus *M. nivale*. A statistically significant difference was found between the sensitivity to fungicides of populations from geographically distant regions (F_t *5.32* < F_f *23.2* for the intervention method, F_t *5.32* < F_f *37.7* for the rubbing method). The data indicate the heterogeneity of the snow rot pathogen in terms of sensitivity to the modern assortment of seed dressing agents.

Keywords: snow rot, rotting, *Microdochium nivale*, winter cereals

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INTRODUCTION

Microdochium nivale (Fr.) Samuels & Hallet is the most common low-temperature phytopathogen affecting cereals and grasses in the areas with stable snow cover [1]. In the Republic of Belarus, the disease is one of the most common harmful ones [2]. According to V. Gorshkov et al. [3], in Russia as early as the 1970s, snow rot was considered a disease affecting cereals only in the regions where plants were covered with snow for at least 100 days. In the southern regions of Russia, the pathogen occurred sporadically until 1995; since 2000 the dynamics of its occurrence and development have been observed. At present, the pathogen is widespread throughout the country where winter grain crops are cultivated on an industrial scale.

Effective protection of winter cereal crops against pink snow rot is possible by treating the seeds with fungicidal preparations based on contact active substances, such as fludioxonil and prochlorazole [2]. European researchers also indicate that the only available mechanism of chemical control of the disease in Northern Europe is pre-sowing seed treatment with fungicides [4]. Currently, a number of specialized fungicide seed dressing agents have been developed and approved for use, which can significantly reduce the lesion of plants by the causative agent of pink snow rot [5]. At the same time, there is no effective strategy for protecting crops against pink snow rot due to a number of restrictive measures, such as reducing the list of approved drugs and peculiarities of winter treatment. In our opinion, foliar application of

fungicides to protect winter grain crops from snow rot is difficult to carry out in the autumn period due to the fact that the air temperature during fungicide application should not be below 12 °C, and 10-14 days should pass from the moment of treatment until winter grain crops go into dormancy (autumn cessation of vegetation).

At the same time, the problem of resistance is acute and has great negative consequences in plant protection in the farms of almost all categories [6]. One of the first published data on the loss of *M. nivale* sensitivity to benzimidazoles is the research of the problem of pink snow rot lesion of golf courses. Ten years later, the problem of snow rot resistance to this active ingredient was already widespread [7]. Resistance to strobilurins was first revealed by French researchers when analyzing the causes of epiphytoty in 2007, 2008 [8]. Field tests of strobilurin-based fungicides efficacy were conducted and the formation of several resistance mechanisms as well as positive cross-resistance was found at once. Currently, the dominant position in the market of chemical fungicides is occupied by triazoles, widespread introduction of which has improved the phytosanitary situation in the grain fields. However, the studies of O.P. Gavrilova et al. [9] indicated that 45% of *M. nivale* strains are resistant to triazole-containing preparations. It is worth noting that an increase in the rate of drug consumption leads to the acceleration of the formation of resistant forms of pathogens and to the destruction of useful soil microflora.

In multi-year studies of Belarusian scientists who screened the most common disinfectants, high biological efficacy of Bariton, SC (86.9%), Quinto Duo, SC (92.4%), Maxim Forte, SC (93.4%), and 100% efficiency of Quinto Plus, SC were noted [2]. A sensitivity study of *M. nivale* isolates sampled on wheat crops in the Central Black Earth region of the Russian Federation showed complete inhibition of the colony growth by Maxim, SC and Quinto Duo, SC [5].

The data on the sensitivity of *M. nivale* population to the basic assortment of fungicides in the south of Russia are insufficient and need to be supplemented.

The purpose of the study was to investigate the sensitivity of two geographically distant populations of the pink snow rot pathogen to nine modern fungicides.

MATERIAL AND METHODS

The studies were carried out at the Republican Unitary Enterprise "Plant Protection Institute" (The agrotown of Priluki, Republic of Belarus) and the Federal Scientific Center for Biological Plant Protection (Krasnodar, Russia) in 2021, 2022 using the unique scientific installation (USI) base "Phytotron for isolation, identification, study and maintenance of races, strains, phenotypes of pathogens" (http://ckp-rf.ru/usu/ No. 671925) and BRC (bioresource collection) facilities of the FSBSI FSCBPP (Federal Scientific Center for Biological Protection of Plants) "State Collection of Entomoacariphages and Microorganisms" (USU registration No.: 671925). Climatic conditions were simulated using a Binder KBWF 720 climatic chamber.

Nine fungicides included in the State Catalogue of Pesticides were selected for the study: Maxim Forte, SC (azoxystrobin 10 g/l + tebuconazole 15 g/l + fludioxonil 25 g/l), Vybrance Trio, FC (sedaxane 25 g/l + tebuconazole 10 g/l + fludioxonil 25 g/l), Polaris, ME (imazalil 25 g/l + prochlorazole 100 g/l + tebuconazole 15 g/l), Quinto Duo, SC (prochloraz 60 g/l + triticonazole 20 g/l), Quinto Plus, SC (triticonazole 33, 3 g/l + fludioxonil 33.3 g/l + fluxapiroxad 33.3 g/l), Bariton Super, SC (protioconazole 50 g/l + tebuconazole 10 g/l + fludioxonil 37.5 g/l), Scarlet, ME (imazalil 100 g/l + tebuconazole 60 g/l), Oplot Trio, WSC (azoxystrobin 40 g/l + difenoconazole 90 g/l + tebuconazole 45 g/l), Credo, SC (carbendazim 500 g/l)[1].

The material was a pure culture of the fungus *M. nivale*. Monospore cultures were obtained, followed by a mixture of isolates from each region. The species identity of the isolates was

[1]State Catalogue of pesticides and agrochemicals permitted for use in the Russian Federation. Ministry of Agriculture of the Russian Federation. Pesticides. Official publication. M., 2021. vol. 1. 795 p.

determined using molecular methods. The belonging of the strains to *M. nivale* species was established using real-time PCR with species-specific primers [10, 11]. PCR was performed using a CFX96 Real-Time System thermal cycler (BioRad, USA). Pure culture of pink snow rot pathogen was screened on potato-glucose agar. The fungus was cultured at 10-15 °C (12 h) under 30W UVB lamps (280-315 nm). When screening fungicides, we used a modified agar block method. Calculation of drug amounts and preparation of their working solutions was performed using the Chekmarev calculation method according to the recommended norms of application for seed material treatment with standard working fluid consumption [12]. Fungicide solutions were introduced into the nutrient medium using two standard methods: by kneading in the medium and by rubbing the preparation on the medium surface with a spatula.

Statistical processing was performed using Statistica 13.3 software; the differences between the samples were evaluated using Fisher's criterion (with $a = 0.05$); the relationship between the features was calculated using the Cheddock scale. Biological efficacy was calculated using the generally accepted Abbott's formula on day 7 for inhibition of pathogen mycelial growth on solid nutrient medium[2].

RESULTS AND DISCUSSION

Complete inhibition of the growth of the Belarusian pathogen population colonies when the preparation was applied to the medium by interference was found in most fungicides (see Table 1); 100% suppression by the fungicide containing the active substance fludioxonil was also observed in the studies of *Microdochium* fungi strains isolated from cereals and grasses of different geographical origin [9]. Scarlet, ME caused incomplete inhibition of colony growth with a biological efficacy of 97.6%. The drug contains imazalil, a substance of imidazole class. The active ingredient is highly dangerous for aquatic biocenoses and toxic to humans, but it is distinguished by high activity against helminthosporiosis and fusarium rot of grain crops, as well as high activity against pathogens resistant to benzimidazole [13]. Imazalil-containing preparations have a synergistic effect against difficult to control diseases that are transmitted both through seeds and soil, but their presence in a preparation with other active substances with different mechanism of action reduces the risk of resistant strains of phytopathogens [14]. Tebuconazole, a third-generation triazole fungicide, is an effective systemic fungicide for seed pre-sowing treatment of cereal crops. It is important to note that tebuconazole-based products slow down the rate of resistance development to the whole group of triazoles. Biological efficacy of the preparation Credo, SC was 75.4%. The active ingredient carbendazim is one of the first systemic fungicides of benzimidazole class. In spite of wide manufacturing implementation and effective use, it has a number of drawbacks, such as slow movement through the host plant and rapid formation of resistant populations.

Screening of the fungicides inhibiting the growth of North Caucasian population of *M. nivale* also revealed differences in the biological effectiveness of the preparations. When the fungicide solution was added to the nutrient medium, complete inhibition of the growth of North Caucasian population of *M. nivale* was revealed in the experiment with the fungicides Polaris, ME, Quinto Duo, SC and Bariton Super, SC. It should be noted that Polaris, ME and Quinto Duo, SC contain the active ingredient prochloraz from the imidazole class. Due to high efficiency for inhibition of colony growth of all the studied populations, it can be determined that the substance is effective against *M. nivale* population. The high effectiveness of this active ingredient against bacterioses is also worth noting. Bariton Super, SC fungicide besides widespread tebuconazole includes the active ingredient of relatively recent introduction into production, protioconazole (triazole class), whose action is also aimed at increasing the habitus and power of the host plant. The

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

Табл. 1. Скрининг эффективности фунгицидов против белорусской и северокавказской популяций *M. nivale* методом вмешивания (ФГБНУ ФНЦБЗР, 2022 г.)

Table 1. Screening of the effectiveness of fungicides against the Belarusian and North Caucasian populations of *M. nivale* by an intervention method (FSBSI FSCBPP, 2022)

Preparation	Belarussian population		North Caucasus population	
	Colony diameter, mm	Biological effectiveness, %	Colony diameter, mm	Biological effectiveness, %
Maxim Forte, SC	0	100	18,7 ± 1,25	57,3
Vybrance Trio, FSC	0	100	5,7 ± 1,2	87,0
Polaris, ME	0	100	0	100
Quinto Duo, SC	0	100	0	100
Quinto Plus, SC	0	100	10,0 ± 1,6	77,1
Bariton Super, SC	0	100	0	100
Scarlet, ME	1,3 ± 0,5	97,6	1,3 ± 0,3	96,9
Oplot Trio, WSC	0	100	3,0 ± 0,8	93,1
Credo, SC	13,7 ± 2,6	75,4	2,7 ± 0,6	93,9
Control	55,7 ± 1,2	–	43,7 ± 2,3	–

active ingredient fludioxonil (chemical class of phenylpyrroles) is one of the most popular and most successful classes of fungicides, since in 30 years of intensive use in agricultural plant protection almost no cases of field resistance were registered [15]. The mechanisms of its action have not yet been thoroughly studied. It has been revealed that the substance inhibits mainly conidia germination, embryonic tube and mycelial growth.

A high level of biological efficacy was observed in Scarlet, ME (96.9%), Credo, SC (93.9%) and Oplot Trio, WSC (93.1%). Oplot Trio, WSC fungicide contains azoxystrobin (strobilurine chemical class) and difenoconazole, tebuconazole (triazole chemical class). Azoxystrobin, being a synthetic analogue of natural toxins, positively affects photosynthetic activity and habitus of a host plant, but repeated use of the drug leads to rapid accumulation of resistant races of pathogens [14]. Diphenoconazole, in addition to fungicide, has a growth-stimulating effect on the plant; tebuconazole is widely used as an effective fungicide with a weak retardant effect.

The biological efficacy of Vybrance Trio, FC was found to be 87.0%, and that of Quinto Plus, SC was 77.1% (see Fig. 1). These fungicides consist of a combination of active substances of triazole and phenylpyrrole chemical classes. Also, the fungicides Vybrance Trio, FC included a relatively new drug sedaxane, which has not only fungicidal action, but also, in combination with fludioxonil, provides prevention of pathogens with high potential for resistance development [15]. Minimum value of biological efficacy was found in Maxim Forte, SC - 57.3%. The drug contains a combination of active ingredients based on strobilurines (azoxystrobin), triazoles (tebuconazole) and phenylpyrroles (fludioxonil).

The use of the method of introducing the preparation into the nutrient medium with uniform distribution on the surface of agar plate with a spatula revealed the increase of the preparation efficiency in all experimental variants (see Table 2). When the substance is distributed over the agar surface, the area of this surface is similar to that of wheat seeds during dressing [12]. However, when the substance is introduced into the medium by the interference method (kneading in), the concentration of the preparation decreases, which provokes the growth of fungus colonies. When comparing the correlation between the results obtained using the two methods, the coefficient was found to be very high for both populations (for the Belarusian population r_{xy} = 1.0, for the North

Caucasian population r_{xy} = 0.99). Although the results had a direct correlation between the two methods of fungicide application in the medium, the samples were statistically different (for the Belarusian population F_t 5.12 < F_f 10713, for the North Caucasus - *Ft* 5.32 < *Ff* 430.4).

Screening of fungicides inhibiting the development of the Belarusian population of *M. nivale* on agar plates revealed 100% inhibition of mycelial growth when applying Maxim Forte, SC, Vybrance Trio, FC, Polaris, ME, Quinto Duo, SC, Quinto Plus, SC, Bariton Super, SC, Scarlet, ME, Oplot Trio, WSC (see Fig. 2). Mycelium growth was not completely inhibited by the application of Credo, SC, and the biological efficiency was 77.4%.

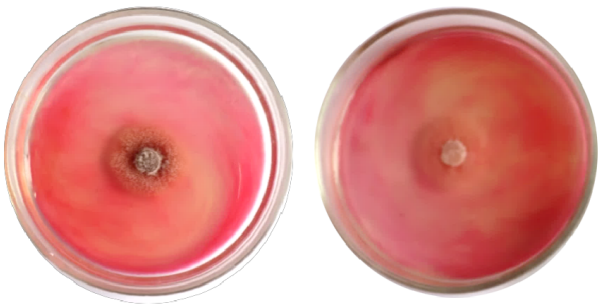

Рис. 1. Ингибирование роста колоний северокавказской популяции *M. nivale* при внесении препарата Кинто плюс, КС в среду методом вмешивания (слева) и растирания (справа)

Fig. 1. Inhibition of the growth of colonies of the North Caucasian population of *M. nivale* when introducing drug Kinto Plus, CS into the medium by the method of intervention (left) and rubbing (right)

Polaris, ME, Quinto Duo, SC, Bariton Super, SC, Scarlet, ME, Oplot Trio, WSC completely inhibited colony growth of the North Caucasian population of *M. nivale* on agar plates. When Credo, SC was applied, insignificant growth of colonies was observed; the biological efficiency was 97.7%. Supplementation of fungicide Vybrance Trio, FC also did not fully inhibit the colony growth, biological efficiency was 95,0%. The drug Quinto Plus, SC had this indicator at 88.5%. The lowest value of biological efficacy was observed in Maxim Forte, SC - 65.7%.

The comparative analysis between the fungicide sensitivity of pathogen populations from geographically distant regions revealed a statistically reliable difference between the results obtained (when using the interference method, F_t 5.32 < F_f 23.2, when using the rubbing method, F_t 5.32 < F_f 37.7). Thus, the results obtained indicate the heterogeneity of the pink snow rot pathogen in terms of sensitivity to fungicides.

Табл. 2. Скрининг эффективности фунгицидов против популяций *M. nivale* методом растирания (ФГБНУ ФНЦБЗР, 2022 г.)

Table 2. Screening of the effectiveness of fungicides against *M. nivale* populations by a rubbing method (FSBSI FSCBPP, 2022)

Preparation	Belarussian population		North Caucasus population	
	Colony diameter, mm	Biological effectiveness, %	Colony diameter, mm	Biological effectiveness, %
Maxim Forte, SC	0	100	17,8 ± 3,0	65,7
Vybrance Trio, FSC	0	100	2,6 ± 0,8	95,0
Polaris, ME	0	100	0	100
Quinto Duo, SC	0	100	0	100
Quinto Plus, SC	0	100	6 ± 1,1	88,5
Bariton Super, SC	0	100	0	100
Scarlet, ME	0	100	0	100
Oplot Trio, WSC	0	100	0	100
Credo, SC	14,7 ± 2,6	77,4	1,2 ± 0,7	97,7
Control	65,0 ± 0,6	–	52 ± 4,3	–

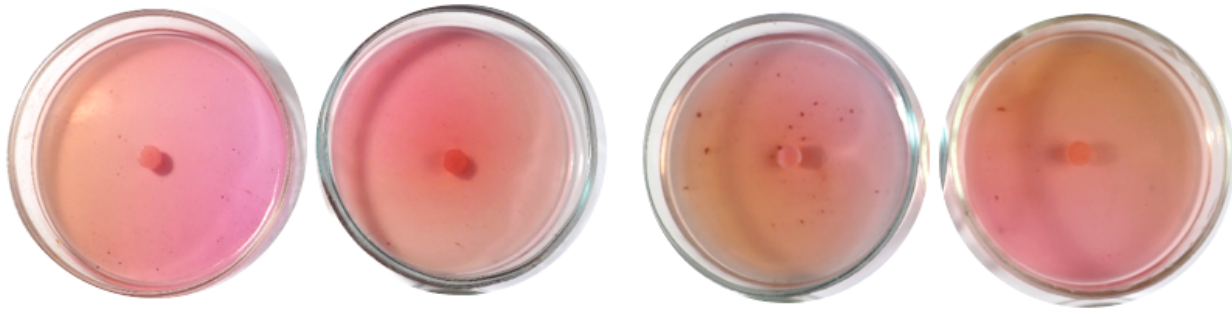

Рис. 2. Полное ингибирование роста колоний белорусской (слева) и северокавказской (справа) популяций *M. nivale* при внесении препаратов Скарлет, МЭ (слева) и Поларис, МЭ (справа) методом растирания

Fig. 2. Complete inhibition of colony growth of the Belarusian (left) and North Caucasian (right) populations of *M. nivale* when applying Scarlet, ME (left) and Polaris, ME (right) preparations by rubbing

CONCLUSIONS

1. Screening of nine chemical fungicides against *M. nivale* population in a pure culture revealed preparations with 100% fungicidal effect against both studied populations: Polaris, ME, Quinto Duo, SC and Bariton Super, SC. Oplot Trio, WSC, Vybrance Trio, FC, Maxim Forte, SC showed 100% efficacy only against the Belarusian population of the pathogen.

2. The use of two methods of introducing the preparation into the nutrient medium (kneading in and rubbing on the surface) has a high correlation coefficient (for the Belarusian population r_{xy} = 1.0, for the North Caucasian population r_{xy} = 0.99). The interference method inhibits the colony growth to a lesser extent; therefore, it is more preferable in the study of sensitivity to preparations of pure culture of fungus *M. nivale*.

3. A statistically significant difference was found between the sensitivity to fungicides of the populations from geographically distant regions (F_t 5.32 < F_f23.2 when using the interference method, F_t 5.32 < F_f 37.7 when using the rubbing method), indicating the heterogeneity of the pink snow rot pathogen in sensitivity to the modern assortment of seed dressing agents.

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ИСПОЛЬЗОВАНИЕ БИОЛОГИЧЕСКИХ ПРЕПАРАТОВ В ПОСЕВАХ СОИ

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Приведены результаты исследований по изучению влияния биопрепаратов на растения сои в условиях Приморского края. Эксперимент проведен в 2020, 2021 гг. в условиях деляночного опыта. Изучение препаратов производили на растениях сои сорта Приморская 86. Объекты исследований – микробиологический препарат Биокомпозит-коррект, органоминеральное удобрение Биостим Старт. Схема опыта включала следующие варианты: без обработки (контроль); обработка семян Биокомпозит-корректом; обработка семян и опрыскивание растений Биокомпозит-корректом; обработка семян Биокомпозит-корректом + Биостим Стартом; обработка семян Биокомпозит-корректом и Биостим Стартом + опрыскивание растений Биокомпозит-корректом. Применение биопрепаратов способствовало снижению интенсивности развития септориоза относительно контроля (29,8%) на 5,2–6,8%. Максимальная в опыте биологическая эффективность (23,1%) отмечена в варианте с обработкой семян сои Биокомпозит-коррект. Комплексная обработка препаратом Биокомпозит-коррект обеспечивала снижение проявлений пероноспороза на 8,2%, биологическая эффективность составила 37,8%. Биопрепараты положительно сказались на росте и развитии растений. Наибольший прирост растений в фазу полной спелости отмечен в варианте с применением Биокомпозит-корректа + Биостим Старта + опрыскивание растений Биокомпозит-корректом (56,6 см), в контроле – 49,3 см. При использовании биопрепаратов количество клубеньков превышало контроль на 17,4–34,1%, количество листьев – на 28,3–39,5%. Масса 1000 семян по вариантам опыта варьировала в пределах 180,0–190,6 г, в контроле – 157,5 г. Масса семян с одного растения в вариантах опыта была выше контрольной на 41,3–70,6%. Изучаемые препараты обеспечивали увеличение урожайности во всех вариантах опыта. Биологическая урожайность составила от 3,3–3,7 т/га при урожайности в контроле 2,5 т/га.

Ключевые слова: соя, биопрепараты, развитие болезни, эффективность, структура урожая, урожайность

THE USE OF BIOLOGICAL PRODUCTS IN SOYBEAN CROPS

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The results of research on the effect of biopreparations on soybean plants in the Primorsky Territory are presented. The experiment was conducted in 2020, 2021 under the conditions of a plot experiment. The preparations were studied on soybean plants of the Primorskaya 86 variety. The objects of research are microbiological preparation Biocomposite-correct and organomineral fertilizer Biostim Start. The experiment scheme included the following variants: without treatment (control); treatment of seeds with Biocomposite Correct; treatment of seeds and plants spraying with Biocomposite Correct; treatment of seeds with Biocomposite Correct + Biostim Start; treatment of seeds with Biocomposite Correct and Biostim Start + plants spraying with Biocomposite Correct. The use of biopreparations contributed to a decrease in the intensity of septoriosis development relative to the control (29.8%) by 5.2-6.8%. The maximum biological efficiency in the experiment

(23.1%) was observed in the variant with treatment of soybean seeds with Biocomposite-correct. Complex treatment with Biocomposite-correct provided a reduction of downy mildew manifestations by 8.2%, the biological effectiveness was 37.8%. The biological products had a positive effect on the plant growth and development. The largest plant growth in the phase of full maturity was noted in the variant with Biocomposite Correct + Biostim Start + plant spraying with Biocomposite Correct (56.6 cm), in the control - 49.3 cm. When using biopreparations, the number of nodules exceeded the control by 17.4-34.1%, the number of leaves by 28.3-39.5%. The thousand-seed weight varied between 180.0-190.6 g in the experimental variants, and 157.5 g in the control. The seed weight per plant in the experimental variants was higher than the control by 41.3-70.6%. The studied preparations provided an increase in the yield in all the variants of the experiment. The biological yield was 3.3-3.7 t/ha with the yield of 2.5 t/ha in the control.

Keywords: soybean, biological products, disease progression, effectiveness, yield parameters, yield

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INTRODUCTION

Soybean is a valuable crop in many countries of the world. It is grown in the main agricultural regions of 90 countries. Global production of this crop reaches 253 million tons. Soybean is the main cultivated crop in the agricultural structure of the Far Eastern regions of Russia. The Primorsky Territory and the Amur Region are the leading regions of the Far East in soybean cultivation. Soybean and corn are the main export crops for the Primorsky Territory. The main buyers of soybeans are China, Japan and South Korea. There are 43.5% (1.2 mln ha) of the total area of soybean cultivation in the country on the territory of the Far Eastern Federal District. Of these, 22.3%, or 277 thousand hectares, of the land sown with this crop is located in the Primorsky Territory. The Primorsky Territory accounts for 387,000 tonnes, or 8.6% of the gross soybean yield. The soybean yield is 18 cwt/ha. The gross yield of soybeans in the Far East can be increased both by increasing the yield and by increasing the sown areas. The growth of soybean production largely depends on the efficiency of plant protection against numerous pests, the use of modern methods of phytosanitary monitoring, and the introduction of modern cultivation technologies [1–3].

At the turn of the XX-XXI centuries the interest in biological preparations has increased in the world. The use of biological achievements is recognized as one of the effective ways of development of agricultural technologies, solving the problems arising in the process of modern agricultural production [1]. The use of short rotation crop rotations leads to a number of problems that are not solved by chemical preparations. High load leads to a decrease in fertility, degradation of useful soil microflora, slow decomposition of plant residues, accumulation of pathogenic infection. These processes lead to increased infectious background of soils, high contamination of seed material. These problems can be solved by using biopreparations - microbiological agents [2-4].

Optimization of nutrition and stimulation of plant growth and development is an important

[1] https://www.oilworld.ru oilworld.ru (accessed on: 21.11.2022).
[2] https://milknews.ru/index/fermerstvo/primore-soya.html Milknews (accessed on: 20.11.2022).
[3] https://vladnews.ru/ Vladnews.ru (accessed on: 21.11.2022).

agronomic technique to obtain good and stable soybean yields. Such studies are carried out regularly, but become particularly relevant in certain climatic and production-economic conditions [5-9].

Performance tests in the Central Black Earth zone (Belgorod, Voronezh and Orel regions) showed that the application of Biocomposite-correct in the soil directly during the sowing of sugar beet in the rate of 2.0 l/ha gives an increase in sugar yield by 0.6-1.48 t/ha. In most experiments, along with the increase in yields, the sugar content of root crops increased by 0.1-1.6%. In the Rostov region the reliable increase on winter wheat with the treatment of crops at the rate of 1-2 l/ha reached 4 c/ha. In the Kurgan region on spring wheat with the drug application rate of 1 l/ha the increase was 9 cwt/ha. In soybeans, the yield increase of 2 cwt/ha was observed with the seed treatment at the rate of 1 l/ha [10-13].

The purpose of the work is to obtain experimental data on testing biological preparations for pre-sowing treatment of seeds and vegetative soybean plants against diseases, to determine the effect on productivity and yield of the crop.

MATERIAL AND METHODS

The studies were carried out on the experimental fields of the Seed Production Department of the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K. Chaiki in 2020, 2021. The research objects were microbiological preparation Biocomposite-correct, organomineral fertilizer Biostim Start provided by the employees of AO "Shchelkovo Agrokhim", and the released variety of soybean Primorskaya 86. The variety Primorskaya 86 was created by a team of authors from the Primorsky Agricultural Research Institute (A.P. Vashchenko, N.V. Mudrik, O.I. Khasbiullina, L.A. Dega, E.S. Butovets). The variety of medium maturity (120-124 days). Plants of medium height - 82 cm, the height of the beans attachment 16.0-18.2 cm. Leaves are ternate, medium-sized, oval in shape. The flower corona is white. The bean sparsity is light gray, and the coloring of the beans is dark gray at full maturity. The shape of the seeds is oval-elongated, the seeds are yellow, dull with a brown scar. Weight of 1000 seeds is 185-190 g. Oil content is 19.6-20.6%, protein 39.2-40.1%. In 2014, the variety was included in the State Register of breeding achievements approved for use in the Russian Federation. For the study, soybean seeds were treated with biopreparations one day before sowing (May 19) by hand by semi-dry method. For this purpose, preparations were diluted in pure water (at the rate of 10 l/t) and, without allowing the suspension to settle, it was applied to the seeds, which were then thoroughly mixed until the preparation was evenly distributed. Sowing of soybean seeds was carried out on May 20. The plants were sprayed in the phase of full sprouts and in the phase of budding - the beginning of flowering by hand pneumatic sprayer OP-207.

The experiment scheme included the following variants: without treatment (control); treatment of seeds with Biocomposite-correct; treatment of seeds and spraying of plants with Biocomposite-correct; treatment of seeds with Biocomposite-correct + Biostim Start; treatment of seeds with Biocomposite-correct and Biostim Start + spraying of plants with Biocomposite-correct. The area of the plot is 10 m^2. Repeatability of the experiment is fourfold, the plot arrangement is systematic. Biocomposite-correct is a consortium of five economically valuable strains of several species of beneficial bacteria with a total titer of at least 1 × 10 CFU/ml. It is used for any cropping systems and all links of crop rotation and has fungicidal, growth-stimulating, destructive, antagonistic, nitrogen-fixing and phosphate-mobilizing properties. This makes it possible its wide practical application: from stubble decomposition, suppression of soil phytopathogens and protection against diseases to increased soil fertility and restoration of their beneficial microflora.

Organomineral fertilizer Biostim Start is an amino acid biostimulator. It activates sprouting and germination of seeds, stimulates the development of beneficial microflora in the rhizosphere, is an additional source of energy at the initial stage of seedling development, provides plants with a starter complex of nutrients,

increases immunity and reduces the effects of stress factors[4].

The soil of the experimental plot is meadow-brown, by mechanical composition - heavy loam. Agrochemical characteristics of the soil were as follows: humus content was 3.08-3.13%; easily hydrolyzable nitrogen was 9.5 mg/100 g of soil; P2O5 was 14.12 mg/100 g of soil; pH of the salt solution was 5.3. Soil treatment: autumn plowing at the depth of 22 cm, early spring harrowing, two cultivations and pre-sowing tillage. The forecrop - cereals. No fertilizers were used. Sowing of soybeans was carried out by SKS 6-10 seeder. Seed rate - 90 kg/ha (500 thousand pcs/ha).

Agronomic techniques of soybean cultivation in the experiment were common for the Primorsky Territory[5]. The experiment was laid in accordance with the requirements of the field experiment methodology. The harvesting was carried out manually by variants in one pass. Sheaf samples were collected in each plot from two sites 0.25 m^2 in size (0.35 × 0.71). Plant biometry and yield structure were determined in 40 plants of each experiment variant under laboratory conditions. All records and observations in field experiments were performed according to the current methods and guidelines, preparations were used according to the instructions, and the results were processed by analysis of variance [6-9].

RESULTS AND DISCUSSION

Meteorological conditions differed in the years of the experiments. Meteorological conditions 2020 were unfavorable for soybean in terms of precipitation. Abundance of precipitation was recorded for summer months, and its distribution by ten-day periods was noted to be uneven. July was dry, with precipitation 17.4 mm below normal. Precipitation was 193.5 and 140.1 mm in June and August, respectively, and was 109.5 and 19.1 mm above average. Temperatures were 1.1-2.9°C above the long-term average in each month. Precipitation conditions in 2021 were unfavorable for soybeans. July was dry and rainfall was 74.1 mm below normal. Precipitation in June and August was 78.7 and 79.7 mm (2.3 and 54.3 mm less than normal). Temperatures were 1.8-3.7°C above the long-term average in each month.

In the years of study, fungal diseases had no significant effect on the formation of morphological and economic traits of soybean. Soybean crops were affected by septoriose (*Septoria glycines* Hemmi) and downy mildew (*Peronospora manshurica* Naum). Septoria blight in soybean crops appeared in the primordial leaf phase. The spreading of septoriose was noted in all the variants of the experiment, it was 100%. All tested biopreparations showed a positive effect on the resistance of plants against septoriose in comparison with the control. The use of biopreparations contributed to a decrease in the intensity of disease development, relative to the control (29.8%), by 5.2-6.8%. The maximum biological efficiency (23.1%) was noted in the variant with pre-sowing treatment of soybean seeds with Biocomposite-correct.

The first signs of downy mildew were observed in the second ten-day period of July. Application of the studied preparations reduced spreading of downy mildew to 45.2-53.4% against 69.0% in the control. According to the variants of the experiment, the development of the disease varied from 8,2% (complex treatment with Biocomposite-correct) to 9,9% (treatment of seeds with Biocomposite-correct and Biostim Start) while the indicator value was 13,2% in the control. The most effective was treatment of seeds and spraying of vegetative plants with Biocomposite-correct, where the efficiency was 37,8%.

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[9]*James B.* Sinclair. Compendium of Souben Diseases. Published by The American Phytopathological Society. 1982. 104 p.

The research results show that treatment of seeds with a biological preparation and a biostimulant had a positive effect on the main indicators determining plant productivity (see Table 1). In the experimental variants, a significant effect of increasing the activity of nodule bacteria and formation of nodules on the roots of the root system of plants was noted. According to the research data, the use of the studied preparations increased the number of nodules by 17.4-34.1% in comparison with the control. The root length was 13.7-14.4 cm for the experimental variants, and 12.3 cm for the control. The number of leaves exceeded the control variant by 28.3-39.5%.

Analysis of sample sheaves showed that on average in 2 years soybean plants after the application of preparations were larger than the control variant by 4.7-7.3 cm (see Table 2). The number of beans per plant averaged 28,0 pcs./plant (treatment of seeds with Biocomposite-correct + Biostim Start); 31,1 pcs./plant (treatment of seeds and spraying of plants with Biocomposite-correct), which was higher than the control by 10,3-13,4 pcs respectively. The number of seeds per plant increased by 73,5-85,8%. The best on this indicator was the variant with the application of Biocomposite-correct in the growing season in combination with the presowing seed treatment.

The quality indicator of soybean seed material is the weight of 1000 seeds of the variety, which largely depends on soil moisture and precipitation during the growing season, as well as on the provision of plants with other factors of life. Weight of 1000 seeds varied from 180,0 to 190,6 g. The maximum values of this indicator (190,6 g) were noted in the variant with treatment of seeds with Biocomposite-correct. Seed weight per plant in the experimental variants was higher than the control by 41,3-70,6%.

The yield record showed a significant increase in seed productivity of soybean in all the variants of the experiment. The studied biological preparations provided an increase in soybean yield due to an increase in the indicators of the elements of yield structure and a reduction of disease infestation. The increase of the soybean yield in comparison with the control was 0.8-1.2 t/ha (see figure). The studied preparations increased the crop capacity in all the variants of the experiment. Biological yield was 3.3-3.7 t/ha with a yield of 2.5 t/ha in the control (LSD_{05} = 0.5 t/ha).

CONCLUSION

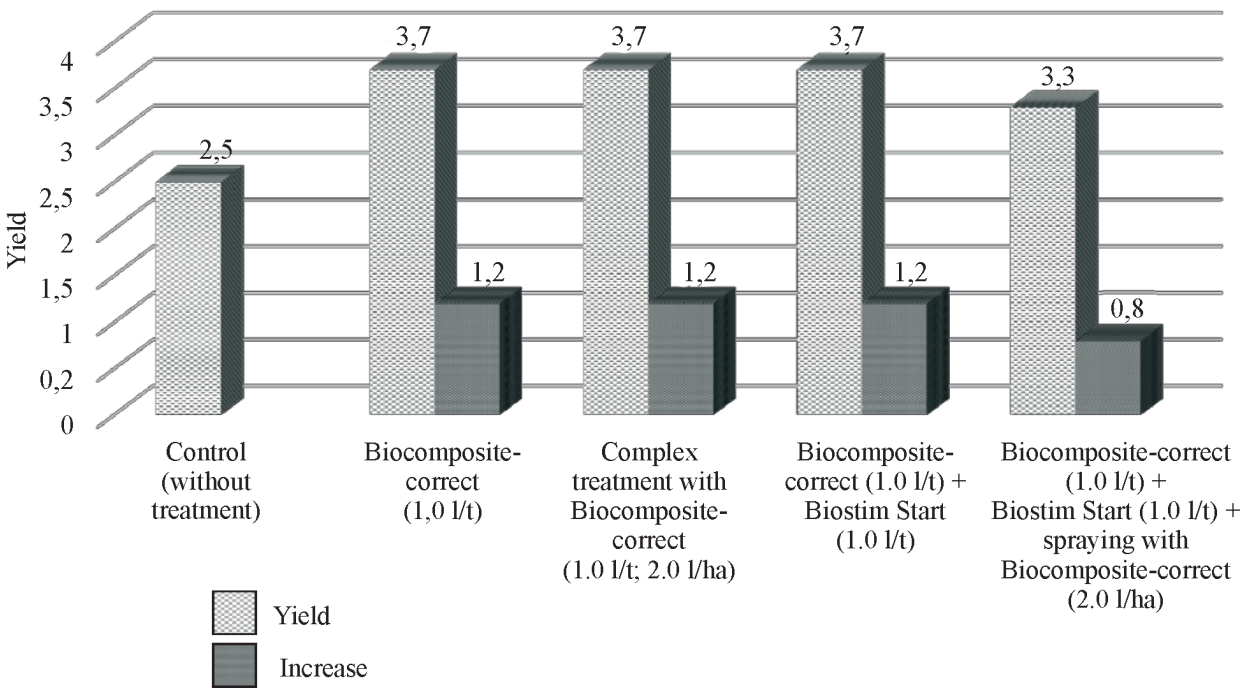
In the course of the research in the Primorsky Territory conditions it was established that the use of biological preparations is promising for using in soybean variety Primorskaya 86. The studied preparations contributed to the reduction of septoriose intensity (29.8% in the control) by 5.2-6.8% and downy mildew (69.0% in the control) by 45.2-53.4%. The use of biological preparations contributed to a significant increase in the weight of 1000 seeds compared to

Табл. 1. Биометрические показатели растений сои в фазу цветения (среднее за 2020, 2021 гг.)
Table 1. Biometric parameters of soybean plants during the flowering stage (average for 2020, 2021)

Experiment variant	Tubercles, pcs.	Root length, cm	Leaves, pcs.
Control (without treatment)	56,3	12,3	24,0
Seed treatment with Biocomposite-correct (1,0 l/t)	66,1	14,1	30,8
Seed treatment and plant spraying with Biocomposite-correct (1.0 l/t; 2.0 l/ha)	74,6	14,4	32,4
Seed treatment with Biocomposite-correct (1.0 l/t) and Biostim Start (1.0 l/t)	73,5	13,7	31,3
Seed treatment with Biocomposite Correct (1.0 l/t) and Biostim Start (1.0 l/t) and plant spraying with Biocomposite Correct (2.0 l/ha)	75,5	14,2	33,5
LSD_{05}	0,7	0,3	2,1

Табл. 2. Структурные показатели сои в зависимости от обработки семян (среднее за 2020, 2021 гг.)
Table 2. Structural parameters of soybean depending on the treatment of seeds (average for 2020, 2021)

Variant	Plants height, cm	Number of beans, pcs./plant	Number of seeds, pcs./plant	Weight of seeds per plant, g/ plant	Thousand-kernel weight, g
Control (without treatment)	49,3	17,7	40,5	5,8	157,5
Seed treatment with Biocomposite-correct (1,0 l/t)	54,0	31,0	75,2	8,8	190,6
Seed treatment and plant spraying with Biocomposite-correct (1.0 l/t; 2.0 l/ha)	55,4	31,1	75,1	9,9	186,2
Seed treatment with Biocomposite-correct (1.0 l/t) and Biostim Start (1.0 l/t)	56,1	28,0	70,3	8,2	183,7
Seed treatment with Biocomposite Correct (1.0 l/t) and Biostim Start (1.0 l/t) and plant spraying with Biocomposite Correct (2.0 l/ha)	56,6	29,1	72,4	8,7	180,0
LSD_{05}	2,3	6,0	18,8	0,8	7,1



Влияние препаратов на урожайность сои (среднее за 2020, 2021 гг.), т/га
Effect of biological products on soybean yield (average for 2020, 2021), t/ha

the control (157.5 g) by 22,5-30,0%. The studied preparations provided an increase in yield in all the variants of the experiment. Biological yield was 3.3-3.7 t/ha with a yield of 2.5 t/ha in the control.

Treatment of seeds with environmentally safe preparations Biocomposite-Correct and Biostim Start, as well as spraying them on crops (flowering phase) contributes to obtaining more highly productive plants while reducing environmental pollution.

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ИСТОРИЧЕСКИЕ АСПЕКТЫ ПОРОДООБРАЗОВАНИЯ СВИНЕЙ В СИБИРИ (ОБЗОР)

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Представлены в историческом описании исчезнувшие или находящиеся на грани исчезновения сибирские породы свиней с целью лучшего понимания породообразовательного процесса в отечественной системе разведения и гибридизации свиней, определяющего улучшение продуктивных и породных качеств. Обзор пород свиней в Сибири дан с точки зрения истории их выведения, использованных селекционно-генетических методов и полученных достижений. Отсутствие живых представителей исчезнувших пород не позволяет изучить более глубоко их физиологические, морфологические особенности, потенциал продуктивности на высоком уровне кормления как в условиях современных промышленных комплексов, так и с использованием современных генетических методов селекции. Для обзора использованы литературные источники, в которых достаточно полно описаны породы и типы, приведены данные по продуктивности в условиях существовавшей в то время системы содержания и кормления. Освещены аспекты становления, развития и современного состояния свиноводства, а также существующие в отрасли проблемы. Дано описание следующих пород: сибирской северной, кемеровской, скороспелой мясной (СМ-1), новосибирского типа крупной белой породы, ачинского типа крупной белой породы, кемеровского заводского мясного типа свиней (КМ-1), чистогорской породы, алтайской мясной. Показаны методические подходы и селекционные достижения в выведении новых пород и породных типов в Сибири. Отмечено важное практическое значение селекционно-генетических методов в системе промышленного производства в современных условиях. Рассмотрен вопрос о возможности использования генетического потенциала отечественных пород свиней в условиях импортозамещения на основе прогрессивных технологических и методических подходов ученых и практиков в условиях Сибири.

Ключевые слова: породы свиней, селекция, типы, линии, методы, показатели продуктивности

HISTORICAL ASPECTS OF PIG BREEDING IN SIBERIA (REVIEW)

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Historical descriptions of extinct Siberian pig breeds or those on the verge of extinction are presented for a better understanding of the breeding process in the domestic pig breeding and hybridization system, which determines the improvement of productive and breed characters. An overview of pig breeds in Siberia is given in terms of the history of their breeding, the breeding and

genetic methods used and the achievements obtained. The absence of living representatives of extinct breeds does not allow to study more deeply their physiological, morphological features, the potential of productivity at a high level of feeding both in conditions of modern industrial complexes and using modern genetic breeding methods. Literature sources used for the review describe in sufficient detail breeds and types, and give data on productivity under the conditions of the then-existing system of housing and feeding. Aspects of the formation, development and the current state of pig breeding, as well as the existing problems in the industry are highlighted. The following breeds are described: Siberian Northern, Kemerovo, Early Maturing Meat (EM-1), Novosibirsk Large White Breed, Achinsk Large White Breed, Kemerovo Factory Meat Pigs (KM-1), Chelyabinsk Breed, Altai Meat Breed. Methodological approaches and breeding achievements in the breeding of new breeds and breed types in Siberia are shown. The important practical significance of breeding and genetic methods in the system of industrial production in modern conditions is noted. The issue of the possibility of using the genetic potential of domestic pig breeds under conditions of import substitution on the basis of advanced technological and methodological approaches of scientists and practitioners in the conditions of Siberia was considered.

Keywords: pig breeds, breeding, types, lines, methods, performance indicators

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By the beginning of the 1980s there were 24 pig breeds in Russia, among which only the Large White breed was widely distributed in all regions of the former USSR due to its high productivity and good adaptation properties. Other breeds, despite some advantages in meat and fattening qualities, were bred locally, and their adaptability to local conditions gave them an advantage over the Large White Breed. In Siberia, such breeds included the Siberian Northern, Kemerovo, and Early Maturing Meat (EM-1), as well as the later types created with the participation of these breeds, which were not widespread, but remained a valuable source of genetic diversity.

Stiff competition in industrial pork production in the conditions of large livestock complexes brought to the fore the use of breeds with high genetic potential for productivity, which led to the displacement of domestic breeds inferior to the imported ones, which led to their near extinction.

Currently, due to the problems of import substitution, it is of great interest to study the experience of creating domestic breeds and types of pigs and the history of their improvement. Unfortunately, the absence of living representatives of extinct breeds does not allow to study more deeply their physiological, morphological features, the potential of productivity at a high level of feeding both in conditions of modern industrial complexes and using modern genetic breeding methods. Literature sources were used for the review, in which the breeds and types are described in sufficient detail, the data on productivity under the conditions of the then existing system of housing and feeding are given.

The purpose of the work is to present Siberian breeds of pigs that are extinct or on the verge of extinction in a historical description for a better understanding of the breeding process in the domestic system of breeding and hybridization of pigs.

One of the most famous Siberian pig breeds is the *Siberian Northern Breed*, registered as

a breeding achievement in 1942. The authors are M.O. Simon, A.I. Ovsyannikov, I.T. Skorik, P.I. Ternitsky, E.T. Savina, A.F. Lysakov. The scientists had the task of creating a breed with the productive characteristics of the Large White Breed and the survival ability of native pigs. Native pigs were small, late maturing animals with a live weight of 60-70 kg and small (6-8 piglets) fecundity. At the same time, they had such valuable qualities as unpretentiousness, endurance and strength of the constitution. The work on creation of the new Siberian breed was based on the method developed by the prominent Soviet breeder academician M.F. Ivanov. The essence of this technique was that the first- and second-generation crossbreds (depending on the degree of inheritance of desirable traits) were bred "in themselves" in good feeding and housing conditions[1]. The selection of breeding stock was very strict, rejecting animals that did not meet the desired requirements. Annual rejection reached up to 80%. Particular attention was paid to the selection of boars of the Large White Breed, giving preference to animals of those lines that had the best acclimatization to Siberian conditions and had high productivity indicators. Animals of the second generation were bred "in themselves" and crossbred with boars of the Large White Breed and the third generation of crossbreds were bred "in themselves". When the first lines of boars and maternal families were created, a considerable number of Large White boars were used to "loosen up" the hereditary basis of local pigs and to select the best combinations of parental pairs[2].

The result of the work was animals that were not inferior in size and fecundity to the Great White breed of pigs, but much better adapted to Siberian cold[3]. The breed was constantly in the process of improvement, especially during the 70s-80s. From 1968 to 1973, the Siberian Research Institute of Animal Husbandry (SibNIPTIZh) breeders managed to increase gestation rate by 2.3 days to 202.3 days (the age of reaching 95 kg live weight)[4]. In the best boar line Kedra this indicator was 199,6 days, which is higher than in other lines by 7,0-7,8 days. Carcasses were characterized by high meat qualities. The carcass length of boars of the leading lines was 93,23-95,7 cm, the thickness of the fat at the level of the seventh rib was 3,53-3,55 cm. The carcasses contained on average 55.63-57.11% muscle tissue.

To improve the meat qualities and to increase early maturity, the pigs of the Siberian Northern breed were crossed with animals of other breeds with higher growth energy (such as Lacombe). The length of half carcasses of the animals increased by 1.3-2.7 cm. The meat of pigs of the Siberian Northern breed and their mixtures with Lacombe breed had better taste qualities compared to Landrace and purebred Lacombe pigs, probably due to the higher content of fat in it[5].

Further breeding of the Siberian Northern breed was conducted in the direction of improving early maturity, meat qualities and payment for feed. The breed was evaluated by the traditional method based on the results of control fattening.

Young animals of the Siberian Northern breed on fattening, depending on the lineage, reached 100 kg live weight in 187.3-197.0

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[2]Kryuchkovsky A.G., Podletskaya N.N., Belenkov E.P., Burlak Z.K., Bakhmutova R.Y., Zhulidov V.A., Samodurov E.K., Zubova L.I. Pig breeding in Siberia. Moscow: Kolos, 1981. 159 p.

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days[6]. At the same time, it was noted that the potential of the Siberian Northern breed may not have been fully revealed due to the insufficient level of feeding not fully balanced in terms of protein[7].

Selection of the Siberian Northern breed to improve the early maturity and reproductive ability of the animals made it possible to achieve a good genetic potential at that time. In 1989 the best animals of the Kedra 25 line had the growth energy at the control fattening of 804 g which was 124 g higher than the average in the herd. Thus, the genetic potential of the Siberian Northern breed (SN) was comparable to the newly bred pig breeds[8].

At the same time, it should be noted that the Siberian Northern breed has long been used at the "Kudryashovsky" pig complex in purity, as well as in crosses with other breeds. Its most successful combination, as experiments have shown, was with an early-maturing beef breed (EM-1) in a comparative evaluation with the Large White [1]. Siberian Northern breeding sows × EM-1 had a higher multiple birth rate by 8.2% and milk yield by 10.1% in comparison with Siberian Northern sows × Large White. The SN × EM-1 yelts had a lower back fat thickness (by 13.4%), a higher weight of the hind quarter (by 5.2%) and the area of the "loin eye" (by 14.0%) compared to the crossbreeding of Siberian Northern with Large White breed.

Creation of an Early-Maturing Meat breed (EM-1) was caused by the need to have a breed of animals satisfying the technologies of large complexes, which began to be actively created in the 1980s. Old domestic breeds did not fully meet the requirements of intensive production, and imported breeds such as Landrace were not adapted to our natural and economic conditions and could not provide breeding material for the rapidly developing pig breeding. Large-scale pedigree testing of 15 breeds and two types, carried out under the control of the Main Directorate of Animal Husbandry of the USSR Ministry of Agriculture together with the Animal Husbandry Department of VASKHNIL, showed that the breeds bred in the country have relatively high productivity, but the genetic potential of fattening qualities requires improvement. Creation of the breed was simultaneously held in 73 large state and collective farms of Russia, Ukraine, Belarus and Moldova under the guidance of scientists from 20 scientific research institutes and higher educational institutions of agriculture. After the collapse of the USSR, two breeds were tested in 1993 on the basis of a single breeding material - the Early Maturing Meat breed (EM-1) in Russia and the Ukrainian Meat breed in Ukraine [2].

When creating the breed EM-1 different variants of crossing were worked out. For example, when crossing boars of Poltava Meat type PM-1 with the breeding sows of Kemerovo factory type KM-1 progenies that reached 100 kg in 180 days, animals of Sputnik line - in 178,8 days with the hairpin thickness of 27,7 mm, weight of the hind leg 10,7 kg, body length 95,5 cm were obtained [3]. Further breeding work with EM-1 breed was carried out on traditional methods of evaluation of mothers, their daughters, determination of genetic correlations between productive indices of mothers and daughters, as well as studying the coefficients of repeatability of traits [4].

[6]Khan P.A., Zabolotsky A.P. Meat and fattening qualities when combining different lines of boars and families of sows of the Siberian Northern breed on the stud farm "Cherepanovskoe". Breeding and pedigree work in industrial animal husbandry: scientific-technical bulletin. Vol. 12 / SB VASKHNIL, SibNIPTIZh. Novosibirsk. 1985. pp. 34-37.

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[8]Lisitsyna L.V. Improvement of genetic potential of pigs of the Siberian Northern breed. Breeding and pedigree work in the intensification of animal husbandry in Siberia: collection of scientific papers, SB VASKHNIL, SibNIPTIZh. Novosibirsk, 1989. pp. 46-52.

To improve the fattening and meat qualities of the created breed EM-1 breeders used introductory crossbreeding with KM-1 type (Kemerovo Factory Meat type of beef pigs). The most successful combination was noted in the crossing of the breeding sows of EM-1 type and boars of KM-1 type which resulted in the youngsters' maturity coming to the age 172,4 days which is 16,5 days less than the purebred animals of EM-1 type. Reducing the proportion of the factory type KM-1 blood decreased the growth energy of the young and slightly worsened the meat quality of the progeny [5].

In order to create hybrids for fattening at industrial complexes, crossing of different breeds and identification of the best among them was carried out. Among six crossing variants of the Large White Breed and its first-generation hybrids and EM-1 (maternal basis) with German Landrace (GL) it was found that reproductive capabilities (milk yield of the breeding sows, litter weight at weaning) were higher in the Large White Breed (LB) with Landrace boars and in the three-way cross variant (LW × GL) × EM-1. Milk yield was 65.5-66.9 kg, litter weight - 172.7-181.1 kg. However, higher early maturity was observed in the cross LW × EM-1 - 204 days, which is higher by 10-26 days compared to other variants [6].

The Kemerovo pig breed is one of the best domestic breeds, which originated from local pigs improved by boars of the Large White breed in the 1930s. The main purpose of selecting this breed was to produce early maturing animals for cross-breeding with Large White pigs. The management of this project was entrusted to Professor A.I. Ovsyannikov, Doctor of Science in Agriculture and Professor I.I. Gudilin, Doctor of Science in Agriculture. Active creation of the breed began much later, when it began to be improved by complex reproductive crossing with the Berkshires and the Large Black Breed. In the formation of several lines and families the Siberian Northern breed and the Siberian Black and White breed were used. The Kemerovo breed was registered as an independent breed in 1960.

At the first stage, a Kemerovo breed group of fat type pigs was created. These mixtures were covered with Berkshire boars. The half-blooded Berkshire breed mother stock with black and white color was covered again with Berkshire or crossbred boars (3/4 of the blood of the Berkshire breed). The result was animals with 60% Berkshire blood. The breeding nucleus consisted of four lines with five related groups of boars and eight families with 10 related groups of mothers.

At the second stage, a single "admixture of new blood" of local improved pigs (third to fifth generations), Large Black, Siberian Northern and Siberian Black-and-White breeds were carried out.

The pigs of the Kemerovo breed differed by the high indices of development and reproductive qualities: multiple births - 10-11 piglets, milk yield - 50-55 kg, weight of the litter at the age of 2 months - 170-180 kg. The animals had high precocity and growth rate, the average daily gain during fattening period was 730-780 g, weight of 100 kg was 175-180 days old, hairline thickness over the 6th-7th thoratic vertebra was 27-29 mm.

It should be noted that the improvement of existing at that time breeds and types of pigs was continuously carried out on the breeding farms of the complexes, new improved forms of animals were created. For example, as a result of selection for improvement of reproductive and fattening qualities the factory universal type of the Kemerovo beef breed (UKM) was formed at the CJSC APC "Chistogorsky", which showed 176,7 days early maturity, which was 24,9 days fewer than the yelts of the Kemerovo breed, which had a thinner (10,8 mm) back fat[9]. A successful combination of the Kemerovo breed with

[9]Ryavkin O.V. Economically useful and biological qualities of pigs of the Universal factory type (UKM) Kemerovo breed: Ph. Novosibirsk, 2012. 18 p.

other breeds was noted in the experiments on crossing it with Landrace, Duroc, Pietrain pigs to obtain hybrids and subsequent fattening [7]. The use of half-blooded breeding sows (Kemerovo × Landrace) crossed with the Pietrain boars ensured better fertility, growth of offspring during the suckling and fattening periods, as well as less fat deposition along the backbone.

In 1968, work on the creation of specialized synthetic lines of bacon and meat direction began in the Kemerovo Region under the leadership of VASKHNIL academician A.I. Ovsyannikov and a senior researcher of VIZh Candidate of Science in Agriculture I.A. Tarasov. The animals of the Kemerovo and Landrace breeds were chosen as the parent stock. First-generation mixtures served as source material for creating Siberian bacon pigs of the *Kemerovo factory beef type of pigs (KM-1)*. The type was registered in 1978. The patent holders are OJSC "Yurginsky" Breeding Plant, LLC APC "Chistogorsky", Novosibirsk State Agrarian University.

When obtaining EM-1, the following scheme was used: first generation crossbreeds were covered again with boars of the Landrace breed. From the resulting progeny crossbred boars (3/4 Landrace + 1/4 Kemerovo) were selected, which with half-blood sows (1/2 Kemerovo + 1/2 Landrace) gave the parent material to create a factory type (5/8 Landrace + 3/8 Kemerovo) suitable for breeding "in itself". Cross-bred animals of the first and second generations (1/2 Landrace + 1/2 Kemerovo and 3/4 Landrace + 1/4 Kemerovo) were also included into the alpha-line. As a result of "in-house" breeding, especially half-blooded crosses, animals of black and white color were excluded from the alpha-line, selecting only white pigs. The desirable type was obtained from the breeding of high-blooded "in-house" pigs for three generations. The breeding work was carried out in the direction of increasing early maturity, meat qualities, and feed efficiency[10] [8].

Animals of the Kemerovo meat type are well adapted to the conditions of Siberia, have strong limbs and bones, good fattening and high productivity of fattening and meat qualities - the average daily gain on control fattening is 800 g at the age of reaching 100 kg 165 days of live weight, the thickness of the fat 28 mm [9].

The Achinsk type of the Large White Breed pigs were bred at the Achinsk breeding farm in the Krasnoyarsk Region. The authors are N.M. Bashkirova, V.A. Bekenev, I.P. Belozerova, V.A. Dudarev, V.G. Mantikova[11].

Animals of the Achinsk type are characterized by high reproductive qualities. Breeding was based on purebred breeding with strict selection and homogeneous selection of animals with high productivity. At the same time herd genealogical structure was created by lines, families and related groups. Animals of the Achinsk type are well developed, with a strong constitution, long body and high productivity, adapted to the harsh climatic conditions of Siberia. The reproductive rate of sows in the last 5 years has averaged 11,5-11,6 pigs per farrowing, the milk yield was 64,3-66,7 kg, the yield of litters per weaning was 10,1-10,2 pigs, the average live weight of one piglet at 2 months of age reached 20,1-20,6 kg. Boars belonging to four genealogical lines - Samson, Drachun, Svat, and Stalactite - and nine related groups were used in the breeding facility.

Pigs of the Achinsk type differ from other types of Large White Breed by their exterior - original structure of mammary gland, prominent lobes; by high and stable reproductive quality - multiple reproduction, milk yield and live weight of the litter at 2 months of age and especially by reproductive qualities

[10]Grishkova A.P., Tarasov N.A., Nechaeva E.V. Selection of KM-1 type pigs for high meat and fattening qualities. Intensification of pig breeding in the Kemerovo region: collection of scientific works, Novosibirsk, 1990. pp. 42-45.

[11]Bekenev V.A., Bashkirova N.M., Belozerova I.P., Dudarev V.A., Mantikova V.G. Breeding achievement in animal breeding - type of pigs of the large White breed "Achinsky". Patent № 1994, application № 9811316. Application. 17.07.2001.2001a.

[10].

Genetic diversity in the breed was maintained by breeding by type, but inter-type crossing was studied to increase fattening qualities. The comparative evaluation of the productivity of pigs of the Achinsk and Katun types and their crosses showed that the animals of the Achinsk type had higher average daily gains and reached 100 kg live weight faster by 7.5 days compared to the Katun type. At the same time, animals obtained from intertype crossing, where the breeding sows were of the Katun type and the boars of the Achinsk type, occupied a middle position in terms of precocity. They reached a live weight of 100 kg in 189 days, while the opposite selection (Achinsk type sows and Katun type boars) had a precocity of 191.7 days, i.e. at the level of the Katun type [11].

Under the requirements of intensive pig breeding and market conditions, the *Large White breed* also developed in Siberia. The selection and genetic parameters of the target standard of new lines for natural-economic conditions of Siberia were established as follows: multiple density of breeding sows - 11-12 piglets, milk yield - 52-55 kg, weight of the litter at weaning at 2 months - 190-200 kg, young immaturity - 180-185 days, feed expenses - 3,6-3,8 fodder units per 1 kg of growth, average daily fat gain - 750-780 g, thickness of the fat layer - 30-31 mm. Using various selection methods during the period of 13 years (1981-1993) the efforts of SibNIIPTIZh scientists on the basis of CJSC Breeding Farm "Bolshevik" and SAE EPF Breeding Plant "Borovskoye" a new breeding type of *Novosibirsk Big White* Breed Pigs (NBW)[12] was created and tested. The authors of the type were V.A. Bekenev, E.F. Grishina, A.G. Kryuchkovsky, G.I. Mazanova, Z.I. Moreva, V.I. Frolova, G.P. Yudina[13]. Selection of the animals by complex evaluation and at high selection pressure was mainly aimed at improving the early maturity of parental groups and genealogical lines which had a good reserve of hereditary variability within the closed populations as well. Homogeneous selection by pedigree and intensive breeding work had a positive effect on the reproductive performance of mothers. At the age of 3 months, 20 boar piglets were selected for each boar introduced into the main herd and 6 pigs for a breeding sow introduced into the main herd. The NBW-1 line yelts ranked first by their precocity (weight reached 120 kg at the age of 212 days) among other breeds and types of pigs of domestic stud farms at the comparative fattening event held at the All-Union Agricultural Exhibition and Convention Centre in 1985. Further work was focused on the breeding of line-populations to obtain outstanding economically useful traits. The progeny of the boar Samson 7021 had an average daily gain of 1018 g and feed consumption of 3.18 fodder units per 1 kg of gain.

The progeny of the boar Samson 7295 had early maturity of 156.8 days. Both boars are related to each other (second to third generations), and their ancestor Samson 2507 was the best in the herd by the fattening qualities. At the time of testing, the NBW type outperformed all other breeds and types of pigs bred in Russia in terms of early maturity and average daily gain, and was almost as good as the breeds bred abroad in the countries with a developed pig breeding industry [12]. The NBW type has the following productivity indices: multiple pregnancy - 11 piglets per farrowing, milk yield - 57 kg, weight of the litter at weaning at 2 months - 194 kg, early maturity - 173,5 days, average daily gain on fattening - 842 g, feed consumption per 1 kg of

[12]*Бекенев В.А., Гришина Е.Ф., Фролова В.И., Крючковский А.Г., Мазанова Г.И., Морева З.И., Юдина Г.П.* Селекционное достижение в животноводстве – тип свиней крупной белой породы «Новосибирский». Патент № 1032, заявка № 9353386. Заявл.1.1.1993.

[13]*Фролова В.И.* Выведение и совершенствование типа свиней Новосибирский крупной белой породы::автореф. дис…. канд. с.-х. наук. Новосибирск, 2007. 26 с.

gain - 3,5 fodder units, carcass length - 95,1 cm, hairline thickness - 31 mm, the weight of the back third of the half carcass - 10,4 kg. The genetic potential of early maturity is 156 days, the average daily gain is 1017 g [13].

Further intensification of pig breeding and competition with foreign producers has changed the requirements for breeding material in general: an increase in early maturity, increased carcass meatiness, multiple sows and boneflesh strength. The *Chistogorsky* breed was created on the basis of CJSC APC "Chistogorsky" in 2016. The authors are A.A. Arishin, V.A. Volkov, N.L. Tretiakova, A.P. Grishkova, and N.A. Chalova[14]. The breed was bred based on introductory crossing of the Large White Breed of domestic selection (sows) with Large White Breed boars of English (PIC, Poland) and French selection (France Hybrid, France) as well as Yorkshire boars ("Yubileyny" stud farm, Tyumen Region). The breed is well adapted to the conditions of industrial technology. The animals are of white color. The fecundity of mothers is average - 13,2 pigs. The age at which boars reach 100 kg is 161,3-166,7 days, the average daily gain during the period of growth is 851-894 g, the fat is thin - 16,1-16,5 mm, the fodder cost is 2,75-2,68 kg. The age of reaching 100 kg of piglets averaged 178.5 days, the thickness of the fat was 17.3 mm [14].

According to the same scheme, the Altai Meat pig breed was bred under modern conditions on the basis of the Large White Breed, Landrace breed and boars of the Maxgro breed. It was included in the State Register in 2017. The authors of the breeding achievement are N.I. Strekozov, N.A. Zinovieva, B.L. Panov, A.M. Yugan, A.N. Lukyanov, V.N. Sharnin, A.I. Kichigin, A.I. Rud, A.P. Kosarev, N.A. Glazkova, L.V. Khripunova.

CONCLUSION

During the twentieth century dozens of breeds of farm animals were bred in Russia. The achievements of Siberian scientists-breeders also made a significant contribution to this. All of the pig breeds listed above, excluding the early maturing beef breed and, possibly, some others, have disappeared, but in the last years of their existence geneticists have managed to conduct research on animal identification, revealing their genetic profile by STR analysis and microsatellites, using any biological material, including museum skull samples [15]. For example, a high affinity of EM-1 pigs with Landrace breed and estrangement from Duroc and Yorkshire breeds was established, which is consistent with the historical origin of the breed [16]. When studying the genetic diversity of some domestic and foreign breeds in a comparative aspect, it was found that the Kemerovo breed is characterized by a relatively low level of genetic diversity, but it is higher than that of other local breeds. Cluster analysis allowed us to experimentally prove a high degree of genetic consolidation of the studied breeds, which indicates the uniqueness of their allelofond [17, 18]. General scientific and technological progress in biology, engineering, information technology has a great impact on methods and techniques of the breeding work in modern conditions. Systems of large industrial production in cattle breeding dictate the conditions for maximizing the manifestation of productive qualities, setting the boundaries at the limit of biological species capabilities. In this regard, local and including domestic breeding achievements, based on natural adaptive advantages, are in contradiction with the economic ones. The logical result is the replacement of domestic breeds by the imported ones. This problem exists all over the world. Under current conditions, we see the need to create farms in technological parks at scientific centers for the breeds of farm animals, new, rare, as well as endangered, with the best gene pool and using all modern methods of marker, genomic breeding, reproductive and information and statis-

[14]*Аришин А.А., Волков В.А., Третьякова Н.Л., Гришкова А.П., Чалова Н.А.* Селекционное достижение в животноводстве – порода свиней «Чистогорская». Патент № 8750, заявл.13.12.2016.

tical technologies [19].

The above historical evidence of the effectiveness of domestic breeding shows the potential possibility of improving the available Russian pigs or creating new forms of pigs with a world-class level of productivity and preserving genetic diversity and uniqueness.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ПРОЦЕССА ДЕГИДРАТАЦИИ НА КАЧЕСТВО И БЕЗОПАСНОСТЬ КОРМОВ ЖИВОТНОГО ПРОИСХОЖДЕНИЯ

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Представлены этапы производства сухих кормов для непродуктивных животных и результаты исследований полученной продукции на соответствие ГОСТам. Изучены показатели качества и безопасности сухих кормов для непродуктивных животных из сырья животного происхождения, подвергнутого процессу дегидратации. Установлено, что процесс сушки с конвекционным принципом действия положительно влияет на показатели пищевой ценности готового продукта. Полученная продукция соответствует ГОСТ Р 54954–2012. Эксперимент проведен в 2021, 2022 гг. В качестве объекта исследования использованы селезенки, полученные от клинически здорового крупного рогатого скота (возраст 18 мес) при убое на мясоперерабатывающих предприятиях Алтайского края. Согласно полученным лабораторным результатам установлено, что в исследуемом виде сырья в процессе дегидратации существенно снизился такой показатель, как массовая доля влаги, он составил 5,5 ± 0,01%. Показатели массовой доли белка и золы после процесса сушки остались практически неизменными: 20,27 ± 0,001 и 0,05 ± 0,01% соответственно. Массовая доля сырого жира в исследуемых образцах составляла 0,4 ± 0,01%, что ниже показателей стандарта на 4,6–8,6%. Проведено исследование полученной продукции на соответствие требованиям, предъявляемым к сухим полнорационным кормам взрослых животных (собак). Проведен сравнительный анализ химического состава образцов сухого корма. В исследуемых образцах отмечено необходимое содержание следующих незаменимых макроэлементов: фосфора, кальция и натрия. Выявлено наибольшее содержание кальция (2,3%). Лабораторными методами в соответствии с утвержденными правилами бактериальных исследований установлены показатели безопасности полученных сухих кормов животного происхождения для непродуктивных животных.

Ключевые слова: процесс дегидратации, непродуктивные животные, селезенка, качество кормов

STUDY OF THE EFFECT OF THE DEHYDRATION PROCESS ON THE QUALITY AND SAFETY OF ANIMAL FEED

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The stages of dry feed production for unproductive animals and the results of the research of the resulting products for compliance with GOSTs are presented. The quality and safety parameters of dry feeds for unproductive animals made of raw materials of animal origin subjected to dehydration process have been studied. It was found that the drying process with the convection principle of action, positively affects the indicators of nutritional value of the finished product. The resulting products comply with GOST R 54954-2012. The experiment was conducted in 2021, 2022. Spleens obtained from clinically healthy cattle (age 18 months) during slaughter at the meat processing enterprises of the Altai Territory were used as an object of the study. According to the laboratory results, it was found that in the studied form of raw materials in the process of dehydration such an indicator as the mass fraction of moisture significantly decreased and amounted to 5.5 ± 0.01%. The indicators of the mass fraction of protein and ash after the drying process, remained virtually unchanged: 20.27 ± 0.001 and 0.05 ± 0.01% respectively. The mass fraction of crude fat in the studied samples was 0.4 ± 0.01%, which is 4.6-8.6% lower than the standard. Study of the resulting products for compliance with the requirements for dry full-fat adult fodder (dogs) was carried out. A

comparative analysis of the chemical composition of dry feed samples was conducted. In the tested samples the required content of the following essential macronutrients: phosphorus, calcium and sodium was observed. The highest calcium content (2.3%) was detected. Laboratory methods in accordance with the approved rules of bacterial studies established safety indicators of dry animal feed for unproductive animals.

Keywords: dehydration process, unproductive animals, spleen, feed quality

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INTRODUCTION

One of the conditions for the effective development of the livestock industry is sustainable feed production [1, 2]. In the modern concept the term " feed" defines a product for feeding animals that does not have a harmful effect on their organism[1]. The modern market of feed for pets, depending on the method of manufacture, is represented by complete and incomplete, dry and wet, dietary, functional and supplementary feed [3]. The most common Russian foods are brand names "Zoogurman" and "Caesar" [4]. According to the experts of the "Zoobusiness in Russia" magazine, the production of feed for non-productive animals such as cats and dogs was 124.8 thousand tons of finished products by the end of 2021[2]. In accordance with the subprogram "Development of animal feed and feed additives production" one of the main objectives is to increase feed production using secondary raw materials from the processing industries of the agro-industrial complex[3].

Analysis of the literature showed that most of the processed by-products of slaughter (blood and its elements, glands and bone) are used in the manufacture of medical and veterinary organotherapeutic drugs, nutrient media, meat and bone meal[4] [5-11]. Some by-products of the first and second categories are used in the production of finished meat products such as sausages, cold cuts, jelly, zeltsy, pates [12]. The spleen is less widely used in the meat processing industry. It is not only an organ of hematopoiesis and immunity protection during animal life, but also a source of fodder protein of animal origin. A number of authors have proved a high rate of digestibility of spleen proteins[5].

The owners' choice in favor of dry feed is obvious: natural composition; content of all nutrients required to meet the needs of the pets' organism; long shelf life. One of the modern technological processes for dewatering of raw materials is dehydration [13-15]. This process has advantages because it maintains the qual-

[1]GOST R 54954-2012 Feed and feed additives for nonproductive animals. Terms and definitions. Moscow: Standartinform, 2020.

[2]Russian pet food production is growing. URL: https://zooinform.ru/ (accessed on: 09.06.2022).

[3]The development of animal feed and fodder additives production: Russian Government Resolution No. 1489 of September 3, 2021. URL: https://base.garant.ru/402789234/ (accessed on: 04.04.2022).

[4]Gorbunova N.V., Rudik F.Ya., Bystrova I.S. Development of the technology of poultry bone processing with obtaining the powder of functional purpose. Innovations in the intensification of production and processing of agricultural products: Proceedings of the International Scientific-Practical Conference, Volgograd, June 17-18, 2015, ed. by Acad. RAS I.F. Gorlov. Volgograd, 2015. pp. 279-282.

[5]Lebedeva L.I., Nasonova V.V., Verevkina M.I. Rational use of low-value by-products in sausage production. Proceedings of the International Scientific and Practical Conference "Innovations in the intensification of production and processing of agricultural products". 2015. pp. 202-224.

ity and nutritional value of the finished product. [16]. Feeds for non-productive animals must meet the requirements of regulatory and technical documentation of the manufacturer. Quality and safety control of raw materials and finished products is of great importance in the production process. Since the processing of low-value raw materials in the conditions of import substitution is growing, the use of slaughter products for obtaining feeds and additives is currently relevant.

The purpose of the study is to investigate the effect of the dehydration process on the quality and safety indicators of dry animal feed.

The research objectives are:

– evaluate the organoleptic and physical-chemical characteristics of raw materials of animal origin for feed production;

– describe the process of feed production;

– conduct laboratory tests of finished feed for non-productive animals;

– analyze the data of the dehydration process and indicators of the obtained dry animal feed.

MATERIAL AND METHODS

The study was conducted in 2021, 2022. Spleens obtained from clinically healthy cattle (9 heads, age 18 months) at slaughter at meat processing enterprises of the Altai Territory were used as an object of the study. Generally accepted methods of animal feed quality evaluation were used: determination of crude ash content using crucible and desiccator filled with effective water-absorbing substance; determination of mass fraction of crude fat by skimmed residue; determination of moisture content by sample drying at 103 °C in a desiccator. Methods used are: the Kjeldahl method for determining the mass fraction of protein; atomic absorption method for determining calcium in the samples prepared by dry ashing; photometric method for determining phosphorus content with sample mineralization by dry or wet ashing; ionometric method for determining sodium using a glass sodium-selective electrode.

Physico-chemical quality parameters of raw materials were studied in the chemical toxicological department of an accredited testing laboratory "AKVTS" (Barnaul). The content of protein, fat, moisture, ash was carried out using an automatic titrator Titroline 5000/20 M2, electronic scales AS-121S and a drying cabinet ShS-80-01 SPU. At manufacture of forages for preservation of protein and removal of moisture the method of dehydration or drying of raw materials was used. Ready-made dry full-fat animal fodder was examined for compliance with the requirements of GOST[6].

RESULTS AND DISCUSSION

The main criteria for the quality of raw materials of animal origin are organoleptic and physico-chemical parameters (see Fig. 1).

The organoleptic evaluation of the spleens, selected from clinically healthy cattle, showed: the surface of the material was clean; blood and impurities were removed; the shape of the organ was flat, with rounded edges; the consistency was elastic, grey with a violet tint, without foreign smell; the absolute weight of the organ was 0.724-0.920 kg, length 29-40 cm. The physical and chemical characteristics of the spleen meet the requirements presented in Table 1.

Packaged and labeled spleens obtained at slaughterhouses in the Altai Territory come in separate batches for the production of chilled feed to meat processing plants accompanied by veterinary documents (see Fig. 2).

All sections of the production room are divided into zones by partitions, which exclude the intersection of raw materials and finished products. Prepared and cleaned raw materials with a total weight of up to 150 kg are placed on Teflon nets with an anti-stick effect and sent to the "Dehydration Zone" for drying.

The drying process takes place in the chamber KS-16 with the convection principle of operation at a temperature no higher than 65 ° C for 10-36 hours with constant circulation of air inside the device. At the end of the drying process complete fodder enters the "Packing Zone", where on the table with the help of electronic scales of VET-15-1/2-1S-AB brand further products are weighed into individual dis-

[6]GOST R 55453-2013 Feed for non-productive animals. General technical conditions. Moscow: Standardinform, 2014.

Рис. 1. Селезенка крупного рогатого скота (18 мес)
Fig. 1. Spleen of cattle (18 months)

Табл. 1. Физико-химические показатели качества селезенок крупного рогатого скота, %
Table 1. Physical and chemical indicators of the quality of spleens of cattle, %

Mass fraction	Test results	Error (uncertainty)
Moisture	66,5	6,7
Protein	23,59	1,89
Fat	0,9	0,2
Ash	0,14	0,04

posable packaging, sealing bags with the help of manual pulse table sealer FS-400 ABS. Then the dry fodder is labeled and sent to the warehouse for storage of finished products in clean dry, well-ventilated conditions at a temperature of 25 ° C and relative humidity of no more than 80% for up to 7 months. Samples taken from the batch from the manufacturer's warehouse are sent to the testing laboratory.

According to the laboratory results, it was found that in the studied form of raw materials in the process of dehydration such an indicator

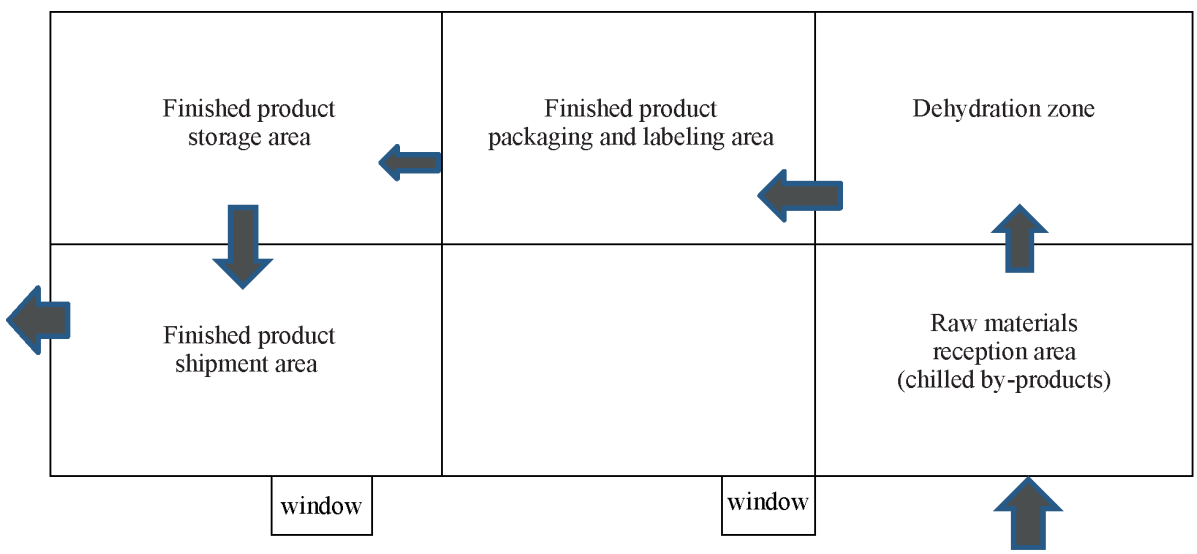


Рис. 2. План цеха по изготовлению сухих кормов животного происхождения для непродуктивных животных
Fig. 2. Plan of the workshop for the production of dry animal feed for unproductive animals

as the mass fraction of moisture (5.5 ± 0.01%) significantly decreased (see Fig. 3).

Such indicators as the mass fraction of protein and ash remained practically unchanged after the drying process: 20.27 ± 0.001% and 0.05 ± 0.01%, respectively. The mass fraction of crude fat in the studied samples was 0.4 ± 0.01%, which was 4.6-8.6% lower than the standard. Therefore, the fodder with inadequate indices refers to incomplete dry food for maintenance of adult animals (dogs). The mineral indices of forages were also examined for compliance with the requirements of normative and technical documentation of the manufacturer (see Fig. 4).

A comparative analysis of the chemical composition of dry feed samples was carried out. It was noted that the samples under study contain such essential macronutrients as phosphorus, calcium and sodium. The high content of calcium (2,3 ± 0,001%) was detected. According to the approved rules of bacterial examination of fodders[7] safety indicators of dry fodders of animal origin for nonproductive animals were established by laboratory methods (see Table 2).

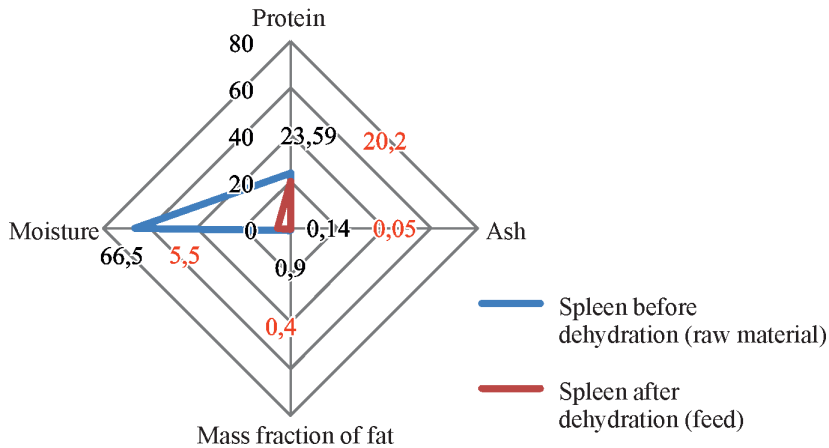
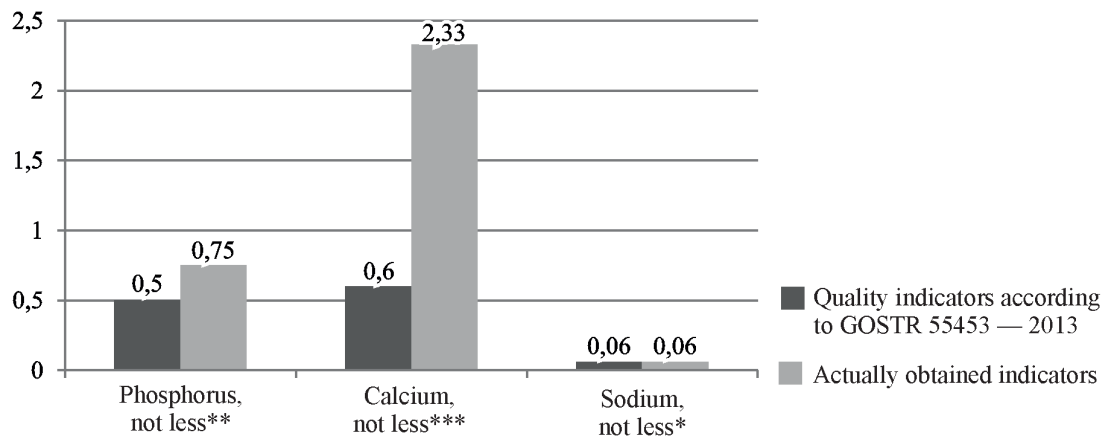


Рис. 3. Показатели качества селезенки до и после процесса дегидратации

Fig. 3. Spleen quality indicators before and after the dehydration process



*$p \leq 0.05$.
**$p \leq 0.01$.
***$p \leq 0.001$.

Рис. 4. Показатели качества сухих полнорационных кормов животного происхождения для непродуктивных животных

Fig. 4. Quality indicators of dry complete feed of animal origin for unproductive animals

[7]Rules of bacterial examination of fodder. Chief Veterinary Administration of the Ministry of Agriculture of the USSR. Moscow: Kolos, 1976.

Табл. 2. Показатели безопасности сухих кормов животного происхождения для непродуктивных животных

Table 2. Safety indicators of dry animal feed for unproductive animals

№ п/п	Indicator	Unit of measure	Test results	Error (uncertainty)	Standard	RD for the test method
			Mycotoxins			
1	Aflotoxin B1	mg/kg	Less than 0,001	–	No more than 0,010	MF for the determination of aflotoxin B1 dated 26.07.1972
			Pesticides			
2	Pesticides	mg/kg	DDT and its metabolites less than 0.02; HCCH (ß isomer) less than 0.014 (a-,ß isomers) less than 0.02	–	DDT and its metabolites no more than 0.05; HCCH (isomers) no more than 0.2	GOST 13496.20–2014
			Microbiological indicators			
3	Enteropathogenic E. coli types	–	Not detected	–	Not acceptable	Rules for bacterial examination of fodder, approved by the Main Directorate of the Ministry of Agriculture of the USSR dated 10.06.1975
4	Salmonella		Not detected	–	Not acceptable	Rules for bacterial examination of fodder, approved by the Main Directorate of the Ministry of Agriculture of the USSR dated 10.06.1975
			Nitrites and nitrates			
5	Nitrites	mg/kg	Less than 0.01	–	No more than 10,0	GOST 13496.19–2015
6	Nitrates	mg/kg	25	± 6	250	GOST 13496.19–2015
			Radionuclides			
7	Strontium 90	mg/kg	Less than 3,7	–	100	IFC No. 40152.4Д362/01.00294–2010
8	Cesium 137	Bq/kg	Less than 7,1	–	600	GOST P54040–2010
			Safety Indicators			
9	Total Toxicity	–	Nontoxic	–	Not acceptable	GOST 31674–2012
			Toxic elements			
10	Cadmium	mg/kg	Less than 0,1	–	No more than 1,0	GOST 30692–2000
11	Arsenic	mg/kg	0,10	± 0,02	No more than 2,0	GOST 26930–86
12	Mercury	mg/kg	Less than 0,0015	–	No more than 0,4	GOST 26927–86
13	Lead	mg/kg	Less than 0,1	–	No more than 5,0	GOST 30692–2000

Analysis of the tabulated data shows that the feeds meet the standards, which makes it possible to further sell them freely.

CONCLUSIONS

1. The method of raw material dehydration has a positive effect on the preservation of the useful properties of the product. The content of protein of animal origin is 20,27 ± 0,001%, which indicates a high nutritive value of the finished feed. It is determined that the composition of the feed contains the following macronutrients: calcium, phosphorus, sodium. The highest indicator was noted for calcium content (2,3 ± 0,001%).

2. In the process of dehydration of meat raw materials there is a release of moisture, which increases the shelf life of finished feed up to 7 months. The residual moisture content is 5.5 ± 0.01%, which is 60.5% lower than the same indicator of the studied raw materials.

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ИСПОЛЬЗОВАНИЕ *BACILLUS SUBTILIS* В КАЧЕСТВЕ НОСИТЕЛЯ ОРАЛЬНОЙ ВАКЦИНЫ ПРОТИВ *STREPTOCOCCUS SUIS*

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Из-за прогрессирующего роста бактерий, вызванного широким применением антибиотиков, лечение стрептококкоза становится все более сложной задачей. Необходима надежная вакцинация против *Streptococcus suis.* Современные возможности молекулярной диагностики и генной инженерии создают перспективы для прямого клонирования протективных эпитопов гена Lmb местного штамма *S. suis* в предложенную систему доставки антигена иммунной системы свиней. Среди носителей оральных вакцин *Bacillus subtilis* признана относительно экологически чистым носителем с эффективной системой секреции белка и адаптивным метаболизмом, способная продуцировать споры в относительно жестких условиях. Это свойство спор может использоваться для повышения стабильности и возможности повторного использования вакцин. Изучена возможность использования протективных эпитопов Lmb *S. suis* в составе *B. subtilis* в качестве носителя оральной рекомбинантной вакцины против *Streptococcus suis*. Нуклеотидные последовательности *S. suis* получены в базе данных GenBank после предварительного анализа литературных данных об известных протективных антигенах *S. suis* различных серотипов. Анализ нуклеотидных последовательностей проводили с использованием программного обеспечения Unipro UGENE v. 43.0. Для поиска T (CTL и Th) и B зависимых эпитопов гена Lmb использовали The Immune Epitope Database (IEDB). Приведено описание сконструированной на основе компьютерного дизайна вакцины, в которой спрогнозирована локализация CTL, B и Th эпитопов. Описаны результаты клонирования последовательности антигенно-активного эпитопа белка *S. suis* Lmb в *B. subtilis* для последующего перорального введения и изучения изменений иммунологических реакций и побочных реакций у животных. Выявлена возможность клонировать эпитопы рекомбинантного белка Lmb *S. suis* в полилинкер вектора pBE-S. В перспективе представляется возможным создать новую недорогую и удобную в эксплуатации вакцину против *S. suis,* не требующую инъекционного введения.

Ключевые слова: *Streptococcus suis,* оральная вакцина, *Bacillus subtilis*, эпитоп, Lmb

USING *BACILLUS SUBTILIS* AS AN ORAL VACCINE CARRIER AGAINST *STREPTOCOCCUS SUIS*

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Due to the progressive growth of the bacteria caused by the widespread use of antibiotics, treatment of streptococcosis is becoming increasingly difficult. Reliable vaccination against *Streptococcus suis*

is necessary. Modern molecular diagnostic and genetic engineering capabilities create prospects for direct cloning of the protective epitopes of the Lmb gene of the local *S. suis* strain into the proposed delivery system of the pig immune system antigen. Among oral vaccine carriers, *Bacillus subtilis* is recognized as a relatively environmentally friendly carrier with an efficient protein secretion system and adaptive metabolism capable of spore production under relatively harsh conditions. This spore property can be used to increase the stability and reusability of vaccines. The possibility of using the protective Lmb epitopes of *S. suis* in *B. subtilis* as a carrier of an oral recombinant vaccine against *Streptococcus suis* was studied. The nucleotide sequences of *S. suis* were obtained from the GenBank database after a preliminary analysis of literature data on the known protective antigens of *S. suis* of various serotypes. Nucleotide sequence analysis was performed using Unipro UGENE v. 43.0. The Immune Epitope Database (IEDB) was used to search for T (CTL and Th) and B dependent epitopes of the Lmb gene. A computer-designed vaccine in which localization of CTL, B, and Th epitopes is predicted is described. The results of cloning the sequence of the antigenically active epitope of the *S. suis* Lmb protein in *B. subtilis* for subsequent oral administration and study of changes in immunological reactions and adverse reactions in animals are described. The possibility to clone the epitopes of recombinant *S. suis* Lmb protein into the pBE-S polylinker vector was revealed. In the long term, it seems possible to create a new inexpensive and easy-to-use vaccine against *S. suis* that does not require injection.

Keywords: *Streptococcus suis,* oral vaccine, *Bacillus subtilis*, epitope, Lmb

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INTRODUCTION

Streptococcus suis (S. suis) is a gram-positive coccus [1] that can be divided into 35 serotypes according to different antigens of the *Streptococcus* capsular polysaccharide *[2]*. Due to the progressive increase in bacterial resistance caused by the widespread use of antibiotics, the treatment of *S. suis* is becoming increasingly difficult, leading to an increasing need for effective vaccination against it *[3]*.

The route of transmission of *S. suis* in pigs is usually as follows: piglets become infected in the mother (vertical transmission) or from other animals in the herd (horizontal transmission) [4]. Despite the fact that contact with infected meat or animals through wounds is insignificant, the predominant route of *S. suis* transmission to humans is the consumption of undercooked, infected pork. In both pigs and humans, *S. suis* can cause meningitis, septicemia, and other diseases. This infection causes an acute zoonotic infectious disease [5, 6].

Over the years, scientists have studied various new vaccines. In our study, it was decided to choose an oral vaccine with live bacteria as the carrier. We believe that oral administration can be simple and easy to implement in practice and can also stimulate mucosal immunity [7].

Among oral vaccine applicators, the bacterium *Bacillus subtilis* (*B. subtilis*) is recognized as a relatively environmentally friendly host with an efficient protein secretion system and adaptive metabolism. This microorganism can also produce spores under relatively harsh conditions [8]. This property of spores can be used to increase the stability of vaccines under relatively unfavorable conditions of storage and application [9]. The technology of using spore-forming bacteria has been successfully applied in various industries, including vaccine production [10]. Thus, *B. subtilis* is an optimally suitable carrier of vaccine antigens.

After selecting a strain as a vaccine vector, we need to develop a vaccine. Lmb is an extracellular protein first discovered in *S. agalactiae* in 1999 [11], then in various *Streptococcus* species [12, 13]. Subsequent studies have shown that Lmb protein may have protective ability against streptococcal infection (see Fig. 1).

Lmb is a surface protein involved in the absorption of zinc ions (possibly a zinc receptor). These proteins associated with bacterial adhesion belong to the lipoprotein receptor family. Immunization of mice has shown that specific antibodies produced by the Lmb protein can effectively resist streptococcal infection[1].

The purpose of the study was to investigate the possibility of using the protective Lmb epitopes of *S. suis* in *B. subtilis* as a carrier of an oral recombinant vaccine against *S. suis*.

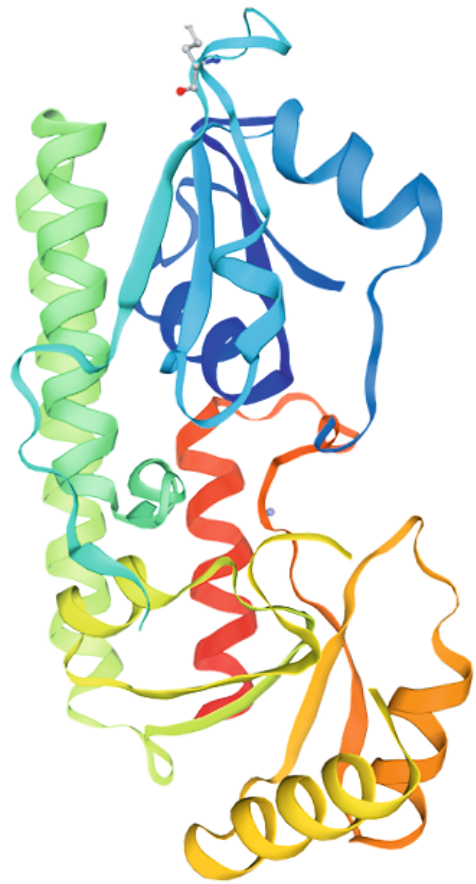

Рис. 1. Lmb: поверхностный белок, связывающий ламинин

Fig. 1. Lmb: surface laminin binding protein

MATERIAL AND METHODS

The work was performed at the Pharmacogenomics Laboratory of the Institute of Chemical Biology and Fundamental Medicine SB RAS, as well as in the Molecular Biology Sector of the Siberian Federal Center of Agro-BioTechnologies RAS. The *S. suis* nucleotide sequences were obtained in the GenBank database after preliminary analysis of the literature data on the known protective antigens of *S. suis* of various serotypes. The nucleotide sequences were analyzed using Unipro UGENE v. 43.0. The Immune Epitope Database (IEDB) was used to search for T (CTL and Th) and B dependent epitopes of the Lmb gene (see footnote 1).

Primer design was performed to clone and model the cloning process of Lmb gene regions containing T (CTL and Th) and B dependent epitopes by ligation at the BamH I, HindIII restriction sites into the shuttle vector pBE-S polylinker. *S. suis* DNA was isolated by silicosorption method from field isolates provided by Alexis LLC. PCR was performed using generally accepted methods on a Tercik amplifier ("DNA Technology" LLC, Russia).

To clone a fragment of the Lmb gene, the following primers were developed:

– Fwd Lmb: 5'-GAGGGATCCGCGATGTTAAAGAAAGTGATAAG-3';

– Rev Lmb: 5'-GACAAGCTTGGGTAAAAGTTCACCAATCGC-3'.

[1]URL: http://www.iedb.org/.

RESULTS AND DISCUSSION

We used a computer-based vaccine design to predict the candidate epitopes (i.e., antigenic determinants) obtained using the algorithms provided on the website (see footnote 1). After screening the laminin-binding protein (Lmb) was selected as the vaccine antigen (see Fig. 2).

According to bioinformatic analysis, one CTL epitope was found at the positions 12-20 of Lmb amino acid residues; four B-cell epitopes were found at the positions 65-75, 131-141, 179-189 and 279-287 of Lmb amino acid residues, respectively. Epitopes 1 Th were found at the positions 12-20 of Lmb amino acid residues (see Table 1).

The study applied techniques to analyze a possible other epitope of the protein sequence and then used the pBE-S vector to transform the com-position containing the protective Lmb epitope in *B. subtilis*. Enteroinvasive *B. subtilis* strain 53 IHBFM (isolated and studied earlier) was used as a vector strain.

The pBE-S vector is capable of expressing the recombinant protein in *B. subtilis* cells and has an additional source of replication (origin) in *Escherichia coli* cells. The primers we developed have additional Bam H1 and Hind III restriction sites, which makes it possible to clone the epitopes found in the polylinker of this vector, including their amplification from primary *S. suis* isolates and pathological material (see Fig. 3).

Bioinformatic analysis of S. suis Lmp gene revealed antigenic epitopes which are promising for recombinant vaccine creation: one CTL epitope was found at the positions 12-20 of Lmb amino acid residues, four B-cell epitopes - at positions 65-75, 131-141, 179- 189 and 279-287 amino acid residues Lmb, respectively. Th 1 epitopes were found at the positions 12-20 of

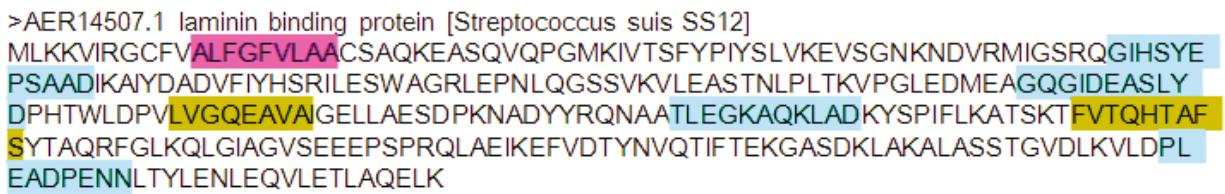

Рис. 2. Локализация эпитопов ЦТЛ и В-клеток Lmb по данным биоинформатического анализа.

Примечание. Эпитоп ЦТЛ (цитотоксические Т-клетки, цитотоксические Т-лимфоциты) отмечен фиолетовым, сегменты В-клеточного эпитопа – синим, эпитоп Th – зеленым.

Fig. 2. Localization of CTL epitopes and B-cells Lmb according to bioinformatics analysis

Note. The CTL epitope (cytotoxic T-cells, cytotoxic T-lymphocytes) is marked in purple, the B-cell epitope segments are marked in blue, the Th-epitope is marked in green.

Табл. 1. Аминокислотные и нуклеотидные последовательности CTL, B и Th эпитопов Lmb белка *S. suis* (SS12)

Table 1. Amino acid and nucleotide sequences of CTL, B, and Th epitopes of *Lmb* of *S. suis (SS12)* protein

№	Nucleotide sequence	Amino acid sequence
	Predicted epitope B	
1	GGCATACACTCTTATGAACCATCGGCTGCGGAC	GIHSYEPSAAD
2	GGTCAAGGGATTGATGAAGCTAGTTTATATGAC	GQGIDEASLYD
3	ACTTTAGAGGGAAAGGCGCAAAAGTTGGCAGAC	TLEGKAQKLAD
4	CCTCTTGAAGCAGATCCAGAAAATAAT	PLEADPENN
	Predicted epitope CTL	
1	GCCTTATTCGGTTTTGTTTTAGCAGCT	ALFGFVLAA
	Predicted epitope Th	
1	TTGGTTGGTCAGGAAGCTGTTGCGATT	LVGQEAVAI
2	TTTGTCACTCAACACACAGCCTTCTCT	FVTQHTAFS

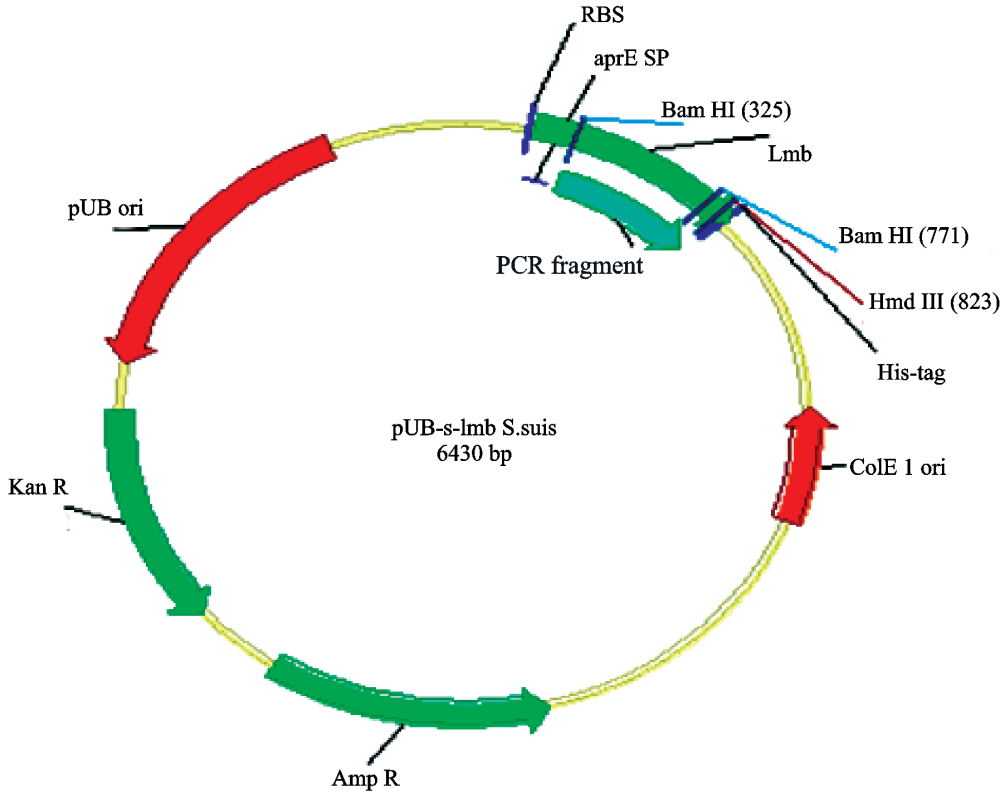

Рис. 3. Карта плазмидного вектора pBE-S со вставкой *S. suis* Lmb:

pUB ori – ориджин для рода *Bacillus* (сайт старта начала репликации плазмиды); ColE 1 ori – ориджин для *E. coli*; Kan R – ген устойчивости к канамицину (экспрессируется в бактериях рода *Bacillus*); Amp R – ген устойчивости к ампициллину (экспрессируется в *Escherichia coli*); His-tag – гистидиновый хвост на никелевых колонках для выделения рекомбинантного белка; Hind lll (823), Bam Hl (771), Bam Hl (325) – сайты рестрикции; Lmb – фрагмент антигена *S. suis;* aprE Sp; RBS – промотерная область для экспрессии белка у микроорганизмов рода *Bacillus*

Fig. 3. Map of plasmid vector pBE-S with *S. suis* Lmb insert:

pUB ori - origin for *Bacillus* genus (plasmid replication start site); Col E1 ori - origin for *E. coli*; Kan R, kanamycin resistance gene (expressed in *Bacillus* bacteria); AmpR, ampicillin resistance gene (expressed in *Escherichia coli*); His-tag, histidine tail on nickel columns for recombinant protein isolation; Hind lll (823), Bam Hl (771), Bam Hl (325), restriction sites; Lmb, fragment of *S. suis;* aprE Sp; RBS, promoter region for protein expression in microorganisms of the genus *Bacillus*

Lmb amino acid residues. The proposed delivery system for recombinant protective antigens of *S. suis* includes the plasmid vector pBE-S as part of the enteroinvasive strain *B. subtilis* B53 IHBFM.

CONCLUSIONS

1. The possibility to clone the epitopes of recombinant *S. suis* Lmb protein into the pBE-S vector polylinker was revealed.
2. In the long term, it seems possible to create a new inexpensive and easy-to-use vaccine against *S. suis* that does not require injection.

Modern possibilities of molecular diagnostics and genetic engineering create perspectives for direct cloning of protective epitopes of Lmb gene of local *S. suis* strain into the proposed system of antigen delivery to pig immune system.

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ФИТОБИОТИКИ В РАЦИОНАХ КУР-НЕСУШЕК РАЗЛИЧНЫХ КРОССОВ, ВЛИЯНИЕ ГЕНОТИПА НА ОПЛАТУ КОРМА

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Представлены результаты ввода фитогенных кормовых добавок из местных растительных ресурсов в рационы кур яичного направления продуктивности различных генотипов. Определена степень усвоения (переваримости, использования) питательных веществ корма и конверсия потребленных кормов (затраты корма на 10 шт. яиц и на 1 кг яичной массы). Проанализированы затраты обменной энергии и протеина корма на единицу произведенной продукции. Состав изучаемых фитогенных кормовых добавок: 1,5% (от основного рациона) муки бурых морских водорослей (ламинарии) и 1,5% – муки из местных дикоросов. Установлено, что их применение в рационах кур-несушек способствует интенсификации обменных процессов, происходящих в организме всех генотипов птицы. Усвоение гигровлаги потребленного корма за анализируемые периоды возросло на 2,9–3,6%, переваримость протеина – на 2,9–4,3%, жира – на 3,1–4,0%, БЭВ – на 3,9–4,6%, использование азота – на 4,9–5,9% к контрольным показателям каждого генотипа. Интенсификация обменных процессов способствовала повышению оплаты корма продукцией. Снижение затрат корма на производство 10 шт. яиц составило 5,5–7,3%, на 1 кг яичной массы – 8,4–13,9% к контролю. Уменьшились затраты обменной энергии и протеина корма на производство единицы продукции. В результате анализа полученных данных выявлено, что куры-несушки всех генотипов положительно реагировали на включение в основной рацион биологически активной кормовой добавки. Наиболее «отзывчивым» генотипом (кроссом) на поступление с рационом нутриентов, входящих в состав фитогенной кормовой добавки, является кросс «Декалб Уайт». Птица данного кросса показала наиболее высокие результаты интенсивности обменных процессов организма и оплаты корма продукцией.

Ключевые слова: куры-несушки, кроссы птицы, генотип, кормовые добавки, растительные ресурсы, фитогенные кормовые добавки, обмен веществ, конверсия корма

PHYTOBIOTICS IN THE DIETS OF LAYING HENS OF VARIOUS CROSSES, INFLUENCE OF THE GENOTYPE ON THE PAYMENT OF FORAGE

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The paper presents the results of research on the introduction of phytogenic feed additives from local plant resources in the diets of egg-laying hens of different genotypes. The degree of assimilation (digestibility, use) of the feed nutrients and the conversion of the consumed feed (feed costs per 10 eggs and per 1 kg of egg weight) were determined. The costs of metabolizable energy and protein of feed per unit of production were analyzed. The composition of phytogenic feed additives under study: 1.5% (of the basic diet) flour of brown seaweeds (kelp) and 1.5% - flour of local wild herbs. It was found that their use in the diets of laying hens helps to intensify metabolic processes occurring in the body of all genotypes of poultry. The digestibility of the consumed forage hygroscopic moisture during the periods analyzed increased by 2.9-3.6%, protein digestibility by 2.9-4.3%, fat digestibility by 3.1-4.0%, nitrogen-free extractive substances by 3.9-4.6%, nitrogen use by 4.9-5.9% to the control indices of each genotype. Intensification of metabolic processes contributed to an increase in the payment for feed by products. Reduction of feed expenses for production of 10 eggs amounted to 5,5-7,3%, for 1 kg of egg weight - 8,4-13,9% to the control. The cost of metabolizable energy and protein of feed to produce a unit of product decreased. The

analysis of the data revealed that laying hens of all genotypes responded positively to the inclusion of biologically active feed additive in their basic diet. The most "responsive" genotype (cross) to the intake of nutrients included in the phytogenic feed additive with the diet is the cross "Dekalb White". The birds of this cross showed higher results of intensity of metabolic processes of the body and payment for feed by products.

Keywords: laying hens, poultry crosses, genotype, feed additives, plant resources, phytogenic feed additives, metabolism, feed conversion

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INTRODUCTION

The Decree of the President of the Russian Federation dated 21.01.2020[1] set for agricultural producers the tasks of ensuring food security of the population and reducing the dependence on imports of the state. To meet domestic demand for edible eggs Russian poultry farmers are required to produce at least 45.3 billion eggs per year by 2025 (in 2021 produced 44.9 billion eggs). The implementation of these plans will necessitate an increase in the production of concentrated feed and improving its quality in accordance with the needs of poultry.

The Resolution of the Government of the Russian Federation of 03.09.2021 which includes the subprogram "Development of feed and feed additives for animals"[2] sets the goal of creating a sustainable feed base including the organization of production of feed additives with directed and complex action based on biologically active components which allow increasing the balance of nutrition of agricultural and poultry products. In Russia poultry egg production meets the domestic needs of the population at the expense of its own production. From 2014 to 2017 the increase in gross egg production was more than 3 billion eggs per year. Later on, including 2021, there was almost no increase in egg production. In 2020, the average price of poultry meat was down 5.7% from 2019, but the price of eggs was up 3.8%. Increased egg production and egg quality could help restore the degree of profitability and offset the increase in production costs, which were 20-25% in 2020[3].

In poultry farming there is the highest return on resources spent per unit of production, including feed (2-3 times lower than in pig and cattle breeding), due to which the industry develops confidently and efficiently. Poultry productivity is the main economic and useful trait that has a fairly high degree of variability. In Russia, increasing egg production is carried out by intensive factors: increasing the productivity and safety of poultry, improving the quality and consumer properties of products, as well as increasing the conversion of feed [1].

Of all farm animals, laying hens are the most intensive producers of biologically valuable di-

[1]Decree of the President of the Russian Federation No. 20 of January 21, 2020 "On Approval of the Food Security Doctrine of the Russian Federation".

[2]On Amendments to the Federal Scientific and Technical Program for the Development of Agriculture for 2017-2025. Decree of the Government of the Russian Federation of 03.09.2021, No. 1489, Moscow.

[3]Bobyleva G. A. Save and multiply: an overview of the Russian poultry and egg production sector. URL: https:// www.agbz.ru/articles/obzor-rossiyskogo-sektora-proizvodstva-myasa-ptitsy-i-yaits/ (Accessed on: 15.04.2022).

etary protein. At an annual egg production rate of 250 eggs a hen produces about 875 g of protein per 1 kg of live weight. At the same time, a cow with an annual milk yield of 5000 kg of milk produces only 275 g of protein per 1 kg of live weight. Such high protein production in chickens is possible due to the efficient conversion of protein from the feed they consume into egg protein (20-25%).

In this regard, the provision of laying hens with nutrients and biologically active substances to meet the vital needs of birds and implement the genetically inherent productivity potential must be different than in other farm animals. The increased demand for quality and nutritive value of feed is associated with the physiological properties and features of metabolism in different periods of the life cycle of birds. These include the development of embryos in the confined space of the egg; high growth rate; intensive, decreasing with age, metabolism in young birds; the presence of the pre-lay period, during which there is a restructuring of the body, including biochemical changes affecting all aspects of metabolism; the role of the skeleton in mineral metabolism (performing not only homeostasis functions but also participating in egg formation); the presence of the mechanisms providing nutrient extraction from blood in the ovary and the oviduct, their binding and deposit in the egg elements. Peculiarities of bird digestion are rapid movement of feed through the gastrointestinal tract, insufficient synthesis and limited absorption of endogenous vitamins in the digestive tract. Lack or deficiency of essential nutrients in the diet of laying hens causes metabolic disorders in the body, growth retardation, reduced productivity and product quality[4-6].

Due to the fact that the Russian feed industry is not ready for the production of high-quality complete feeds for the poultry industry, specialists and scientists involved in feeding poultry pay much attention to the use of phytobiotics (plant components) in feeds, and this trend has currently increased.

The problem in feeding poultry is the uncontrolled use of antibiotics. Their excessive use in poultry diets reduces resistance to human pathogens, in the body of which antibiotics are transferred with food. Bacterial resistance and the property of antibiotics to remain in animal products have led to restrictions on the use of antibiotics as growth promoters and feed additives in most developed countries. The use of synthetic antibiotics (AGP) as prophylactic doses in animal feed is banned in the European Union[7] [2, 3].

As an alternative to antibiotics, experts in the field of animal nutrition and nutritionists recommend phytobiotics. Studies have been conducted using phytobiotics in feeding poultry where antimicrobial, antioxidant, anti-inflammatory and stimulating effect of phytobiotics has been confirmed. The antioxidant function of phytobiotics can positively affect the stability of the feed, contribute to the extension of its shelf life. Researchers have proved that the inclusion of phytobiotics in poultry diets has a positive effect on the productivity of poultry and the quality of products (eggs). Studies on stimulation of metabolic processes in laying hens and increasing feed conversion by enriching poultry diets with phytogenic feed additives of different composition have shown positive results[8, 9] [4-11].

The main requirement for the production of edible eggs, along with productivity and prod-

[4]Fisinin V.I., Egorov IA, Droganov I.F. Feeding farm poultry: textbook. Moscow: GEOTAR-Media, 2011. 344 p.

[5]Matyushkin V., Krisanov A., Egorov I. et al. Production of livestock products: textbook. Saransk: Mordovian University Publishers. 2008. pp.157-233.

[6]Ivanova O.V. Biologically active additives in poultry farming. Krasnoyarsk: Krasnoyarsk State Agrarian University, 2010. 142 p.

[7]EU Regulation, No. 1831/2003.

[8]Rabazanov N. The use of nettle meal in feeding broiler chickens: Ph. D. in Biology. 06.02.02, Sergiev Posad, 2003. 22 p.

[9]Mammaeva T.V. Ecological and biological substantiation of the use of kelp as a feed additive in diets of chickens: Ph. D. in Biology: 03.00.16, Kamchatka NIISKh, Habarovsk, 2002. 23 p.

uct quality is a high food conversion ratio. Currently, the poultry industry aims to use highly productive genotypes (crosses) of poultry, selected and differentiated according to these requirements. Domestic breeders are studying the possibility of transforming the genetic potential into new breeds, breed groups and poultry crosses. However, due to the lack of a breeding base working with genotypes of the Russian selection, many poultry farms use industrial crosses of laying hens of foreign breeding companies (Isa Brown, Hysex Brown, Hysex White, Dekalb White)[10, 11].

In this regard, specialists engaged in poultry production need information about the effectiveness of a particular poultry genotype for the production of quality products with a high degree of food conversion.

We have conducted studies on the enrichment of laying hens' diets of various foreign crosses (genotypes) with phytogenic biologically active feed additives [12, 13].

The purpose of the study is to determine the genotype of laying hens with the highest degree of digestibility of feed with biologically active substances coming in phytogenic feed additives; to evaluate the food conversion ratio.

The research objectives are to analyze the data obtained from the studies on the use of phytogenic feed additives in the diets of different genotypes of laying hens, to identify the most "responsive" cross of poultry, which has a high degree of food conversion.

MATERIAL AND METHODS

The research was conducted in LLC Poultry farm "Dukchinskaya" (Magadan), on different genotypes of laying hens: "Isa Brown", "Hysex White", "Hysex Brown", "Dekalb White". The use of phytogenic feed additives containing brown seaweed meal (*Laminaria*) and wild-growing herbs meal (composition: common tansy (*Tanacetum vulgare*), common yarrow (*Achilléa millefólium*), narrow-leaved willow-herb (*Chamaenerion angustifolium*), great nettle (*Urtica dioica*) having identical biological activity was studied in feeds.

In the present study, a specific age period of laying hens of the studied crosses - 40-55 weeks - was chosen for analysis. The keeping and feeding conditions of all birds corresponded to the norms recommended by ARRTPI (All-Russian Research and Technological Poultry Institute) and did not differ from each other during the analyzed periods. Experiments on the introduction of feed additives into the diets of different genotypes of laying hens were performed according to a similar scheme (see Table 1).

The composition and nutritive value of the BDs of all laying hens genotypes were in the acceptable range for comparison (see Table 2).

The studies were conducted according to the methodological recommendations[12]. The data were processed using the methods of N.A. Plokhinsky[13]. The results of the studies are presented as a percentage of the control group of each cross (genotype) for the analyzed period.

RESULTS AND DISCUSSION

The use of the studied feed additives in the basic diets of laying hens allowed to enrich the feed with nutrients included in phytobiotics, which helped to stimulate metabolic processes in the poultry organism (see Table 3).

Intensification of metabolic processes of the poultry body increased the productivity of all

[10]Golovkina O.O. Comparative assessment of egg crosses "Highsex Brown" and "Highsex White". Breeding, selection and genetics of farm animals. 2020. URL: http:// azt.vscc.ac.ru/article/28454/ full (accessed on: 15.03.2020).

[11]Description of the cross Dekalb: all about keeping and breeding. Farmexpert, 2020. URL: https://ferma. Expert/pticy/ kury/ porody-kury/dekalb/ (accessed on: 15.03.2020).

[12]Methodology of scientific and industrial research on the feeding of farm poultry: recommendations. Edited by V.I. Fisinin, Sh.A. Imangulov. Sergiev Posad, 2004. 33 p.

[13]Plokhinsky N.A. Guide to biometrics for zootechnicians. Moscow: Kolos, 1969. pp.76-87.

Табл. 1. Схема опытов
Table 1. Scheme of the experiments

Group	Number of birds, heads	Feeding Features
Control	50	BD (basic diet)
Experimental	50	BD + 1.5% flour from kelp + 1.5% flour from local wild herbs

Табл. 2. Состав и питательная ценность основного рациона
Table 2. Composition and nutritional value of the basic diet

Component	Content, %
Wheat	56,88 ± 0,72
Barley	3,94 ± 0,17
Oats	3,84 ± 0,85
Soybean meal	10,25 ± 0,55
Sunflower meal	12,25 ± 0,65
Full fat soybeans	2,66 ± 0,44
Limestone flour + shell flour	10,18 ± 0,09
100 g of mixed fodder contains:	
Metabolic energy, kcal/100 g	246,88 ± 0,89
Crude protein	16,35 ± 0,19
Crude fat	2,21 ± 0,03
Linoleic acid	1,14 ± 0,01

Табл. 3. Усвоение (переваримость, использование) питательных веществ корма, % к контролю
Table 3. Assimilation (digestibility, use) of feed nutrients, % of control

Indicator	"Iza Brown"	"High-sex White"	"High-sex Brown"	"Dekalb White"
Hygro-moisture consumption				
Control	65,3	65,1	64,8	64,9
Experiment	68,2	68,2	67,6	68,5
To the control group	+2,9	+3,1	+2,8	+3,6
Nitrogen used				
Control	41,9	41,6	41,8	41,6
Experiment	47,1	46,5	46,9	47,5
To the control group	+5,2	+4,9	+5,1	+5,9
Crude protein digestibility				
Control	77,2	78,6	79,3	79,9
Experiment	80,6	81,5	82,5	84,2
To the control group	+3,4	+2,9	+3,2	+4,3
Digestibility of raw fat				
Control	75,6	76,2	76,9	81,5
Experiment	78,7	79,9	80,1	85,5
To the control group	+3,1	+3,7	+3,2	+4,0
Digestibility of Nitrogen-free Extractive Substances (NES)				
Control	75,2	76,1	77,3	79,8
Experiment	79,1	80,2	81,7	84,4
To the control group	+3,9	+4,1	+4,4	+4,6

Note. Here and in Tables 4, 5: the control for a bird of each cross (genotype) was a bird of the same cross (genotype) receiving the basic diet.

the studied poultry crosses (genotypes), in connection with this increased food conversion ratio (see Table 4).

As a result of analytical studies, it was found that the introduction of phytogenic feed additives from local plant resources into the diets of laying hens helped to improve the quality and consumer properties of the products (eggs) (see Table 5).

CONCLUSION

It was found that as a result of the use of phytogenic feed additives in the diets of different genotypes of laying hens, the most intense metabolic processes occurred in the body of laying hens of the cross "Dekalb White". There was an increase in productivity, quality of products, as well as the highest degree of food conversion by the laying hens of this genotype. The body of laying hens spent the least amount of

Табл. 4. Основные зоотехнические показатели
Table 4. Main zootechnical indicators

Indicator	"Iza Brown"	"Highsex White"	"Highsex Brown"	"Decalb White"
Performance indicators of laying hens				
Gross egg yield				
Control, pcs.	3571	3685	3654	3701
Experiment, pcs.	3789	3939	3902	3979
To the control group, %	106,1	106,9	106,8	107,5
Oviposition intensity				
Control, %	82,6	82,3	82,9	82,6
Experiment, %	88,5	89,1	89,3	89,7
To the control group (+, –), %	+5,9	+6,8	+6,4	+7,1
Egg mix yield				
Control, kg	166,9	169,3	172,4	173,3
Experiment, kg	185,8	186,9	194,6	202,9
To the control group, %	111,3	110,4	112,9	117,1
Feed conversion				
Feed consumption per 10 eggs				
Control, kg	1,45	1,44	1,46	1,47
Experiment, kg	1,37	1,36	1,37	1,36
To the control group, %	94,5	94,1	93,8	92,7
Feed consumption per 1 kg of egg weight				
Control, kg	2,99	3,10	2,98	2,94
Experiment, kg	2,64	2,77	2,73	2,53
To the control group, %	88,4	89,3	91,6	86,1
ME feed consumption per 10 eggs				
Control, MJ	15,3	15,29	14,92	14,99
Experiment, MJ	14,47	14,40	13,97	13,90
To the control group, %	94,6	94,2	93,6	92,7
ME feed consumption per 1 kg of egg weight				
Control, MJ	24,91	23,99	24,50	24,52
Experiment, MJ	22,00	21,45	22,42	21,06
To the control group, %	88,3	89,4	91,5	85,9
Feed protein consumption per 10 eggs				
Control, g	232	230	234	235
Experiment, g	229	227	231	229
To the control group, %	98,8	98,5	98,9	97,5
Feed protein consumption per 1 kg of egg weight				
Control, g	381	385	382	380
Experiment, g	363	364	353	349
To the control group, %	95,3	94,6	92,5	91,8

Табл. 5. Показатели качества и потребительских свойств яиц
Table 5. Indicators of quality and consumer properties of eggs

Indicator	"Iza Brown"	"Highsex White"	"Highsex Brown"	"Decalb White"
Morphometric indicators of eggs				
Egg weight				
Control, g	57,27**	59,70***	59,10**	59,30***
Experiment, g	58,93***	61,67**	62,94***	63,57***
To the control group, %	102,90	103,30	106,50	107,20
Yolk weight				
Control, g	15,21***	15,37**	15,28**	15,41***
Experiment, g	15,68**	15,82***	15,95***	16,29***
To the control group, %	103,10	102,90	104,40	105,70
Egg white weight				
Control, g	34,50**	34,70***	35,00**	34,90
Experiment, g	36,02***	36,19***	36,72***	36,92**
To the control group, %	104,40	104,30	104,90	105,80
Certified eggs				
Control, %	92,80	92,10	93,80	93,90
Experiment, %	95,90	95,50	97,10	97,70
To the control group (+,–), %	+3,10	+3,40	+3,30	+3,80
Breakage, check				
Control, pcs.	68	68	73	75
Experiment, pcs.	65	66	69	70
Control, %	1,90	1,85	2,00	2,03
Experiment, %	1,72	1,68	1,77	1,76
To the control group (+,–), %	–0,18	–0,17	–0,23	–0,27
Qualitative indicators (content in 100 g of egg weight)				
Dry matter				
Control, g	23,64***	23,71**	23,70**	23,82***
Experiment, g	24,54**	24,28**	24,58***	24,92***
To the control group, %	103,80	102,40	103,70	104,60
Fat				
Control, g	8,42**	8,71***	8,57**	8,61**
Experiment, g	8,65***	9,02**	8,96***	9,05***
To the control group, %	102,70	103,60	104,50	105,10
Protein				
Control, g	10,99***	11,20**	11,21**	11,18**
Experiment, g	11,29**	11,47***	11,67**	11,84***
To the control group, %	102,70	102,40	104,10	105,90
Carotenoids				
Control, μg/g	13,42**	13,18**	13,55***	14,75***
Experiment, μg/g	14,87***	14,46***	15,34**	17,27***
To the control group, %	110,80	109,70	113,20	117,10

** $p \leq 0,01$.
*** $p \leq 0,001$.

feed, metabolic energy and protein for the production of 10 eggs and 1 kg of egg weight.

The genotype of the cross "Dekalb White" was the most "responsive" to dietary enrichment with nutrients contained in the studied phytogenic feed additive from local plant resources (1.5% of kelp meal + 1.5% of meal from local wild fruits in addition to the basic diet).

The results obtained correspond to the goal set for the developers of the cross - to get a bird with high productive qualities and the degree of food conversion. Currently, laying hens of the cross "Dekalb White" are the most promising of the foreign crosses for the production of high quality products with the appropriate payment for feed production.

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ВЛИЯНИЕ АГРОКЛИМАТИЧЕСКИХ УСЛОВИЙ НА ЗАБОЛЕВАЕМОСТЬ БРУЦЕЛЛЕЗОМ СЕВЕРНЫХ ОЛЕНЕЙ В АРКТИЧЕСКИХ РАЙОНАХ ЯКУТИИ

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Изучено распространение бруцеллеза среди северных оленей в зависимости от агроклиматических условий их содержания. Эксперимент проведен в Момском, Нижнеколымском и Эвено-Бытантайском районах Якутии в 2012–2019 гг. Показано, что за исследуемый период по всем районам годовая температура воздуха была выше нормы на 1,1…1,9 °С за счет более значительного ее повышения в холодный период (на 1,5…2,8 °С) по сравнению с теплым (на 0,5…0,6 °С). Наибольшее повышение температуры отмечено в апреле (на 2,8…4,4 °С) и ноябре (на 2,2…4,1 °С), в весенне-летний период – в мае (на 0,9…1,7 °С), в июле она была ниже нормы на 0,2…1,0 °С. Годовое количество осадков на территории Эвено-Бытантайского района изменялось незначительно, на территории Момского и Нижнеколымского районов увеличилось на 40 и 70 мм соответственно. Заболеваемость бруцеллезом северных оленей в зависимости от места (района) их содержания и погодных условий составляла от 0 до 3,86% (коэффициент вариации 131%), меньше заболевших животных было на территории Нижнеколымского района (0,20%), больше – Эвено-Бытантайского (1,15%). Между заболеваемостью северных оленей бруцеллезом и температурой за холодные месяцы и годовой температурой установлена отрицательная связь (r = –0,19…–0,42), с температурой весенне-летних месяцев – средняя положительная (r = 0,30…0,53) с достоверным уровнем в июле. В целом, на заболеваемость температура оказывала большее влияние (r^2 = 0,115), чем осадки (r^2 = 0,092), однако между суммой осадков за год и заболеваемостью животных выявлена существенная обратная связь (r = –0,48; r^2 = 0,23). За все месяцы между этими показателями также наблюдалась отрицательная корреляция (r = –0,13…–0,41), за исключением апреля и августа (r = 0,10 и 0,11 соответственно). В зимние месяцы данная зависимость была более значимой (r = –0,30…–0,40), чем в летние (r = –0,13…–0,27).

Ключевые слова: арктические районы Якутии, агроклиматические условия, потепление климата, бруцеллез северных оленей, заболеваемость животных, корреляция

EFFECT OF AGRO-CLIMATIC CONDITIONS ON THE INCIDENCE OF BRUCELLOSIS OF REINDEER IN THE ARCTIC REGIONS OF YAKUTIA

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The spread of brucellosis in reindeer depending on agroclimatic conditions of their housing was studied. The experiment was conducted in Momsky, Nizhnekolymsky and Eveno-Bytantaysky districts of Yakutia in 2012–2019. It was shown that the annual air temperature for the studied period in all districts was higher than the norm by 1.1 ... 1.9 °C due to its more significant increase in the cold period (by 1.5 ... 2.8 °C) compared to the warm period (by 0.5 ... 0.6 °C). The highest temperature increase was registered in April (by 2.8 ... 4.4 °C) and November (by 2.2 ... 4.1 °C), in spring-summer period - in May (by 0.9 ... 1.7 °C), in July it was 0.2 ... 1.0 °C below the norm. The annual precipitation on the territory of the Eveno-Bytantaysky district changed slightly, and on the

territory of the Momsky and Nizhnekolymsky districts increased by 40 and 70 mm, respectively. The incidence of brucellosis of reindeer, depending on the place (area) where reindeer are kept and weather conditions, ranged from 0 to 3.86% (coefficient of variation of 131%), fewer sick animals were in the Nizhnekolymsky district (0.20%), more – in Eveno-Bytantaysky (1.15%). There was a negative correlation (r = –0,19...–0,42) between the incidence of brucellosis in reindeer and the temperature during the cold months and the annual temperature, with the temperature of the spring-summer months - medium positive (r = 0,30...0,53) with a reliable level in July. In general, temperature had a greater effect on morbidity (r^2 = 0.115) than precipitation (r^2 = 0.092), but a significant inverse relationship (r = –0.48; r^2 = 0.23) was found between annual precipitation sum and animal morbidity. In all months there was also a negative correlation between these indicators (r = –0.13...–0.41), except for April and August (r = 0.10 and 0.11, respectively). In winter months, this dependence was more significant (r = –0.30...–0.40) than in summer (r = –0.13...–0.27).

Keywords: Arctic regions of Yakutia, agro-climatic conditions, climate warming, reindeer brucellosis, animal morbidity, correlation

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INTRODUCTION

Important conditions for the sustainable development of the agro-industrial complex of the Republic of Sakha (Yakutia) are control of the livestock production and study of the factors affecting animal morbidity. Periodic veterinary analysis of multi-year data makes it possible to assess the epizootic situation more quickly and effectively plan and carry out measures to prevent and eliminate dangerous diseases.

Brucellosis is a chronic disease of animals caused by the bacteria, united under the common name Brucella. Arthritis, bursitis, tendovaginitis, orchitis, mastitis, abortions in breeding stock are observed in sick reindeer, which negatively affects reproduction, complicates breeding work and leads to a decrease in animal productivity. The main sources of brucellosis are sick domestic and wild reindeer, and the factors of transmission are infected pastures and calving places [1]. Particularly dangerous are individuals that release large amounts of brucellosis into the external environment during abortion and even during normal childbirth [2]. Animal brucellosis is registered everywhere in the world, but is predominantly found in the Mediterranean basin, the Persian Gulf, the Indian subcontinent, Mexico, Central and South America, Southeast Asia, Africa, as well as in all areas of the Asian North, including Yakutia [3-5]. The presence of brucellosis infection in the Taimyr, Yakut and Chukchi populations of wild reindeer has been revealed[1]. In domestic reindeer, it was diagnosed by the serological method in 1942, by the bacteriological method in 1955, and in wild reindeer - in 1960. [6].

Control of brucellosis by culling positive animals is effective only when animal husbandry is highly cultured [7]. In the Russian Federation, the brucellosis control system, including its diagnosis, prevention, implementation of restrictive veterinary and sanitary, and organizational and economic measures, developed in the second half of the 20th century [8].

One of the factors influencing the epizootic situation for this disease is natural and climatic conditions. The Earth's climate has changed over the century, both globally and regionally,

[1]Vinokurov N.V. Features of the diagnostic value of the indirect hemagglutination reaction in brucellosis of reindeer: Ph.D. in veterinary sciences. Yakutsk, 2010. 18 p.

and the process of change has accelerated significantly in recent decades [9]. Since the mid-1970s, the average surface air temperature in Russia has been rising at an average rate of 0.43 °C per decade, which significantly exceeds the rate of global warming. Particularly significant climate changes are observed in the Arctic and subarctic permafrost zone [10]. The increase in annual temperatures is mainly due to its increase in winter. At the same time, lengthening of the warm period of the year is registered: spring comes 10-15 days earlier and autumn ends 15-20 days later compared to the middle of the last century [11].

Studying the influence of environmental conditions on the epizootic situation of reindeer brucellosis in different natural and climatic conditions is of scientific and practical interest. It is especially relevant for the Arctic zone of Yakutia, where this issue is poorly studied under the conditions of the changing climate.

The purpose of the study is to identify changes in agroclimatic conditions and assess their impact on the incidence of brucellosis in reindeer in different Arctic regions of Yakutia.

MATERIAL AND METHODS

The Arctic zone of Yakutia is characterized by a sharply continental climate, no shortage of heat, a long period with no sun in summer and no sunlight in winter. The duration of the period with snow cover is about 220 days, the absolute minimum temperature reaches -67 ° C, the absolute maximum reaches 35 ° C. The region occupies more than 50% of the total area of Yakutia, it includes 13 uluses (districts), in which traditional trades of peoples of the North, including reindeer breeding prevail. About 74% of all herds of reindeer of the republic are situated there, the considerable part of them (over 51 thousand animals, or more than 28% of the total herd of the Republic) is kept in three districts different by natural and climatic conditions: Momsky, Nizhnekolymsky and Evено-Byantaysky. In these districts there is often an unfavorable epizootic situation with brucellosis of reindeer[2].

The initial data on animal disease incidence for 2012-2019 were obtained from statistical reports of the Department of Veterinary Affairs of the Republic of Sakha (Yakutia) and its subordinate organizations - District Veterinary Offices with veterinary testing laboratories. The reports on detection of positive reindeer herds for brucellosis by the Yakutsk Republican Veterinary Testing Laboratory were used.

Reindeer positive to the simultaneous application of 3-4 serological methods of research (complex serodiagnosis) were considered as brucellosis patients. In our studies, the following serological diagnostic methods were used: Rose Bengal test reaction (RBT), in vitro hemagglutination reaction (HR), complement-fixation test (CFT), immunodiffusion reaction (IDR) with 0-polysaccharide antigen[3] [12, 13].

Analysis of agroclimatic conditions for 2012-2019 was carried out on the basis of archival data of meteorological stations Honu (Momsky district), Chersky (Nizhnekolymsky district) and Batagai-Alyta (Eveno-Bytantaisky district). Average monthly and annual values of air temperature and the amount of precipitation were the studied indicators. Statistical processing of the obtained data was performed by the method of variation and correlation according to B.A. Dospekhov[4] using the Snedecor[5] and Microsoft Office Excel 2007 software packages.

RESULTS AND DISCUSSION

According to the Veterinary Department of the Republic of Sakha (Yakutia), in 2012-2019,

[2]System of agriculture in the Republic of Sakha (Yakutia) for the period of 2021-2025: methodological handbook. Ministry of Agriculture of the Republic of Sakha (Yakutia). FSBIS FRC Yakut scientific center of the Siberian Branch of the Russian Academy of Sciences. Yakut scientific-research institute of agriculture named after M.G. Safronov. Belgorod: Publishing house of Sangalov K.Y. 2021. 592 p.

[3]Vashkevich R.B. Plate agglutination reaction in brucellosis of reindeer. Epizootology and immunoprophylaxis of diseases: collection of scientific papers Novosibirsk, 1983. pp. 16-20.

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

[5]Sorokin O.D. Applied statistics on the computer. Novosibirsk, 2004. 162 p.

the region annually registered from 35 to 47 points unfavorable for reindeer brucellosis. During this period, 14 such unfavorable locations were registered in the Momsky District, 8 in the Nizhnekolymsky District, and 8 in the Eveno-Bytantaisky District.

Analysis of statistical data on the incidence of reindeer in the studied areas of the Arctic zone of Yakutia for 2012-2019 showed that the number of animals positive for brucellosis infection varied from 0.08 to 3.68% of the total number of examined animals. The variability of this indicator was very significant, the coefficient of variation was 131%. No positive reindeer were detected in the Momsky district in 2016 and 2018, and in the Nizhnekolymsky district in 2018 and 2019, (see Table 1).

During the analyzed years, the lowest number of brucellosis diseased animals was registered in the territory of the Nizhnekolymsky District (0.20%), the highest - in the Eveno-Bytantaysky District (1.15%). On average by districts higher incidence of brucellosis of reindeer was registered in 2012 and 2015 (respectively 1.03 and 1.66%), and lower - in 2016 and 2017 (0.38 and 0.29%). The highest number of diseased animals in the territory of the Momsky (0.88%) and Nizhnekolymsky (0.43%) districts was detected in 2012, Eveno-Bytantaisky (3.68%) - in 2015.

Табл. 1. Динамика эпизоотии по бруцеллезу северных оленей в арктических районах Якутии за 2012–2019 гг.

Table 1. Epizootic dynamics of reindeer brucellosis in the Arctic regions of Yakutia for 2012–2019

Indicator	Momsky district	Nizhnekolymsky district	Eveno-Bytantaisky district	Total
2012				
The total number of researched, heads	10060	16127	16335	42522
Of those responding positively: heads	89	69	281	439
%	0,88	0,43	1,72	1,03
2013				
The total number of researched, heads	15114	18450	15600	49164
Of those responding positively: heads	115	40	69	224
%	0,76	0,22	0,44	0,46
2015				
The total number of researched, heads	3325	13003	10718	27046
Of those responding positively: heads	8	46	394	448
%	0,24	0,35	3,68	1,66
2016				
The total number of researched, heads	2200	8897	14103	25200
Of those responding positively: heads	0	14	83	97
	0,0	0,16	0,59	0,38
2017				
The total number of researched, heads	6415	14267	17039	37721
Of those responding positively: heads	32	12	65	109
%	0,50	0,08	0,38	0,29
2018				
The total number of researched, heads	7207	12500	12850	32557
Of those responding positively: heads	0	0	164	164
%	0,0	0,0	1,28	0,50
2019				
The total number of researched, heads	4716	8432	14709	27857
Of those responding positively: heads	32	0	114	146
%	0,68	0,0	0,78	0,52
2012–2019				
The total number of researched, heads	49037	91676	101354	242067
Of those responding positively: heads	276	181	1170	1627
%	0,56	0,20	1,15	0,67

To provide safety of reindeer and their epizootic well-being only veterinary help is not enough, timely prevention and elimination of brucellosis is possible with taking a complex of measures. For planning and operative realization of sanitation works accurate and objective information is necessary not only about the level of epizootic situation and state of the herd, but also about the conditions of animals' keeping.

Analysis of weather conditions showed that agrometeorological indicators in the studied areas differed significantly: the average annual air temperature for the years under study in Nizhnekolymsky District was -8.7 °C, in Eveno-Bytantaisky District -13.4, in Momsky District -14.0 °C.

An increase of average annual air temperature by 1,1 ... 1,9 °C (on average by 1,5 °C) in the period from 2012 to 2019 in comparison with the norm - the mean annual value for the last 50 years (see Table 2) was observed on the territory of these regions.

More considerable warming was observed in April (by 2.8 ... 4.4 °C) and November (2.2 ... 4.1 °C), in spring-summer period - in May (by 0.9 ... 1.7 °C) and August (by 1.0 ... 1.1 °C). In all the regions only in July a decrease in air temperature by 0.2 ... 1.0 °C was noted in comparison with the mean annual value.

The analysis of distribution of the atmospheric precipitation on the territory of the studied areas in 2012-2019 allowed to identify some features of their distribution. The least amount and insignificant variability of precipitation for the year (181 mm with the norm of 179 mm) were recorded at the meteorological station Batagai-Alyta (Eveno-Bytantaisky district). In the territory of the Momsky (meteostation Honu) and Nizhnekolymsky (meteostation Chersky) districts the annual amount of precipitation was 263 and 294 mm, which was more than the mean annual value by 41 and 70 mm respectively (see Table 3).

Табл. 2. Температура воздуха в арктических районах Якутии за 2012–2019 гг., °С
Table 2. Air temperature in the arctic regions of Yakutia for 2012–2019, °C

Indicator	January	February	March	April	May	June	July	August	September	October	November	December	Total for the year
Momsky district (Honu weather station)													
Average	–44,1	–41,6	–29,1	–10,4	4,7	12,4	14,6	11,5	2,6	–12,3	–32,8	–43,7	–14,0
Norm	–46,0	–42,4	–31,1	–13,2	3,0	12,2	14,8	10,5	2,1	–14,7	–35,5	–45,1	–15,4
Deviation from the norm	1,9	0,8	2,0	2,8	1,7	0,2	–0,2	1,0	0,5	2,4	2,7	1,4	1,4
Eveno-Bytantaisky district (Batagai-Alyta weather station)													
Average	–44,6	–42,4	–27,4	–8,1	4,7	14,5	15,2	12,7	3,1	–12,8	–32,8	–43,0	–13,4
Norm	–45,5	–42,3	–29,3	–11,7	3,8	13,5	16,2	11,6	2,6	–14,3	–35,0	–43,3	–14,5
Deviation from the norm	0,9	–0,1	1,9	3,6	0,9	1,0	–1,0	1,1	0,5	1,5	2,2	0,3	1,1
Nizhnekolymsky district (Chersky weather station)													
Average	–30,3	–29,6	–21,1	–9,2	0,7	10,8	12,5	10,7	4,1	–6,7	–18,6	–27,5	–8,7
Norm	–32,4	–30,9	–23,7	–13,6	–0,2	10,1	12,9	9,6	3,2	–9,2	–22,7	–30,4	–10,6
Deviation from the norm	2,1	1,3	2,6	4,4	0,9	0,7	–0,4	1,1	0,9	2,5	4,1	2,9	1,9
Average for the districts													
Deviation from the norm	1,6	0,7	2,2	3,6	1,2	0,6	–0,5	1,1	0,6	2,1	3,0	1,5	1,5

Табл. 3. Сумма осадков в арктических районах Якутии за 2012–2019 гг., мм
Table 3. Precipitation sum in the Arctic regions of Yakutia for 2012–2019, mm

Indicator	January	February	March	April	May	June	July	August	September	October	November	December	Total for the year
Momsky district (Honu weather station)													
Average	7,4	8,6	4,4	5,3	14,1	42,1	77,1	45,2	22,2	15,2	14,0	7,1	263
Norm	7,0	7,2	4,9	5,4	12,6	37,1	49,8	40,1	23,4	14,7	12,1	7,8	222
Deviation from the norm	0,4	1,4	–0,5	–0,1	1,5	5,0	27,3	5,1	–1,2	0,5	1,9	–0,7	41
Eveno-Bytantaisky district (Batagai-Alyta weather station)													
Average	6,1	5,2	2,7	4,2	17,3	33,3	29,5	29,9	19,9	14,3	12,6	5,5	181
Norm	6,3	5,7	4,6	5,1	14,0	29,6	34,2	30,8	18,0	13,0	10,3	7,8	179
Deviation from the norm	–0,2	–0,5	–1,9	–0,9	3,3	3,7	–4,7	–0,9	1,9	1,3	2,3	–2,3	2
Nizhnekolymsky district (Chersky weather station)													
Average	19,8	13,2	11,9	5,4	10,7	29,0	47,0	33,7	36,3	32,8	33,6	21,0	294
Norm	14,2	11,3	9,7	7,8	9,5	18,6	32,2	29,1	29,1	27,1	20,5	15,0	224
Deviation from the norm	5,6	1,9	2,2	–2,4	1,2	10,4	14,8	4,6	7,2	5,7	13,1	6,0	70
Average for the districts													
Deviation from the norm	1,9	0,9	–0,1	–1,1	2,0	6,4	12,5	2,9	2,6	2,5	5,8	1,0	37

The greatest increase in atmospheric precipitation in the Nizhnekolymsky and Momsky districts over the years of research was observed in July (14.8 and 27.3 mm, respectively) and June (10.4 and 5.0 mm), in the winter months the changes were insignificant.

Analysis of the temperature regime for warm (May - September) and cold (October - April) periods of the year showed that climate warming in these areas from 2012 to 2019 was due to a more significant temperature increase in the cold period of the year (by 1.5 ... 2.8 °C) compared to the warm period (by 0.5 ... 0.6 °C) (see Table 4).

According to data from the meteorological station Honu (Momsky District), an increase in the amount of precipitation during the years of the study from 222 (normal) to 263 mm was mainly due to precipitation of the warm period. In the Nizhnekolymsky district (weather station Chersky), the contribution of precipitation of warm and cold periods to the annual increase of 70 mm was almost equal - 32 and 38 mm, respectively. In the territory of the Eveno-Bytantaisky district (meteorological station Batagai-Alyta) significant changes in the amount of precipitation for warm and cold periods were not observed. On average, the ratio of precipitation for cold and warm periods in the studied years was 1: 1.5.

Statistical processing of the received data shows that amount of precipitation for month

Табл. 4. Отклонение агроклиматических показателей за теплый и холодный периоды от нормы в арктических районах Якутии. Среднее за 2012–2019 гг.
Table 4. Deviation of agro-climatic indicators for warm and cold periods from the norm in the Arctic regions of Yakutia. Average for 2012–2019

District	Air temperature during the warm period, °C	Air temperature during the cold period, °C	Precipitation amount for the warm period, mm	Precipitation amount for the cold period, mm
Momsky	0,6	2,0	37,7	2,9
Eveno-Bytantaisky	0,5	1,5	–2,2	3,3
Nizhnekolymsky	0,6	2,8	32,1	38,2
Average	0,6	2,3	22,5	14,8

and year is characterized by more significant variability (coefficient of variation 28-96%, average 69%), than air temperature (13-69%, average 27%) on the territory of the studied areas. The greatest variability of air temperature is noted in May (69%) and September (47%), i.e. in transitional periods from spring to summer and from autumn to winter, and the amount of precipitation - in March (96%) and November (91%) (see Table 5).

Significant climate changes currently occurring in the Arctic regions of Yakutia and periodically emerging unfavorable epizootic situations on reindeer brucellosis in the region cause the need to study the relationship between these factors. Correlation analysis showed that between reindeer brucellosis morbidity and cold period air temperature (September - April) and annual temperature there is a negative weak or medium relationship (r = -0.19...-0.42), and the temperature of warm months (May - August) is medium positive (r = 0.30...0.53) with a reliable level in July (see Table 6).

The coefficient of determination ($r2$) shows that 4-28% of animal morbidity was determined by fluctuations in air temperature by months and 13% by annual temperature.

Precipitation by months had less influence on variability of the studied indicator (on average $r2$ = 0,092) than temperature ($r2$ = 0,115), but there was a significant (r = -0,48) inverse relation between the annual sum of precipitation and reindeer brucellosis incidence with a determination coefficient of 0,23. A weak to medium negative correlation (r = -0.13...-0.41) was also observed between these indicators in all months except April and August (r = 0.10 and 0.11, respectively). In winter months this correlation was more significant (r = -0,30...-0,40) than in the warm period (r = -0,13...-0,27). The revealed correlations logically explain the high level of reindeer morbidity (3.68% of those surveyed) in 2015 in the Eveno-Bytantaisky district compared to the Momsky (0.24%) and Nizhnekolymsky (0.35%) districts, as in this year. In the territory of the Eveno-Bytantaisky district during the spring-summer period (May-August) the average daily air temperature was by 1.2...3.5 °C higher and the amount of precipitation by 44-71 mm less than in the Momsky and Nizhnekolymsky districts.

Табл. 5. Изменчивость агроклиматических показателей по трем районам арктической зоны Якутии за 2012–2019 гг.

Table 5. Variability of agro-climatic indicators in three regions of the Arctic zone of Yakutia for 2012–2019

Month	Air temperature, ℃				Precipitation amount, mm			
	average	minimum	maximum	Coefficient of variation, %	average	minimum	maximum	Coefficient of variation, %
January	–39,4	–47,4	–27,7	19	11,0	1,7	37,7	86
February	–38,4	–48,3	–21,7	19	8,2	0,8	25,6	86
Mart	–26,0	–33,4	–14,5	19	6,2	0,2	23,7	96
April	–9,2	–14,1	–5,3	30	4,5	0,6	16,0	73
May	3,5	–1,4	7,1	69	14,0	1,8	40,0	71
June	12,7	8,7	17,9	17	31,3	5,1	64,9	58
July	14,0	10,8	16,7	13	52,2	9,6	122,0	55
August	11,2	8,3	14,6	15	36,6	8,8	103,0	58
September	3,2	1,4	7,4	47	26,9	3,2	56,9	52
October	–10,7	–16,8	–2,3	34	20,3	5,7	53,7	66
November	–27,5	–35,6	–13,0	26	20,1	4,2	78,5	91
December	–37,7	–46,9	–21,4	24	12,2	2,4	38,9	80
Year	–12,0	–14,5	–7,4	21	243,5	107	391,2	28
Average				27				69

Табл. 6. Влияние агроклиматических показателей на заболеваемость бруцеллезом северных оленей в арктических районах Якутии за 2012–2019 гг.

Table 6. Influence of agro-climatic indicators on the incidence of brucellosis in reindeer in the Arctic regions of Yakutia for 2012–2019

Month	Air temperature		Precipitation amount	
	Correlation coefficient (r)	Determination coefficient (r^2)	Correlation coefficient (r)	Determination coefficient (r^2)
January	–0,40	0,160	–0,41	0,168
February	–0,25	0,063	–0,34	0,116
March	–0,21	0,044	–0,39	0,152
April	–0,21	0,044	0,10	0,010
May	0,32	0,102	–0,13	0,017
June	0,35	0,123	–0,27	0,073
July	0,53*	0,281	–0,16	0,026
August	0,30	0,090	0,11	0,012
September	–0,19	0,036	–0,19	0,036
October	–0,42	0,176	–0,33	0,109
November	–0,32	0,102	–0,30	0,090
December	–0,38	0,144	–0,40	0,160
Year	–0,36	0,130	–0,48*	0,230
Average		0,115		0,092

*Significant at 5% significance level

CONCLUSION

Analysis of the obtained data indicates that in the Arctic regions of Yakutia there are processes aimed at warming the climate. There is an increase in annual air temperature compared to the norm by 1.1 ... 1.9 °C due to its more significant increase in the cold period. Annual precipitation in the territory of some Arctic regions during the study period exceeded the mean annual value by 41-70 mm.

It has been revealed that agroclimatic conditions can have a certain influence on brucellosis morbidity in reindeer in the region. It is shown that a decrease in the amount of precipitation for the year and in winter months, as well as a decrease in air temperature during the cold period of the year (September - April) and an increase in the warm period (May - August) causes an increase in the incidence of brucellosis in animals.

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ТЕОРЕТИЧЕСКОЕ ИССЛЕДОВАНИЕ ЭНЕРГОЭФФЕКТИВНОСТИ ИЗМЕЛЬЧИТЕЛЯ РОТОРНОГО ТИПА

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Изучены возможности энергосбережения при работе измельчителя зерна за счет повышения эффективности взаимодействия сырья с рабочими органами машины. Предложен измельчитель роторного типа, в котором частицы сырья разрушаются исключительно ударными воздействиями в процессе первичных ударов элементами вращающегося ротора и последующих вторичных ударов о неподвижные элементы камеры. При этом конструктивные параметры устройства обеспечивают частицам контакты с поверхностями ударных элементов под углами атаки, близкими к прямому углу, что обеспечивает высокую эффективность удара. Таким образом, каждая частица сырья в зоне удара испытывает только два, следующих друг за другом, контакта с ударными элементами, после чего частицы переработанного продукта выводятся из зоны удара. В такой схеме воздействия на сырье энергия ротора используется наиболее рационально. Эффективность работы предлагаемого устройства рассмотрена на основе потерь кинетической энергии, которые происходят при ударе частиц о поверхности рабочих органов. Взаимодействия сырья с элементами ротора и элементами камеры изучены как единый взаимосвязанный процесс, а совокупность ударных элементов ротора и камеры выделены в конструктивную единицу. Найдено аналитическое выражение, определяющее общие энергетические затраты, необходимые для реализации ударных воздействий в предлагаемом устройстве. Также введен критерий, характеризующий эффективность измельчителя в потреблении механической энергии для разрушения сырья ударными воздействиями. По введенному критерию выполнено сравнение эффективности работы предлагаемого устройства и центробежной дробилки, в которой измельчение сырья также осуществляется ударными воздействиями.

Ключевые слова: измельчитель зерна, удар, потери энергии, эффективность

THEORETICAL STUDY OF THE ENERGY EFFICIENCY OF A ROTARY GRINDER

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The possibilities of energy saving in the work of a grain grinder by increasing the efficiency of interaction of raw materials with the working bodies of the machine have been studied. A rotary

grinder, in which the raw material particles are destroyed solely by impact actions in the process of primary impacts by the elements of the rotating rotor and the subsequent secondary impacts on the stationary elements of the chamber, is proposed. In this case, the design parameters of the device provide the particles with contacts with the surfaces of the impact elements at angles of attack close to the right angle, which ensures high impact efficiency. Thus, each raw material particle in the impact zone experiences only two successive contacts with the impact elements, after which the processed product particles are removed from the impact zone. In this scheme of action on the raw material the rotor energy is used most rationally. The effectiveness of the proposed device is considered on the basis of the loss of kinetic energy that occurs when the particles hit the surface of the working bodies. The interaction of the raw material with the rotor and chamber elements is studied as a single interrelated process, and the set of shock elements of the rotor and chamber are allocated as a structural unit. An analytical expression was found that determines the total energy cost required to implement the impact forces in the proposed device. A criterion that characterizes the efficiency of the grinder in the consumption of mechanical energy for the destruction of raw materials by impact forces is also introduced. A comparison of the efficiency of the proposed device and the centrifugal crusher, in which crushing of raw materials is also carried out by impact effects, is performed according to the introduced criterion.

Keywords: grain grinder, impact, energy loss, efficiency

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INTRODUCTION

Among the machines used for grinding of grain raw materials rotary grinders are widespread. Their popularity is due to the following advantages: simple design, reliability, versatility, ease of maintenance. Improvement of these machines is an urgent task, especially in the aspect of reducing energy consumption [1-5].

One of the ways to improve rotary grinders is to reduce energy consumption by increasing the efficiency of interaction of raw materials with the working bodies of the grinder[1] [6-8]. In the working chamber raw material grinding occurs as a result of blows of rotating rotor elements, as well as blows and abrasion of raw material particles on the working surfaces of the chamber elements. The peculiarity of work of the rotary grinders is that impact action of the rotor element not only loads the particle, but also simultaneously gives it or the formed fragments kinetic energy, which is then consumed in subsequent interaction with the chamber elements. The quality of interaction of the particle with the chamber element is determined by how fully the stock of its energy received from the rotor is used. In this aspect, a number of researchers note that the main reasons for increased energy consumption are irrational energy losses due to poor-quality impact on the raw material, as well as its friction against the chamber elements due to the circular motion. [9, 10].

The authors proposed a rotary grinder, in which the raw material particles, getting into the work chamber, are destroyed in the process of primary impacts by the elements of the rotating rotor (beater) and subsequent secondary impacts on the stationary elements of the

[1]Denisov V.A. Calculation of power consumption of centrifugal-impact crusher. Scientific Proceedings. Mechanization and automation of fodder preparation. MOSCOW: VIESH, 1986. vol. 66. pp. 106-122.

chamber (plates) at the angles of attack, close to 90°, which ensures high efficiency of impact effects (see Fig. 1). In this case the raw material is fed into the chamber perpendicular to the rotor rotation plane, and after the interaction with the plates the processed product particles are removed from the impact zone. Thus, the raw material particles in the impact zone experience only two contacts: with communication of kinetic energy (when the beater strikes) and with absorption of energy (when the particle hits the plate). In this grinding method, there is no friction of the raw material, and the particles are crushed exclusively by impact actions with high efficiency. Consequently, the rotor energy is used as rationally as possible. The impact of the beater completely determines the subsequent impact of the particle on the plate, which makes it possible to consider and mathematically formalize these impacts as a single process. In this case, the beaters and the plates corresponding to them function as a single organ, which can be called a shock-reflection pair [11].

The purpose of the research is a theoretical study of the energy efficiency of the proposed grinder and an analytical expression describing the energy consumption for the implementation of the grinding process.

MATERIAL AND METHODS

It is known that the total kinetic energy of the bodies after a collision is less than before it[2]. The loss of energy is associated with a number of physical processes occurring during the impact, including deformation of the bodies and development in their volumes of defects (cracks, etc.). If the aim of the collision is the destruction of one of the colliding bodies, the loss of kinetic energy indirectly shows the effectiveness of the collision. Then the ratio of losses of kinetic energy to the total energy expenditures for the implementation of the impact can be used as a criterion of the effectiveness of the device, which carries out grinding by an impact.

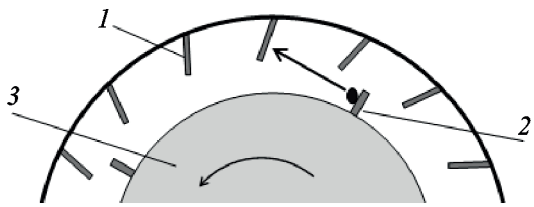

Рис. 1. Рабочие органы измельчителя (*1* – пластина, *2* – било, *3* – ротор)

Fig. 1. Working bodies of the grain grinder (*1* – plate, *2* – beater, *3* – rotor)

In the interaction of raw materials with the impact-reflection pair, the total loss of kinetic energy can be represented as a sum of energy losses in the interaction with the beater and in the interaction with the plate. Let's assume that all contacts of the particles with the surfaces of the working bodies of the grinder occur at right angles. In this case the loss of kinetic energy ΔT can be found by the formula (see footnote 2)

$$\Delta T = (1 - k^2)\frac{m_1 m_2 (v_1 - v_2)^2}{2(m_1 + m_2)}, \quad (1)$$

where m_1, m_2 – the masses of colliding bodies, kg; v_1, v_2 – velocities of the bodies before collision, m/s; k – recovery factor.

Let's consider the interaction of a beater and a particle. Let M be the mass of the beater in kg, m be the mass of the particle in kg, v be the beater's linear velocity, m/s. The initial velocity of the particle before the impact is much less than the velocity of the beater, so for simplicity let's take it as equal to zero. Let's apply (1) for the given case, then the kinetic energy loss expression at the impact of the beater $\Delta T_б$ will take the following form:

$$\Delta T_б = (1 - k^2)\frac{Mmv^2}{2(M + m)}. \quad (2)$$

Since the beater is rigidly fixed to the rotor, most of the rotor mass is involved in the contact with the particle. Consequently, the mass of the particle is much less than the mass of the beater ($m << M$) and in the denominator of the expression (2) it can be neglected, and the mass of the beater can be reduced:

$$\Delta T_б = (1 - k^2)\frac{mv^2}{2}. \quad (3)$$

[2]Yablonsky A.A. Course of theoretical mechanics: textbook for universities. A.A. Yablonsky, V.M. Nikiforova. Moscow: Integral-Press, 2006. 608 p.

After contact with the beater, the particle may survive or collapse into pieces. In the second case, the fragments of the destroyed particle fly away from the beater, forming a bursting cone. For simplification we will assume that the fragments after the impact have the same velocity and move in the direction of the plate along the central axis of the bursting cone. We will also assume that the interaction of all the fragments of the particle with the plate is equivalent to the corresponding interaction of the particle itself if it had survived.

The velocity u, which the particle acquires after the impact of the beater, can be found using a well-known expression (see footnote 2)

$$u = v_2 + (1 + k)\frac{m_1 (v_1 - v_2)}{(m_1 + m_2)}, \quad (4)$$

which, taking into account $v_1 = v$, $v_2 = 0$, $m_1 = M$, $m_2 = m$, $m << M$ will look like this:

$$u = (1 + k)v. \quad (5)$$

Let's assume that the particle's velocity u is conserved up to the moment of its contact with a stationary plate of mass Mp. Let's apply the expression (1) to find the loss of the kinetic energy $\Delta T_п$ when the particle hits the plate

$$\Delta T_п = (1 - k^2)\frac{mM_п u^2}{2(m + M_п)}. \quad (6)$$

The plate is fixed to the body of the chamber, therefore $m << Mn$ and the mass of the particle in the denominator can be neglected:

$$\Delta T_п = (1 - k^2)\frac{mu^2}{2}. \quad (7)$$

It should be taken into account that the recovery factor in the general case depends on many factors, including the impact speed. On the basis of the experiments with different grain crops S.V. Zverev proposed the following functional dependence[3, 4]:

$$k = A - Bv - C\varphi, \quad (8)$$

where A, B, C – empirical coefficients, v – impact velocity, m/s; φ – grain moisture, %.

According to the formula (5) the speed of collision of a particle with a plate is greater than that of collision with a beater and, consequently, these contacts have different recovery coefficients. Let us assume that the empirical coefficients A, B, C are constant and the grain humidity φ is fixed.

Let's denote the coefficients of recovery at contacts with the beater k and plate k_2:

$$\begin{cases} k = A - Bv - C\varphi; \\ k_2 = A - Bu - C\varphi. \end{cases} \quad (9)$$

In the second equation of the system let us substitute formula (5) and the coefficient A expressed from the first equation. By performing the transformations, we obtain:

$$k_2 = k\,(1 - Bv). \quad (10)$$

Let's introduce the notation: $\delta = 1 - Bv$, then

$$k_2 = \delta k. \quad (11)$$

Let us determine the loss of kinetic energy ΔTп in contact with the plate, for which we transform the expression (7), taking into account formulas (5) and (11):

$$\Delta T_п = (1 - k_2^2)\frac{mu^2}{2} = (1 - \delta^2 k^2)\frac{mu^2}{2} =$$

$$= (1 - \delta^2 k^2)\frac{m}{2}(1 + k)^2 v^2 =$$

$$= \frac{mv^2}{2}(1 - \delta^2 k^2)(1 + 2k + k^2); \quad (12)$$

$$\Delta T_п = \frac{mv^2}{2}(1 + 2k + (1 - \delta^2)k^2 - 2\delta^2 k^3 - \delta^2 k^4). \quad (13)$$

Now let's find the total loss of kinetic energy ΔT during interaction of the particle with the impact -reflection pair. For this purpose, let's add expressions (3) and (13) and after transformation we obtain:

$$\Delta T = mv^2\left(1 + k - \frac{\delta^2 k^2}{2} - \delta^2 k^3 - \frac{\delta^2 k^4}{2}\right). \quad (14)$$

Energy expenditures, necessary for the realization of contacts of the particle with the working bodies of the impact-reflection pair,

[3]Zverev S.V. Zvereva N.S. Physical properties of grain and products of its processing: a textbook for students of higher educational institutions studying for a speciality 260601 (170600) "Machines and devices of food manufactures" of a direction of preparation of the certified specialist 260600 (655800) "Food engineering". DeLi Print, 2007. 175 p.

[4]Glebov L.A. et al. Enhancement of the process of grinding components of mixed fodders. Moscow: Central Scientific and Research Institute of the Ministry of Bread and Groceries of the USSR, 1988. 51 p.

are equal to the expenditures of the mechanical energy of the rotor during the interaction of the beater and the particle. After the impact the rotor energy is reduced by the value W, equal to the sum of losses of the kinetic energy at impact of the beater ΔT_b and changes in the kinetic energy ΔE of the particle:

$$W = \Delta T_б + \Delta E. \quad (15)$$

Prior to the contact with the beater the velocity of the particle is insignificant, let us assume that it is zero. Then the change of the kinetic energy is equal to the kinetic energy acquired by the particle immediately after the impact:

$$\Delta E = \frac{mu^2}{2}. \quad (16)$$

Taking into account expression (5), the following formula will look like:

$$\Delta E = \frac{mv^2}{2}(1+k)^2. \quad (17)$$

Let's substitute expressions (3) and (17) in the formula (15) and, having performed the necessary transformations, we obtain the final expression determining energy costs associated with the process of implementation of raw material grinding in the shock-reflective pair:

$$W = mv^2(1+k). \quad (18)$$

Let's introduce the notion of energy absorption coefficient (EAC) as a value equal to the ratio of total losses of kinetic energy in impacts to the energy input for their realization, and denote by γ. The EAC value shows the share of the mechanical energy spent, which was transformed into other types of energy, including those related to the destruction of particles. Accordingly, for a impact-reflection pair, γ is found as the ratio of ΔT to W:

$$\gamma = \frac{\Delta T}{W}. \quad (19)$$

Taking into account formulas (14) and (18), the expression γ for the impact-reflection pair will be:

$$\gamma = \frac{(1 + k - \frac{\delta^2 k^2}{2} - \delta^2 k^3 - \frac{\delta^2 k^4}{2})}{(1+k)}. \quad (20)$$

RESULTS AND DISCUSSION

Ratio (14) allows us to analyze the dependence of total losses of kinetic energy on the recovery coefficient during interaction of raw materials with the impact-reflection pair $\Delta T(k)$. Fig. 2 shows theoretical diagrams of $\Delta T(k)$, built at different values of the beater's speed (30, 40, 50 m/s) per unit mass of raw material (m = 1 kg). The presence of extremums indicates that at certain values of the recovery factor k, the total loss of kinetic energy will be maximum for a given beater speed. However, the recovery factor is a function of speed [see expression (8)], so for a given speed corresponds to a certain recovery factor, which determines the value of total energy losses (marked by dots in the graphs), and it does not correspond to the maximum of the curve $\Delta T(k)$.

Expression (18) allows us to determine the energy costs associated with the process of grinding raw materials, and the EAC [see expression (19)] shows how effectively the energy is used in this process. The notion of EAC can be used as a criterion for comparing the efficiency of devices that grind by impact method.

It is known that destruction of raw materials by impact is also carried out in centrifugal grinders, but in comparison with rotary grind-

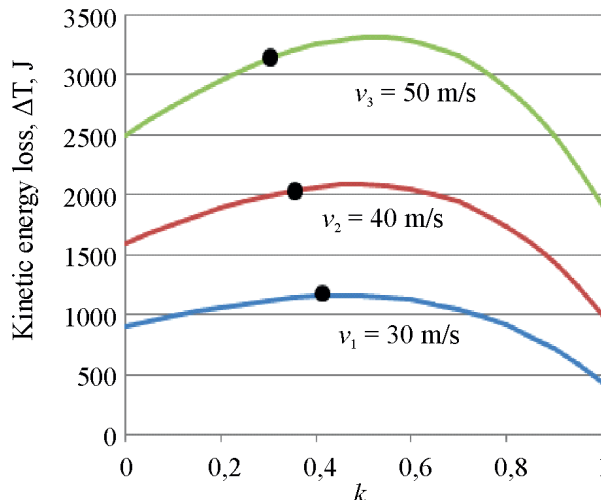

Рис. 2. Графики зависимостей общих потерь кинетической энергии $\Delta T(k)$ при взаимодействии сырья с ударно-отражательной парой

Fig. 2. Graphs of dependences of the total losses of kinetic energy ΔT(k) during the interaction of raw materials with an impact-reflective pair

ers, they are characterized by low energy consumption[5] [12]. Let's define EAC for the centrifugal grinder and compare it with the EAC of the impact-reflection pair. In a centrifugal grinder, raw material particles are accelerated by an accelerating disc and thrown onto stationary baffle elements, where they are destroyed by impact. Let the contact of the particles with the surfaces of the baffle elements occur at right angles. Then the loss of kinetic energy is defined by the expression

$$\Delta T_{цд} = (1 - k^2)\frac{mv^2}{2}, \qquad (21)$$

where m – respectively, the mass, kg; v – particle velocity (m/s), accelerated by the disk.

The energy input for the impact in a centrifugal grinder consists of the kinetic energy imparted to the particle and the work done to overcome the friction of the particle on the blade of the accelerating disk:

$$W_{цд} = \frac{mv^2}{2} + A. \qquad (22)$$

If friction on the blade is disregarded, the work to overcome friction is zero ($A = 0$) and the EAC expression for the centrifugal grinder will be:

$$\gamma_{цд} = \frac{\Delta T_{цб}}{W_{цд}} = 1 - k^2. \qquad (23)$$

Analysis of expressions (20) and (23) showed that for all possible values of the recovery factor $k \in [0,1]$ the inequality is true

$$\gamma \geq \gamma_{цд}. \qquad (24)$$

Consequently, the impact-reflection pair consumes mechanical energy more efficiently than the centrifugal grinder even without taking into account friction in the latter. Dependence graphs of EAC of the impact-reflection pair at different beating speeds (curves *1, 2, 3*) are close to each other (see Fig. 3). It means that the efficiency of impact-reflection pair does not depend on the mode of operation. At $k = 0$ (inelastic impacts), the EAC of the impact-reflection pair and the centrifugal grinder without friction on the blades (curve *4*) are equal to the maximum possible value - unity. As k increases from 0 to 1, the EAC of both the centrifugal grinder and the impact-reflection pair monotonically decrease. The EAC of the centrifugal grinder, in which friction costs are taken into account, will obviously be less than that of the grinder without friction at any value of k (curve *5*).

Substituting formula (8) into the expressions (20) and (23), the corresponding EAC dependences on speed can be obtained: for the impact-reflection pair $\gamma(v)$ and for the centrifugal crusher $\gamma cg\ (v)$ without friction. Expressions of functions $\gamma(v)$ and $\gamma cg\ (v)$ are not given here due to their magnitude, but their theoretical graphs are presented (see Fig. 4). They show the correctness of the relation

$$\gamma(v) \geq \gamma_{цд}(v) \qquad (25)$$

for any values of the velocities realized in practice. For example, calculations performed at a beating speed v = 50 m/s show that the difference between $\gamma(v)$ and $\gamma cg\ (v)$ is about 0.07 (7%). But taking into account friction, the curve $\gamma cg\ (v)$ will be much lower than $\gamma(v)$, and the difference between $\gamma(v)$ and $\gamma cg\ (v)$ will become significant. It should be noted that the shock-reflective pair is opposed to such a centrifugal grinder, in which the speed of collision of particles with the baffling elements is equal to the speed of the beater of the shock-reflective

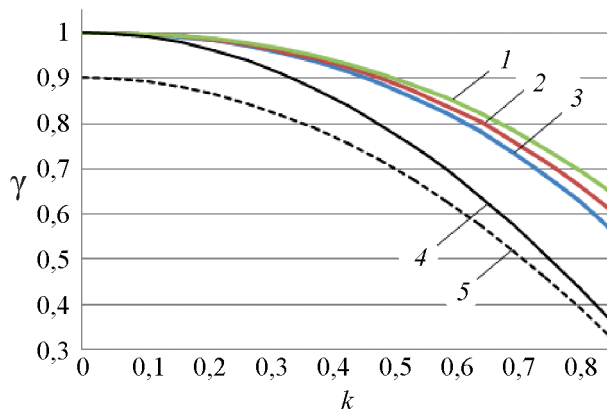

Рис. 3. Графики зависимостей $\gamma(k)$ ударно-отражательной пары (*1* – 30 м/с, *2* – 40 м/с, *3* – 50 м/с) и центробежной дробилки $\gamma_{цд}(k)$ (*4, 5*)

Fig. 3. Graphs of dependences γ(k) of an impact-reflective pair (*1* – 30 m/s, *2* – 40 m/s, *3* – 50 m/s) and a centrifugal crusher $\gamma_{цд}$(k) (*4, 5*)

[5] *Золотарев С.В.* Ударно-центробежные измельчители фуражного зерна (основы теории и расчета). Барнаул: ГИПП «Алтай», 2001. 200 с.

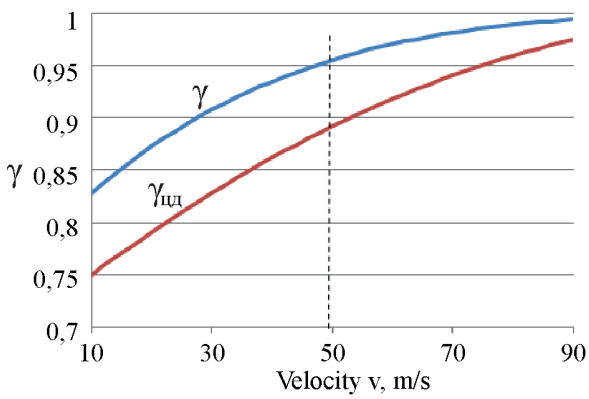

Рис. 4. Графики зависимостей КПЭ для ударно-отражательной пары $\gamma(v)$ и для центробежной дробилки $\gamma_{цд}(v)$ без учета трения

Fig. 4. Graphs of dependences of the energy absorption coefficient for the impact-reflective pair $\gamma(v)$ and for the centrifugal crusher $\gamma_{цд}(v)$ without friction

pair. In calculations and graphs (see Fig. 2-4) empirical coefficients are used (see footnote 3): A = 0,66; B = 0,0043; C = 0,009 for barley at humidity φ = 13%.

CONCLUSION

The analytical expression for determining the energy costs associated with the grinding of raw materials in the working area of the impact-reflection pair of the proposed grinder is found. The criterion characterizing the efficiency of the device in energy expenditures for the destruction of raw materials by impact actions is introduced. The advantage of the proposed grinder in energy efficiency in comparison with centrifugal grinders, which, as a rule, are characterized by low values of energy consumption, is shown on the basis of this criterion.

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ЭФФЕКТИВНОСТЬ ИСПОЛЬЗОВАНИЯ ПШЕНИЦЫ В ОРГАНИЧЕСКОМ ЖИВОТНОВОДСТВЕ

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Для решения задачи органического производства продукции регионального животноводства и создания соответствующей кормовой базы необходимым этапом является концептуальное обоснование перечня основного кормового сырья, перспективного для реализации органических технологий в Сибири. Представлены результаты обоснованности применения модифицированной фуражной пшеницы в органическом производстве продукции животноводства. Предложены пути преобразования пшеницы, обеспечивающие повышение эффективности использования ее в кормлении животных. В задачи исследований входило изучение агротехнических возможностей возделывания пшеницы в Сибири по правилам органического производства, оценка масштабности использования ее на кормовые цели, определение аминокислотного состава региональных сортов пшеницы, обоснование эффективности получения из нее кормовой добавки, оценка возможности применения новой добавки в рационах животных, содержащихся по правилам органического производства. Урожайность яровой пшеницы, возделанной в Сибири по пару и нормам органического производства, составляет от урожайности пшеницы, возделываемой по обычной интенсивной технологии, в среднем 62,5%. Потеря 38% урожая, обусловленная органической технологией, может быть восполнена за счет увеличения площади ее посевов. Средние значения содержания нормируемых аминокислот в пшенице исследованных 82 районированных сортов сибирской селекции меньше справочных значений. Из пшеницы получена экспериментальная кормовая добавка с содержанием лизина порядка 20 г/кг в пересчете на сухое вещество. Это сопоставимо с содержанием лизина в мясокостной муке, шроте подсолнечном – традиционных белковых ингредиентах сибирских комбикормов для моногастричных животных, но не включенных в перечень сырья, разрешенного к использованию в органическом животноводстве. С использованием полученной добавки составлены полнорационные комбикорма для молодняка свиней и птицы. Экспериментально установлено положительное влияние полученной добавки из пшеницы на продуктивность подопытных животных, содержащихся по правилам органического производства.

Ключевые слова: органическое производство продукции животноводства, пшеница, добавка из пшеницы, нормируемые аминокислоты, лизин

EFFICIENCY OF WHEAT USE IN ORGANIC ANIMAL HUSBANDRY

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Conceptual justification of the basic feed raw materials list which is promising for the implementation of organic technologies in Siberia is a necessary step to solve the problem of organic production of regional livestock and the creation of an appropriate feed base. The results of the validity of

the use of wheat in the organic production of livestock products are presented. The ways of transforming wheat to improve the efficiency of its use in animal feed are proposed. The objectives of the research included studying the agronomic possibilities of wheat cultivation in Siberia according to the rules of organic production, assessing the scale of its use for fodder purposes, determining the amino acid composition of regional wheat varieties, justifying the effectiveness of obtaining a feed additive from it, assessing the possibility of using the new additive in the diets of animals kept according to the rules of organic production. The yield of spring wheat cultivated in Siberia on fallow and organic production norms is 62.5% on average of the yield of wheat cultivated on conventional intensive technology. The loss of 38% of the yield due to organic technology can be compensated by increasing the area of its crops. The average values of the content of normalized amino acids in wheat of the studied 82 released varieties of Siberian breeding are less than the reference values. An experimental feed additive with a lysine content of about 20 g/kg in terms of dry matter was obtained from wheat. This is comparable with the lysine content in meat and bone meal, sunflower oil meal - traditional protein ingredients of Siberian feed for monogastric animals, but not included in the list of raw materials permitted for use in organic animal husbandry. Using the obtained additive full-fat mixed fodder for young pigs and poultry were composed. Positive effect of the obtained wheat additive on the productivity of experimental animals kept under the rules of organic production was experimentally established.

Keywords: organic production of livestock products, wheat, wheat additive, normalized amino acids, lysine

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The State Duma Committee on Agrarian Issues of the Russian Federation has developed an interstate standard GOST 33980-2016[1] "Organic production. Production regulations, processing, labelling and implementation". The new GOST complies with the main provisions of the international standard Codex Alimentarius CAC/GL 32-1999 and was enacted in the Russian Federation from January 1, 2018.

It can be stated that the state has determined as promising the creation and sale of organically produced food in order to improve the quality of life, and longevity of the population. This task for the agro-industrial complex of Russia in all aspects is new and therefore attractive to both science and to the domestic market.

The latest research in the field of organic production in the country can be assessed as a positive prerequisite for the successful creation of domestic organic products [1-6].

Objective difficulties in the practical implementation of the rules and regulations of GOST 33980- 2016 is that this normative document contains a number of significant limitations. With regard to the designated topic of work to be performed, the main restrictions (designated in GOST 33980-2016) are the following:

– the use of mineral nitrogen fertilizers is not allowed (clause 5.1.4);

– the use of synthetic herbicides is not allowed (clause 5.1.5);

– synthetic amino acids are not allowed (clause 6.11.5).

n the list of feed raw materials (mandatory Appendix D [1]) permitted for use in organic livestock are absent:

[1]GOST 33980-2016. Products of organic production. Rules of production, processing, labeling and sale. Moscow: Standardinform, 2016. 41 p.

– oil cakes;

– meat (meat and bone) raw materials.

However, it should be noted that the list of feed additives and some substances used in animal feeding (mandatory Appendix E) includes enzymes (clause E.1.2).

Before modern science moves to the listed limitations of agricultural production, it is advisable to conduct a comprehensive study in conjunction with medical experts and economists to assess the merits and effectiveness of organic products.

Given that oil cakes (soybean, sunflower), meat and bone meal, and recently synthetic amino acids are widely used in animal husbandry [2-4], it is necessary to offer an adequate (comparable) in quality substitute. We need a feed additive that, firstly, can be produced in Siberia, secondly, it must meet the standards of GOST 33980-2016, and thirdly, be effective in feeding animals.

The purpose of the work is to identify promising forage raw materials to obtain livestock products of organic production in Siberia and to propose ways of its rational use.

Working hypothesis: wheat is a promising regional agricultural raw material for organic feed additives of appropriate quality (amino acid, easily accessible carbohydrate composition).

The research objectives are:

– study the agronomic possibilities of cultivation of wheat in Siberia according to the rules of organic production;

– evaluate the possibility of producing and using significant volumes of deep-processed wheat in the domestic market for animal feed;

– determine the amino acid composition of wheat varieties released in Western Siberia, assess the feasibility of breeding it according to its amino acid content;

– propose a method of obtaining a feed additive from wheat, expected to be effective in the organic production of livestock products;

– estimate the possibility of using the new additive in the formation of diets for animals kept on the technology of organic production;

– experimentally investigate the prerequisites for the use of wheat amino acid supplement in animal feed, taking into account the rules and regulations of organic production.

Wheat is the most common grain crop both in Siberia and Russia as a whole[5]. In recent years, all the needs of the Russian domestic market have been fully satisfied with wheat, so that a significant part of it is annually sold abroad.

Wheat is available in the country; its production is predictable and fairly stable. However, we are talking about a potential increase in the consumption of wheat in the domestic market in large quantities, so it is necessary to assess the rationality of the use of wheat in organic livestock production.

There is nothing new in the use of wheat in grain mixtures for feeding animals. In modern agriculture it is widely used for fodder purposes. For example, the recommended content of wheat in the recipes of full-fat mixed fodder for pigs and meat poultry is respectively up to 25-45% (see footnote 4). According to the recommendations of the VIZh (L.K. Ernst Federal Research Center for Animal Husbandry), the wheat content in mixed fodder for high-yield lactating cows ranges from 15.5% to 26.0%[6].

Literature analysis on the possibility of obtaining wheat by the rules of organic production was conducted since in organic production, wheat, like any other crop must be cultivated without the use of mineral nitrogen fertilizers and synthetic herbicides.

According to the results of the published modern experimental studies of the leading sci-

[2]The reference book of Siberian cattle breeder. Siberian Branch of the Russian Academy of Agricultural Sciences, SibNIPTIZh; edited by M.D. Chamukha, A.S. Donchenko. Novosibirsk, 2000. 220 p.

[3]Fisinin V.I., Egorov I.A., Draganov I.F. Feeding farm poultry. Moscow: GEOTAR-Media, 2011. 344 p.

[4]New in animal feeding: reference manual edited by V.I. Fisinin. M.: Publishing house of RSAU-MSKHA, 2012. 788 p.

[5]Kashevarov N.I. Problems of Agriculture and Fodder Production. Novosibirsk, 2016. 106 p.

[6] Golovin A.V., Vorobieva S.V., Perlov N.P., Anikin A.S. Peculiarities of feeding dairy cows with the milk yield of 8000-10000 kg of milk: analytical review. Dubrovitsy: Russian Agricultural Academy of Sciences, 2013. 56 p.

entists in Siberia [7-10], it was found that in the region the production of wheat that meets the norms of organic production (see footnote 1) is possible: the yield of spring wheat cultivated on fallow under organic production norms (i.e. without mineral nitrogen fertilizers and synthetic herbicides) is on average 62.5% of the wheat cultivated under conventional intensive technology (see Figure 1).

Obviously, this result is positive and opens the technological possibility of using wheat in Siberia for organic production.

However, it should be noted that the real success of organic production in crop production in Russia largely depends on the effectiveness of control (approved for organic production methods and means) of contamination of grains with mycotoxins. Studies in this direction have been conducted in the country [11-16], but radically positive results in this serious issue have not yet been obtained.

Considering the proposal to use more wheat for forage purposes, given that, according to the WHO about 800 million people in the world are starving, the question arises: How ethical is it to increase wheat consumption within Russia to feed farm animals at a time when a large part of the world's population is starving?

To answer the question, a macro-analysis of the world population's food supply was carried out. Taking into account modern world population of 7 billion 812 million people, annual gross output of just 5 leguminous crops amounts to about 3 billion 240 million tons (corn - 1 billion 102 million tons, wheat - 761 million tons, rice - 509 million tons, soybean - 343 million tons, barley - 154 million tons). According to calculations, this foodstuff (after taking into account carry-over stocks and the edible part of products) is enough to provide, on average, more than 2,800 kcal of energy and about 120 g of protein per day for each inhabitant of the planet. This total amount of protein of the world's integrated grain product (corn, wheat, rice, soy, barley) provides (according to Academician N.N. Lipatov's theory[7]

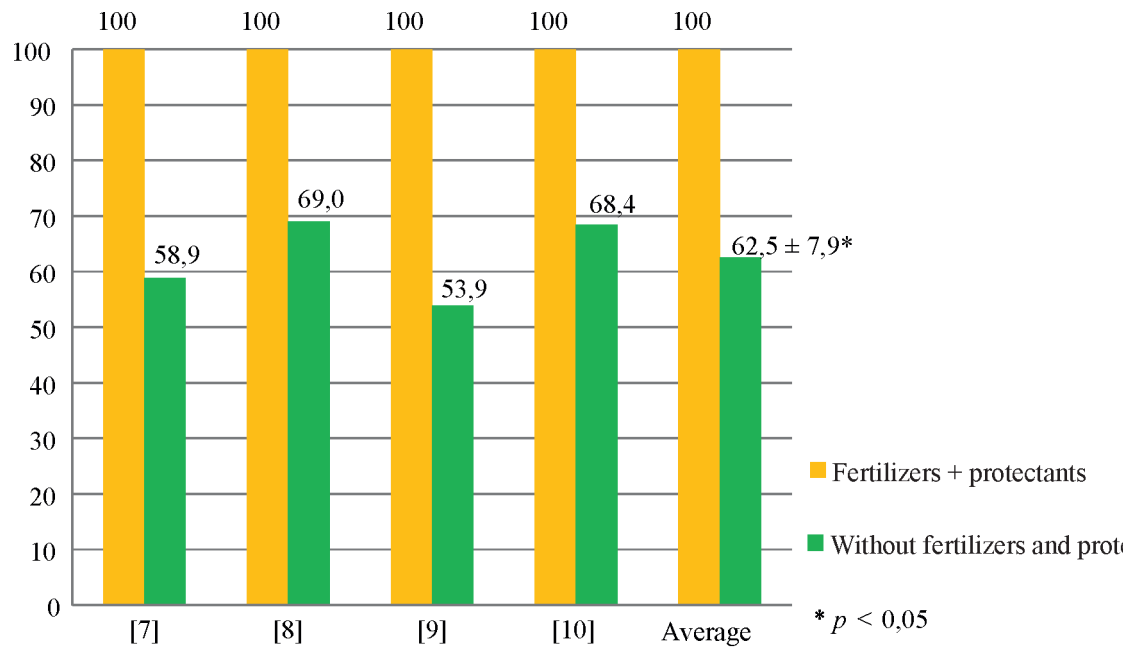

Рис. 1. Соотношение урожайности яровой пшеницы в Сибири по пару при различных вариантах применения минеральных (азотных) удобрений и средств защиты растений (гербицидов), %. [7], [8], [9], [10] – литературные источники, из которых взяты данные.

Fig. 1. Yield ratio of spring wheat in Siberia by fallow at different variants of mineral (nitrogen) fertilizers and plant protection agents (herbicides), %. [7], [8], [9], [10] - literature sources from which the data were taken.

[7]Lipatov N.N. Some aspects of modeling the amino acid balance of food products. Food and processing industry, 1986. pp. 48-52.

and the FAO/WHO protein standard[8]) about 74 g of protein per day, which is utilized by the human body. Taking into account that the Russian norm of protein consumption per day for an adult is 70 g, and energy consumption from 2100 kcal[9], then a conclusion suggests itself: the existing starvation of a significant part of the foreign population has no biological basis, but is caused exclusively by imperfections in the existing sociopolitical and technological world order. The obtained conclusion allows us to hope for the ethics of the potential large-scale use of the Russian wheat in the domestic organic production of livestock products, even under the current sanctions of the "collective West" against the Russian Federation.

Assessment of quality of fodders necessarily takes into account their protein (protein) nutrition. Thus, in modern animal breeding, according to the opinion of academician V.I. Fisinin, protein nutrition should be understood as the properties of feed to meet the need of animals for amino acids (see footnote 4). In a certain sense, speaking about protein, amino acids are meant, speaking about amino acids - protein is meant, so it is more correct to consider amino acid component of all the used feeds, including forage wheat.

It is known that methionine and lysine are the limiting essential amino acids for poultry, lysine, threonine and methionine for pigs (see footnote 4) and methionine for high-yielding lactating cows (see footnote 6). Therefore, the content of these essential amino acids in feeds should be known and taken into account when formulating appropriate diets.

If this state of affairs requires accounting for the amino acid content of wheat used for animal feed, the traditional analysis of the composition of wheat varieties (and other cereals, legumes), as a rule, does not take into account their amino acid content. A contradiction arises: modern zootechnics recognizes the usefulness of taking into account the amino acid composition of wheat, while in agronomic practice such accounting is not common. In this regard, it is advisable to carry out breeding work on fodder crops, taking into account not only the yield of these crops, but also their functional protein elements.

Assuming that wheat varieties have different amino acid content, the analysis of amino acid composition of wheat varieties released in Western Siberia was carried out. The main released wheat varieties of the leading originators in Western Siberia are: Siberian Research Institute of Plant Cultivation and Breeding (SibNIIRS) - branch of the Institute of Cytology and Genetics SB RAS (Novosibirsk), Federal Scientific Centre of Agrobiotechnologies (FSCA) (Barnaul), Omsk Agrarian Scientific Center, and Omsk SAU - were examined for amino acid content on a contract basis at the Integrated Analytical Center of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences (SFSCA RAS). The research was carried out on 82 wheat varieties.

Preliminary analysis showed the following results:

– average values of the standardized amino acids content of the wheat varieties of Siberian breeding under study are less than the reference values of amino acids in wheat (lysine by 24.4% on average, methionine by 38.9, threonine by 26.1%);

– some wheat varieties of Siberian selection have a higher content of normalized amino acids.

According to the results of the preliminary tests Novosibirskaya 32 (soft winter wheat of ICiG selection) exceeds the reference values for lysine by 55.6%, for threonine - by 38.4%. Novosibirskaya 22 (spring wheat of ICiG selection) differs from the tested samples by the highest methionine content: it exceeds the reference value by 122.2%.

Let us consider the potential effectiveness of the feasibility of determining the amino acid

[8]Energy and protein requirements. Technical Report Series No. 522. FAO Nutrition Report Series No. 52. Report of the Ad Hoc Joint FAO/WHO Expert Committee. World Health Organization. Geneva, 1974. 143 p.

[9]Methodological Recommendations MR 2.3.1.2432-08. Rational Nutrition. Norms of physiological requirements for energy and nutrients for different groups of population of the Russian Federation. 2008. 41 p.

composition of feed wheat by the example of diets for egg chickens. Let us analyze for lysine content the diets given in the reference book (see footnote 3) in comparison with the model.

The model ration is focused on organic livestock and has the following differences from the reference analogue:

– averaged (reference) wheat was replaced by Novosibirskaya 32;

– sunflower oil cake by sunflower oilseed meal;

– fodder yeast by baker's yeast;

– synthetic lysine is not used.

Replacement of oil cake by oilseed meal, fodder yeast by baker's yeast, exclusion of synthetic lysine from the model ration is due to the relevant standards of GOST 33980-2016.

As a result of calculations, it was found that the values of total lysine content in both diets are equal to each other (0.82% each) (see Fig. 2). However, the real difference is that the reference diet contains synthetic lysine, while the model diet does not. Consequently, by consciously using a wheat variety with high lysine content, it is possible to obtain a balanced feed without the use of synthetic lysine, which meets the requirement of the standard for organic production.

The calculated result obtained by the example of Novosibirskaya 32 indicates the feasibility of research to determine the amino acid content of wheat and evaluation of the new diet on the productivity of poultry, and in the future, in case of a positive result, it is possible to conduct breeding to create new varieties of wheat with increased lysine content.

It is well known from classic compound feed formulation that it is impossible to provide the normatively required content of protein (amino acids) and energy in the compound feed exclusively from any grains (or any combinations thereof). This is due to the fact that cereals contain relatively large amounts of energy and little protein (amino acids). In terms of dry matter, wheat contains the required energy level recommended for intensively developing animals, but the lysine content of wheat is several times lower than the standard level of lysine in full-fat mixed fodder.

Thus, even some of the most highly lysine wheat is not a priori comparable in amino acid quality with meat and bone meal, nor with oil cakes (soybean, sunflower). Without transforming the amino acid-energy composition of wheat, it cannot serve as an adequate substitute for traditional protein raw materials, which are not recommended for use in organic animal husbandry (meat and bone meal, oil cakes).

In this regard, it is necessary to create a feed additive from wheat, which would differ from standard wheat primarily by a higher content of limiting essential amino acids.

Such a problem was set and basically (in the first approximation) was solved[10]. A positive result was achieved by two-step sequential transformations: first enzymatic hydrolysis (mixture: crushed wheat + water + enzyme), then centrifugation. The enzyme of complex action Protosubtilin GZh produced by "Sibbiopharm" Ltd. (Berdsk, Novosibirsk Region) was used. As a result, two fractions of different content were obtained: one predominantly protein and the second one carbohydrate. Proteins are represented mainly by free amino acids, carbohydrates by medium molecular weight dextrins and sugars.

The lysine content in the experimental wheat additive is about 20.3 g/kg DM, which is comparable with its content in oil cakes (extruded soybean - 25.9 g/kg DM, sunflower - 13.3 g/ kg DM), meat and bone meal (25.8 g/kg DM)[11]. The content of methionine in the experimental supplement is about 1.47 g/kg DM.

Thus, an experimental feed ingredient containing high levels of lysine (the first limiting amino acid in feeding high-yielding monogastric animals) and at the same time meeting the requirements of organic production was obtained from the most common local grain raw material - wheat.

To estimate the potential effectiveness of the experimental wheat additive (by the example

[10]Production method of high-protein wheat grain base for food product preparation: patent: 2453126 Russian Federation: IPC A23J 1/12 / V.G. Ermokhin, T.T. Wolf, V.A. Uglov; № 2010141619/10. Application. 11.10.2010; Bulletin No. 17.

[11]Guidelines on feeding farm poultry. VNITIP. Moscow: Lika, 2018. 226 p.

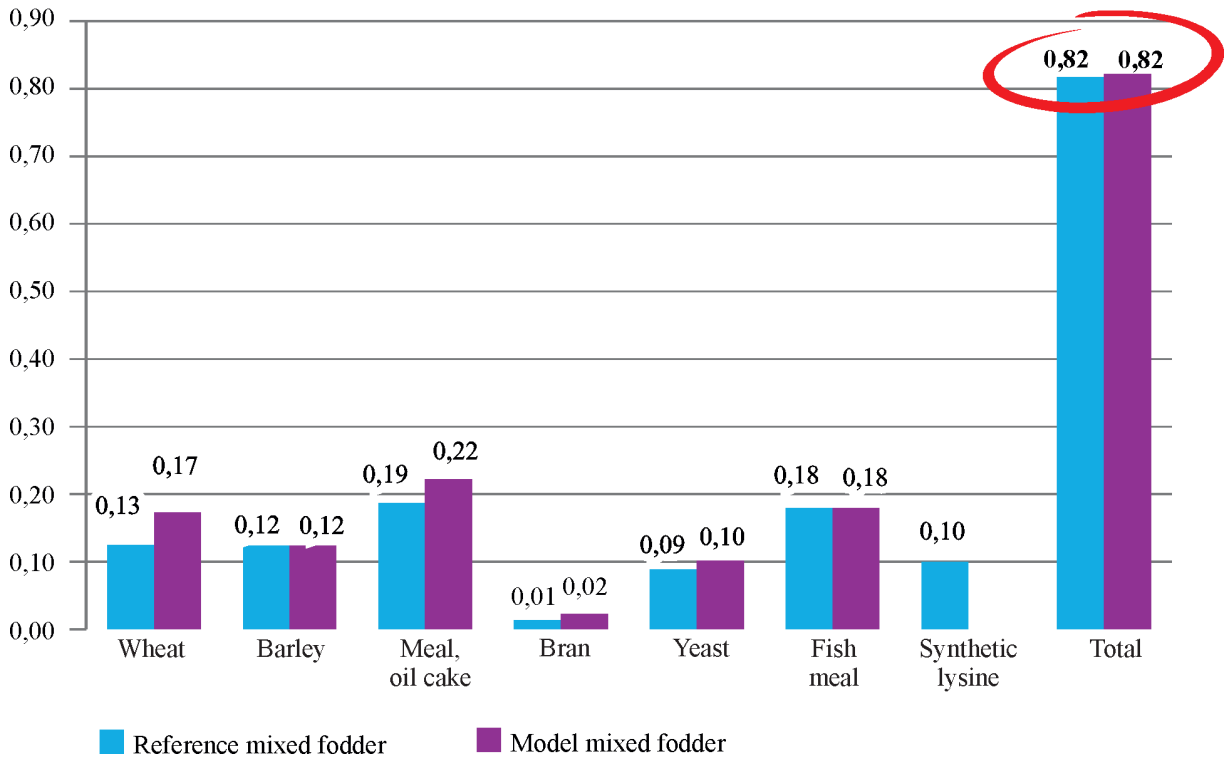

Рис. 2. Содержание лизина в справочном и модельном комбикормах для яичных кур (возраст 21–45 нед), %

Fig. 2. Lysine content in reference and model feeds for egg chickens (age 21-45 weeks), %

of pig production) model recipes of complete organic compound feed for growing pigs of different live weight (from 20-30 to 110-120 kg) were compiled (see Table 1).

The evaluated qualities of mixed fodders of all model formulas correspond to the basic norms of feeding growing pigs with the average daily growth for the whole period of fattening of 650 g.

The primary test of the effectiveness and safety for pigs of the experimental wheat feed additive was carried out at the pig farm of "Uchkhoz Tulinskoye" (Uchkhoz NSAU), Novosibirsk Region. The experiment was conducted on the piglets of EM-1 breed. Breeding sows of the control and experimental groups were selected with equal milk yield. Experimental piglets received 7% of the experimental wheat supplement in their diet. The amount of feed consumed per dry matter on average per one head of control and experimental piglets was equal. During the whole experiment (49 days) the piglets of the experimental group ate the feed noticeably more willingly than the piglets of the control group. The young piglets of the experimental group surpassed their counterparts of the control group in growth by 19,5%: average live weight of experimental piglets increased from 6,7 kg at the beginning of the experiment to 22,6 kg at the end, in the control group - from 6,6 to 19,9 kg (see Table 2) [17].

An experiment on preliminary evaluation of the feasibility of using the experimental wheat additive in the diet of quails reared for meat was carried out at the quail farm of the SibNIPTIZh SFSCA RAS.

The experiment was conducted for 6 weeks (42 days) according to conventional methods[12] on Japanese quails formed at the age of one day into two similar groups (control and experimental) with 45 birds in each group. The birds of both groups received full-rare mixed fodder prepared taking into account the age and physiological characteristics of the quails.

[12]Methodology of scientific and industrial research on the feeding of poultry: recommendations. VNIITIP. Sergiev Posad, 2004, 42 p.

Табл. 1. Модельные рецепты полнорационных комбикормов для растущих свиней различной живой массы

Table 1. Model formulations of complete feed for growing pigs of various live weights

*Significant at the 5% significance level	Composition of model mixed fodder, kg per 1 head per day						Daily consumption of mixed fodder per 1 head	
	Wheat additive	Barley	Dicalcium-phosphate	Chalk	Salt	Premix	natural humidity, kg	calculated per dry matter, kg
From 20 to 30	1,98	0,92	0,012	0,009	0,003	0,002	2,926	1,177
From 30 to 40	2,37	1,11	0,014	0,011	0,004	0,003	3,512	1,417
From 40 to 50	2,70	1,43	0,017	0,017	0,009	0,017	4,190	1,782
From 50 to 60	2,86	1,67	0,020	0,020	0,010	0,020	4,600	2,029
From 60 to 70	2,81	1,96	0,022	0,022	0,011	0,022	4,847	2,279
From 70 to 80	2,66	2,26	0,024	0,024	0,012	0,024	5,004	2,521
From 80 to 90	2,32	2,63	0,027	0,027	0,014	0,027	5,045	2,793
From 90 to 100	1,96	2,98	0,030	0,030	0,015	0,030	5,045	3,045
From 100 to 110	1,76	3,17	0,032	0,032	0,016	0,032	5,042	3,181
From 110 to 120	1,75	3,19	0,032	0,032	0,016	0,032	5,052	3,197

Note. Premix P51-I was used for piglets with live weight from 20 to 40 kg, premix P52-I for pigs with live weight from 40 to 120 kg; wheat premix moisture 82.3%; barley premix moisture 13.0%.

Табл. 2. Результаты испытаний экспериментальной добавки из пшеницы на поросятах

Table 2. Test results of an experimental wheat supplement on piglets

Indicator	Control group	Experimental group
Number of piglets in the group, heads.	10	10
Duration of the experiment, days	49	49
Live weight of one head, kg:		
at the beginning of the experiment	6,6 ± 0,6	6,7 ± 0,6
at the end of the experiment	19,9 ± 1,9	22,6 ± 2,6
Average daily gain, g	271 ± 36	324 ± 45*

*$p < 0,05$.

Табл. 3. Результаты испытаний экспериментальной добавки из пшеницы на перепелятах

Table 3. Test results of an experimental wheat additive on quail

Indicator	Control group	Experimental group
Number of quails in the group, heads	45	45
Duration of the experiment, days	42	42
Live weight of one head, g:		
at the beginning of the experiment	8,6 ± 0,2	8,6 ± 0,2
at the end of the experiment	139,8 ± 9,3	168,3 ± 7,8
Average daily gain, g	3,13 ± 0,21	3,80 ± 0,18*

*$p < 0,01$.

The diet of the young quail of the experimental group contained an experimental supplement of wheat (17.5% for quails aged 1-4 weeks and 18.0% for birds aged 5-6 weeks). Feed ingredients used in the diets of the experimental group birds corresponded to the list of feed raw materials approved for use in organic livestock production (see footnote 1).

According to the results of the experiment, the gain in live weight of the quails of the experimental group statistically significantly ($p < 0.01$) exceeded the gain in live weight of the control group by 21.4% (see Table 3). Biochemical blood parameters of the chicks were within the physiological norm.

Thus, according to the results of the experimental part of the work (primary practical experience based on the use of available laboratory equipment) it can be concluded that the developed wheat protein supplement is an appetizing feed for piglets and quail, has no adverse effects on their health, has a positive effect on productivity, so it can be used in further experimental studies on animals raised by the rules of organic

production.

CONCLUSIONS

1. Modern agronomic techniques fundamentally allow to carry out industrial production of wheat according to the norms of organic production in the zone of Western Siberia.

2. According to preliminary data, some wheat varieties of Siberian breeding are high in essential amino acids limiting for animals, so they are of practical interest for use in animal husbandry.

3. Bio-fractionation of wheat makes it possible to obtain a feed additive of effective quality for use in animal husbandry.

4. Experimental wheat additive is calculated applicable for fattening pigs raised according to organic production standards.

5. The search experiments performed give grounds for deepening the research on the creation and use of wheat additives in the organic production of livestock products in Siberia.

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НАРКОМЫ ЗЕМЛЕДЕЛИЯ ПЕРВОГО СОВЕТСКОГО ПРАВИТЕЛЬСТВА И НАЧАЛО РЕВОЛЮЦИОННЫХ АГРАРНЫХ ПРЕОБРАЗОВАНИЙ В РОССИИ (1917–1920 гг.)

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Представлен анализ деятельности первых советских наркомов земледелия в контексте переустройства аграрной экономики после революции 1917 г. Дано описание причин и особенностей земельного кризиса в России и его влияния на политическую жизнь. Проанализирован характер первых опытов преобразования сельского хозяйства на фоне революционных событий. Приход к власти в России радикальных революционных сил послужил причиной попытки проведения в жизнь проекта «социализации» земли, разработанного партией левых эсеров и поддержанного большевиками. Основу этого проекта составляли специфические представления социалистов о достижении прогресса в сельском хозяйстве лишь путем максимальной централизации аграрного производства и огосударствления земли, исключающего какое-либо частное землевладение. Отдельное место в описании занимает оценка советских законодательных актов, связанных с внедрением коллективных форм землеустройства и государственного управления сельской экономикой. Отмечено, что в течение первых трех лет развития революции были сделаны решительные шаги по реализации данного проекта. Однако практические результаты ясно обнаружили их утопичность. К 1921 г. развитие сельского хозяйства, как и других отраслей на основе огосударствления, привело к общеполитическому кризису в стране и необходимости введения нэпа. Освещена роль первых организаторов советской аграрной системы – наркомов земледелия РСФСР. Приведены некоторые биографические сведения о них, дана оценка их политических взглядов относительно способов решения земельного вопроса в стране. Статья дает оригинальную интерпретацию первых революционных преобразований аграрной экономики России, а также участия в них наркомов земледелия.

Ключевые слова: революция, Наркомат земледелия, Декрет о земле, В.П. Милютин, А.Л. Колегаев, С.П. Середа, крестьянство, сельскохозяйственное производство

PEOPLE'S COMMISSARS FOR AGRICULTURE OF THE FIRST SOVIET GOVERNMENT AND THE BEGINNING OF THE REVOLUTIONARY AGRARIAN TRANSFORMATIONS IN RUSSIA (1917-1920)

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Analysis of the activities of the first Soviet people's commissars of agriculture in the context of the restructuring of the agrarian economy after the Revolution of 1917 is presented. A

description of the causes and features of the land crisis in Russia and its impact on political life is given. The nature of the first experiments in the transformation of agriculture against the backdrop of revolutionary events is analyzed. As radical revolutionary forces came to power in Russia, the project of "socialization" of the land, developed by the Left Socialist Revolutionary Party and supported by the Bolsheviks, was attempted. The basis of this project was the specific ideas of socialists to achieve progress in agriculture only through the maximum centralization of agricultural production and the nationalization of land, eliminating any private land ownership. The assessment of the Soviet legislative acts related to the introduction of collective forms of land management and state management of the rural economy stands out in this description. It is noted that during the first three years of the revolution's development, decisive steps were taken to implement this project. However, the practical results clearly revealed their utopian nature. By 1921, the development of agriculture, as well as other sectors on the basis of governmentalization led to a general political crisis in the country and the need to introduce the New Economic Policy. The role of the first organizers of the Soviet agrarian system, the people's commissars of agriculture of the RSFSR, is highlighted. Some biographical information about them is given, and their political views on the ways of solving the land issue in the country are evaluated. The article provides an original interpretation of the first revolutionary transformations of the agrarian economy of Russia, as well as the participation of the people's commissars of agriculture in them.

Keywords: revolution, People's Commissariat of Agriculture, Decree on Land, V. P. Milyutin, A.L. Kolegaev, S. P. Sereda, peasantry, agricultural production

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Agrarian, or peasant, question is one of the most burning and urgent problems in the history of the Russian state. For decades, the question of land has been the subject of desperate clashes between various social groups, mass popular unrest and revolts, and heated disputes between political parties and their leaders. Ultimately, the problem of land tenure, on which the fate of the vast majority of Russia's population depended, became one of the main causes and the main motive of the 1917 Revolution.

After the abolition of serfdom in 1861, the development of contradictions in Russia's agrarian system proceeded along the line of confrontation between two alternative models: the peasant movement objectively expressed its struggle for the "American" (farmer's) way, i.e., for a decisive division of the landed estates and free existence of private producers; the tsarist government and landlords sought to guide the evolution of the agrarian system along the "Prussian" way with the preservation of large estates' latifundia. At the same time among the various semi-legal and illegal (revolutionary) party groups and associations there were desperate discussions about other models of agrarian development of the country. These were socialist projects that advocated the principles of equalized land distribution (Socialists- Revolutionaries) and collective (cooperative) forms of land use (Social Democrats).

The Provisional Government, which had assumed power in the country after the overthrow of the monarchy in 1917, was clearly aware of the importance of the urgent need for agrarian reform, without which further construction of

new democratic institutions in Russia was impossible. However, the extreme internal political conditions caused by the aftermath of the First World War, the aggravation of the food crisis and the unrestrained desire of peasants to arbitrarily divide the landed estates did not allow the new government in Russia to begin radical changes in the agrarian system. The Provisional Government confined itself to transferring the Cabinet lands to the State (March 25, 1917) and the estates (March 29). It also adopted a resolution urging the peasants to refrain from unauthorized seizures and promising to put the agrarian question to the decision of the forthcoming Constituent Assembly. In May 1917, "Regulations on Land Committees" were issued, on the basis of which local bodies (committees) were formed, which prepared materials on the land issue for the Constituent Assembly.

In October 1917 a new revolution took place in Russia. Power passed into the hands of the Bolsheviks headed by Lenin. From that moment the agrarian reform and the fate of the Russian peasantry began to depend entirely on the will and interests of the people of a radical political philosophy and worldview. Ultimately, this resulted in a chain of unforeseen, largely speculative social experiments with numerous popular casualties.

An important aspect of the analysis of the revolutionary consequences in the field of land relations is the question of the influence of specific figures on the events that took place. In this connection, it is necessary to turn to the personalities of the main initiators and executors of the Bolshevik land project and to a description of the role of the first commissars of agriculture in the implementation of the Soviet agrarian policy. The scientific literature on these individuals is quite diverse. Monographic works and articles show the participation of the commissars in the development of the first legislative acts in the field of agriculture, describe collisions and forms of struggle during the development of land decrees, and also note the tragic turns in the personal fate of the commissars [1-10]. At the same time, some biographical aspects, as modern historiography notes, remain poorly studied.

The first steps to transform agrarian relations in Russia are associated with the adoption of the Decree on Land at the Second Congress of the Soviet of Workers' and Soldiers' Deputies and the appointment of V.P. Milyutin to the post of the People's Commissar of Agriculture.

Милютин
Владимир Павлович
(1884–1937)

Vladimir Pavlovich Milyutin was born in 1884 in the village of Tugantsevo, Lgovsk District, Kursk Province, in the family of a village teacher. He had no complete higher education, studied at the law department of St. Petersburg University, later at the Moscow Institute of Commerce, but did not finish his studies due to a passion for revolutionary ideas and illegal political activities. He joined the Party of Social-Democrats in 1903 as a supporter of its Menshevist wing. Beginning 1911 Milyutin became a professional revolutionary and as a result underwent a whole chain of persecutions by the tsarist government: repeated arrests, five years of imprisonment, and was twice exiled. The February Revolution found him in Saratov. He became the first chairman of the Saratov Committee of the RSDLP (b) and the Soviet of Workers' and Soldiers' Deputies. In April 1917, as a delegate of the Saratov Bolsheviks, Milutin was sent to the April Party Conference and there was elected to the Central Committee. He then becomes comrade to the chairman of the Petrograd City Duma.

On the eve of the armed uprising in Petrograd on October 24, 1917, during the allocation of responsibilities among the members of the Central Committee, Milyutin was appointed organizer of the food business, and the next day - the Commissar of Agriculture of the first Soviet government.

The implementation of the agrarian reform in the country began on the second day of the revolution, October 26 (November 8, New Style), with the adoption of the Decree on the

Land. The decree was based on 242 local peasant mandates drawn up on the initiative of the Social Revolutionary Party even before the Bolshevik revolution, and contained two basic provisions. First, it declared "the abolition of private property forever" and the transfer of land into "the common property of the people"; second, it proclaimed the principle of "socialization" of land, i.e., the equalized distribution of land (at the labor or consumer rate). The Socialist Revolutionary slogan of "socialization" did not correspond to the program goals and demands of the Bolsheviks, but was only a political concession to the peasantry and its political party. This was pointed out by the leader of the Communists, V.I. Lenin. In November 1918 he said: "We Bolsheviks were opponents of the law on socialization of the land. But still we signed it because we did not want to go against the will of the majority of the peasantry. ... We did not want to impose on the peasantry the alien idea that the equalized distribution of land was useless. We thought it was better that the working peasants should see with their own eyes, bear it on their shoulders that the equalized division was nonsense... The division was only good for the beginning. It was supposed to show that the land was leaving the landlords, that it was going to the peasants. But it is not enough. The only way out is in the public cultivation of the land". [11].

The implementation of the program of "socialization" of the land was an inevitable condition for the peasants' support of the Bolshevik government. The fact is that the peasantry - the basic population of the country - was no longer willing to wait for any government decision. Already since the summer of 1917, everywhere the peasantry embarked on the path of self-acquisition and partition of the landed estates. No power could stop this enormous spontaneous process, so the first thing the Soviet government had to do was to legalize and bring within certain limits the destruction of the landed estates.

Under these conditions, the small apparatus of the Commissar of Agriculture sought to master the process and to give the peasant element any kind of organized character. In his memoirs V.P. Milyutin wrote: "Our first concern was, first of all, to contact the places. I remember that my main activity in these days consisted in sending out various kinds of emissaries to the places".

On November 3, a regulation was issued on the volost land committees, which were charged with the duty of "the speediest and most complete liquidation of all vestiges of serfdom" and the " land inventory". They also determined the area of arable land to be cultivated, allotted certain arable plots of land to villages and townships, etc. Subsequently, land committees were transformed into departments of the councils.

The entire period from 1917 to 1918 was filled with the implementation of the strengthening of new bodies with which it would be possible to regulate agriculture and connect the center with the regions.

A secondary comparative problem was the mastery of the central apparatus of the Ministry of Agriculture, where there was resistance, expressed in sabotage, strikes, refusal to work, etc." [12].

The efforts of the People's Commissar Milutin and his staff to implement the Land Decree were unexpectedly interrupted by extraordinary political events.

On November 4, 1917, Vikzhel (the All-Russian Executive Committee of the Union of Railwaymen), threatening a general strike, demanded that the Bolsheviks establish a "homogeneous socialist government," that is, a coalition government with the participation of all revolutionary parties and movements. This was a moment of exceptional importance, predetermining the fate of the revolution and of the country as a whole. An alliance of the Bolsheviks with the other socialist parties (Socialist Revolutionaries, Mensheviks, etc.) made it possible to substantially strengthen the social base of the revolution. Rejection of such a bloc inevitably doomed the country to aggravation of inter-party disagreements, deepening of the internal political crisis, and unleashing of the civil war.

For Lenin and his supporters, however,

compromises with the petty-Bourgeois parties on such a fundamental agenda as the question of power were absolutely unacceptable. Alliances with other leftist forces, even temporary ones, when power had already been won, were judged to be unacceptable concordance with "petty bourgeois democracy" and a betrayal of the revolutionary principles.

People's Commissar Milyutin saw the future in a different light. Not sharing the radicalism of the Bolshevik leadership, he announced his withdrawal from the Sovnarkom and the Central Committee of the RCP (b).

The further career of the former Commissar, who held the post for nine days, continued in less important positions. From May 1918 he became a member of the Presidium of the Supreme Soviet of the National Economy (VSNKh), from November - Deputy Chairman of the VSNKh and simultaneously a member of the Council of Labor and Defense of the Republic. In his new position, Milyutin was one of the key figures in the implementation of the overall governmentalization and centralization of economic management under the name of "Glavkism". During this period all industry and cooperation, as well as small handicraft production, was nationalized. As a basic element of the policy of "war communism", the system of "Glavkism" undermined internal production incentives and soon led to the paralysis of the country's economy. With the transition to the New Economic Policy, it was abolished.

Milyutin turned to party and diplomatic work. In 1922-1924 he was a representative of the Comintern in Austria and the Balkans. Then he was a member of the board of the People's Commissariat of the Workers and Peasants Inspection, from 1925 - deputy chairman of the Communist Academy. At the same time, he was writing scientific articles and books on relevant topics, in particular such major works as "Agrarian Policy in the USSR" (M.; L., 1926), "History of Economic Development of the USSR (1917-1927)" (M.; L., 1927), "The History of the Soviet Union (1917-1927)", "History of the Agrarian Policy in the USSR" (M.; L., 1926). (M.; L., 1928).

While serving in high positions in public administration and academia, V.P. Milyutin shared with this system all its major flaws and fallacies, supported and developed many unreasonable ideas. During the Civil War he was an active promoter of the policy of "war communism" and a supporter of coercive measures, including those against the peasantry. Supporting the Party's course for general collectivization of the village, he sharply criticized the prominent agricultural economists, representatives of the organizational and productive direction of economic thought - A.V. Chayanov, N.D. Kondratyev, N.P. Makarov and others, who defended the idea of preservation and support of individual peasant farms as family-labor type enterprises.

Eventually, Milyutin had to share the fate of those "saboteurs" with whom he had fought and denounced in the 1920s: on July 26, 1937, he was arrested and on October 29, 1937, the Military Board of the USSR Supreme Court sentenced him to death on charges of belonging to a counterrevolutionary right-wing organization. He was shot next day. He was rehabilitated in 1956.

Колегаев
Андрей Лукич
(1887–1937)

The leftist socialist-revolutionary Andrei Lukich Kolegaev was appointed the new People's Commissar of Agriculture. After the resignation of V. P. Milyutin. The nomination of this candidate for the Soviet government was an important concession of the Bolsheviks to the Left Socialist-Revolutionary Party, with which they had cooperated during the preparation and conduct of the October armed uprising in 1917. Kolegaev was a hereditary revolutionary, an active participant in a number of terrorist acts and expropriations. He was born in 1887 in Surgut, Tyumen Province, in the family of an exiled member of the Narodnaya Volya.

He was educated as a land surveyor and studied at the University of Kharkov, but did not graduate. He was expelled from the univer-

sity for his involvement in revolutionary activities, and then deported abroad. For seven years he lived in exile, where he also tried to continue his education, but was more engaged in party-political activities.

At the end of November 1917, A.L. Kolegaev was approved for the post of the People's Commissar of Agriculture. At the same time, the Collegium of the People's Commissariat, composed entirely of leftist social revolutionaries, was formed.

From that moment, the implementation of the Land Decree and the development of the accompanying agrarian laws passed completely into the hands of the Left Socialist Revolutionaries, so the period of land relations reform in the country from 1918 was called "leftist Socialist Revolutionary" [2]. The main content of the reforms at this stage of the revolution was limited to two main tasks: the final elimination of the old agrarian relations, which gave advantages to the landed estates, and the "socialization" of land, which meant its equal (equalized) distribution among the individual categories of the peasantry.

Having different views on the problem of land management, the Bolsheviks and the Leftist Socialist Revolutionaries were in complete agreement on one point: there should be no private ownership of land in Russia. On this basis, both parties strongly advocated the elimination of private farms, especially landowners' estates and large farms ("kulak") households, in which the peasant masses saw the main cause of their oppression and inequality.

On February 19, 1918 the main law of "socialization" was accepted. Like the Decree on Land, it once again proclaimed the "permanent abolition" within the RSFSR of all ownership of land, subsoil, water, forests and the like and the transfer of all land "without any redemption for the use of the working people". It was emphasized that "the right to use the land belongs only to those who work it with their own labor" (Article 3). It also established the order of distribution of the land fund for farming. The first to receive land were agricultural communes, then agricultural associations, followed by rural societies, and only in the last turn - individual families and individuals.

Thus, the first Soviet legislation clearly reflected the peasantry's deep aversion to that form of land ownership, which was associated with landlords and rural "exploiters", and at the same time expressed the peasants' desire to share land according to the "labor norm" as a peculiar type of "peasant's socialism".

However, when discussing the specific ways of implementing the law, the lines of political division immediately emerged. The question of who should have the right to use and dispose of the land became crucial. Who would implement the "foundations of equality and justice" in the division of land? The Leftist Socialist Revolutionaries advocated that the law on "socialization" should fix the rights of local self-government bodies, represented by land committees and zemstvos, which would be entrusted with the function of distributing the land fund. However, the Bolsheviks were against it. During the discussion of the law, they succeeded in eliminating the mention of land committees and zemstvos from the text, replacing them with councils, i.e., organs of state administration, which opened the way to consistent nationalization of the land.

The Leftist Socialist Revolutionary Party's hopes for the development of peasant self-organization and initiative were dashed in favor of the Bolshevik ideals of centralization and statism, with which the leaders of the RCP(b) linked their projects for building socialism in Russia. After the approval of the law, Kolegaev bitterly said: "It was not a law of socialization but a law of nationalization of the land." [quoted from: 1, p. 292].

In March 1918 a new political crisis broke out in Russia. As a result of the signing of the Brest-Litovsk peace treaty with Germany, the Left Socialist Socialist Revolutionaries withdrew from the government by decision of the Central Committee of their party. Declaration of withdrawal was also submitted by the People's Commissar Kolegaev. Leaving his post in the government, he did not completely break with the Bolsheviks and continued to work as

a member of the People's Commissariat board, heading its three departments at once. However, Kolegaev did not stay on this position. He was sent to Kazan, where he became chairman of the Gubispolkom, focusing on the redistribution of land and the liquidation of landlord property. Kolegaev joined the Bolshevik Party in November 1918.

During the following years A.L. Kolegaev remained an active member of various Soviet organizations. In January 1919 he was appointed to a responsible position in the Red Army as the Chief of Supply of the Army of the Southern Front, and then a member of the Revolutionary Military Council (RMC) of the front. At the same time Kolegaev energetically engaged in the collection of food in the Don for the central regions of the country: he led the formation of the food squads from the workers, and organized Prodrazverstka. Soon the measures of the Soviet power caused a wide dissatisfaction of the population. A major Cossack uprising began, which threatened to overthrow the Bolshevik power on the Don.

The Central Committee of the RCP (b) and the Revolutionary Military Council of the Republic took urgent measures. The commander of the Southern Front and the members of the Revolutionary Military Council, including Kolegaev, were replaced. In June 1919, by the decision of the Central Committee, Kolegaev was transferred to the post of the Chairman of the Central Department of military procurements. Later he became a member of the board of the People's Commissariat of Railways, then - a member of the Council of the Supreme Soviet of the National Economy. For some time, he also held a senior position in the Central Statutory Administration, and his last place of work was as manager of the "Uralsvetzvetmet" trust in Sverdlovsk.

The former Commissar's career and life were cut short in a period that is known from the biographies of thousands of other famous statesmen and ordinary Soviet citizens. In December 1936 Andrei Lukich Kolegaev was arrested on charges of counterrevolutionary activity and sentenced to execution. He was executed on March 22, 1937, on his birthday.

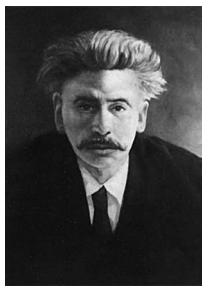
An important stage of the agrarian transformations of the Soviet power - the implementation of the program of "socialization" of land - is connected with the name of Kolegaev. This program led to two main results. First, private land ownership in the country was abolished and the most productive producers of agricultural goods - landlords, leasehold and "kulak" farms - were crushed. Second, millions of poor peasants gained access to land, which resulted in the social equalization of strata within the village by reducing the share of the upper (wealthy) and lower (landless) population groups.

However, the real picture of land redistribution turned out to be much worse than expected. As a witness to the events in the village wrote: "The enormous amount of land, divided among the mass of many millions of peasants, yielded negligible results. ... the increase of the area per eater is expressed in negligible amounts: tenths and even hundredths of a tenth per capita. In the vast majority of provinces this increase did not exceed half a tenth; only in a few did it reach one tenth".

Thus, the positive results of the partition for the small and landless strata of the peasantry were negligible. The negative results were extremely tangible. Large proprietary farms, which yielded high yields, were of great value and supplied the market with large quantities of products, were "torn apart," were destroyed" [2].

Such results of land management could not satisfy the Communist power. The Bolsheviks regarded the goals achieved as the completion of the "petty-bourgeois stage" of agrarian reform, to be followed by the "real" construction of socialism in the countryside through the introduction of collective forms of farming and state regulation of land relations.

The transition to new, "communist" forms of farming began in the summer of 1919, when the leadership of the Narkomzem was already in the hands of the Bolsheviks. The work of the People's Commissariat was headed by veteran party leader S. P. Sereda.



Середа
Семен Пафнутьевич
(1871–1933)

Semyon Pafnutievich Sereda was born in 1871 in Chernigov Province in the family of a railway employee. He finished real school in Smolensk. He was arrested for circle work. He lived in Kaluga, then in Smolensk. He was introduced into zemstvo statistics, which became his speciality. In 1903 he joined the Bolsheviks, was engaged in revolutionary propaganda. From 1901 to 1908 Sereda worked as head of the department in the Smolensk Province Zemstvo Board, later - in the same position in Ryazan.

After the February Revolution of 1917 he was a member of the Executive Committee of the Ryazan Council, and in April 1918 was appointed the People's Commissar of Agriculture. In this position he remained until 1921. He retired due to illness.

After leaving the government, Sereda held important positions in the state apparatus for several more years: he was the Deputy Chairman of the State Planning Committee, a member of the Presidium, then the Deputy Chairman of the Supreme Economic Council of the USSR, and the Head of the Central Statistical Office of the USSR. In the last years of his life (1930-1933) he was Deputy Chairman of the Council of People's Commissars of the RSFSR. Died on May 21, 1933.

Short but very turbulent period of the revolution, during which Sereda was the People's Commissar of Agriculture, was characterized by radical changes in the agrarian system of Russia in accordance with the economic program of the Bolsheviks. First of all, the liquidation of the consequences of the Leftist Socialist-Revolutionary "socialization" began. By administrative decisions of the People's Commissariat of Agriculture local land committees were abolished and replaced by the land departments of the executive committees of the Soviets of Deputies. By the end of the summer of 1918 the Central Land Committee was also abolished, along with the center of the leftist SR - the Peasant Section of the VTsIK (All-Russian Central Executive Committee). In September the first steps on nationalization followed. The estates, agricultural enterprises and land plots of national cultural, educational and industrial significance were transferred to state ownership. [13]. Even more decisive step towards governmentalization was made in December of 1918 at the congress of representatives of Land Departments, the Committee of Poor Peasants and communes. On the Bolsheviks' initiative the congress adopted a draft of a new land law, which clearly stated (Sections 1 and 2), that all the land belonged to the state and was under the direct control of the Narkomzem. In February, 1919 the All-Russian Central Executive Committee with some changes approved the draft of the law "On Socialistic Land Management and Measures of Transition to Socialistic Agriculture".

This specific document fully expressed the Bolsheviks' view of the type of agrarian arrangement which, in their opinion, best served the interests of the peasants and social progress, even if the peasants did not yet see it as beneficial to themselves.

The law stipulated that all land in the country, no matter whose use it was, was considered a single state fund, and was managed by the People's Committees and their subordinate local authorities. The best forms of land use were declared to be large state farms, communes and partnerships, "therefore, all kinds of individual land use should be regarded as passing away and obsolete"[1].

The reorganization of agriculture in Russia began on these principles. Already in May 1918 in the People's Commissariat of Agriculture the Bureau of Communes was established which summarized the experience of the first agricultural collectives and practically led their construction. The government allocated 10 million rubles for its activities. By the end of 1918 all the district and provincial land departments

[1]The Regulation on Socialist Land Management and Measures of Transition to Socialist Farming adopted by the All-Russian Central Executive Committee on February 14, 1919. http://www.libussr.ru/doc_ussr/ussr_442.htm.

also established Bureaus of Communes with the task of registering new communes and artels and controlling their work.

However, priority was given to the construction of state farms. Their socio-political role was seen in the fact that they would be the most progressive type of agricultural enterprises, a kind of model for all other participants in production, creating conditions for the mass transition of the rural economy to socialism. People's Commissar S. P. Sereda was the most ardent supporter and participant in the construction of state farms. Like other Bolsheviks, he shared the conviction that state farms, built on the basis of advanced former landed estates, were the key link in the agrarian reorganization of Russia; that under central state authority (Narkomzem) state farms would achieve the greatest success, since "only the center can determine which branch of agriculture needs possible development, and therefore which Soviet farms in what district should be strengthened, which tasks can be set for them". [2].

During 1919-1920 there was an intensive construction of state farms all over the country. In February 1919 there were 35 of them, and in the summer of 1920, there were 3076.

In parallel, collective farms were also created for the peasants. In 1918 there were 1579 collective farms with 16.4 thousand households, in 1919 - 6188 (81.3 thousand households), in 1920 - 10,600 collective farms (131 thousand households).

The most important task of the People's Commissariat of Agriculture of those years was the organization of the resettlement of peasants to the vacant outskirts. In particular, already by May 1918 the wave of resettlers in Trans-Urals reached 175 thousand people. Even the uprising of the Czechoslovaks and the resulting termination of ties with Siberia could not stop the movement of immigrants to the vast land of Siberia.

CONCLUSION

The era of the first Soviet transformations left a deep mark on Russia's agrarian history. It manifested itself as a difficult search for social reorganization of the country and normal living conditions for millions of people, where no serious reforms had been carried out for centuries at all. Under these conditions, the reorganization of the economy, including agriculture, was in the hands of the most radical revolutionary elements, and the reforms turned into a chain of continuous experiments with unpredictable results.

Collective forms of land use and centralized state management of agrarian production as the main elements of the new system did not bring positive results. Collective farms, state farms and communes created by the Bolsheviks turned out to be lifeless. Their activities quickly revealed the deep contradictions between the state interest and private initiative, the consequence of which was mismanagement, irrational management, cultivation of backward forms of production and general decay. At the end of 1920, all the main shortcomings of the Bolshevik project of economic reform became apparent. The next year the leaders of the RCP (b) had to change the economic course of the Soviet government and go to the New Economic Policy.

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ПЕРЕЧЕНЬ СТАТЕЙ, ОПУБЛИКОВАННЫХ В ЖУРНАЛЕ В 2022 г.

ЗЕМЛЕДЕЛИЕ И ХИМИЗАЦИЯ

РАСТЕНИЕВОДСТВО И СЕЛЕКЦИЯ

КОРМОПРОИЗВОДСТВО

ЗАЩИТА РАСТЕНИЙ

ЗООТЕХНИЯ И ВЕТЕРИНАРИЯ

МЕХАНИЗАЦИЯ, АВТОМАТИЗАЦИЯ, МОДЕЛИРОВАНИЕ И ИНФОРМАЦИОННОЕ ОБЕСПЕЧЕНИЕ

ПЕРЕРАБОТКА СЕЛЬСКОХОЗЯЙСТВЕННОЙ ПРОДУКЦИИ

ПРОБЛЕМЫ. СУЖДЕНИЯ

КРАТКИЕ СООБЩЕНИЯ

ИЗ ДИССЕРТАЦИОННЫХ РАБОТ

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.

REFERENCES:

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

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