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SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

УЧРЕДИТЕЛИ: СИБИРСКИЙ ФЕДЕРАЛЬНЫЙ НАУЧНЫЙ ЦЕНТР АГРОБИОТЕХНОЛОГИЙ РОССИЙСКОЙ АКАДЕМИИ НАУК
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ЗАВИСИМОСТЬ АГРОХИМИЧЕСКИХ И АГРОФИЗИЧЕСКИХ СВОЙСТВ ВЫЩЕЛОЧЕННОГО ЧЕРНОЗЕМА ОТ СИСТЕМЫ ОБРАБОТКИ ПОЧВЫ

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Представлены результаты исследований по изучению зависимости агрохимических и агрофизических свойств выщелоченного чернозема от системы обработки почвы. Работа выполнена в 2015–2019 гг. в длительном стационарном полевом опыте в посевах яровой мягкой пшеницы Сибирский Альянс. Почва опытного участка – чернозем выщелоченный среднемощный среднегумусный тяжелосуглинистый. Предшественниками пшеницы были чистый пар, сидеральный пар (рапс), сидеральный пар (донник). Изучены следующие системы обработки почвы: отвальная глубокая (контроль), комбинированная глубокая, комбинированная минимальная, отвальная минимальная. Отмечено преимущество по содержанию нитратного азота в почве до посева, в фазу кущения и колошения пшеницы по предшественнику сидеральный пар (рапс) при использовании отвальной минимальной системы обработки (осенью заделка сидеральной культуры БДТ-3). Установлено влияние системы обработки на содержание нитратного азота в почве в фазу кущения пшеницы – 15,5%, условий года – 12,9, взаимодействия данных факторов – 20,1%. Выявлена положительная взаимосвязь между содержанием нитратного азота в почве и количеством подвижного фосфора по предшественнику сидеральный пар (рапс), r = 0,7118–0,8917 (R = 0,9500). Высокие показатели содержания P_2O_5 (от 150 мг/кг и выше) отмечены в среднем за 5 лет в фазу колошения пшеницы – от 145,0 до 165,6 мг/кг. Максимальные значения P_2O_5 выявлены по сидеральному пару (рапс) при комбинированной минимальной и отвальной минимальной системах обработки почвы. Достоверное превышение содержания обменного калия в сравнении с контролем по средним показателям за 2015–2019 гг. отмечено при комбинированной глубокой системе обработки – 5,0 мг/кг ($НСР_{05}$). При остальных изучаемых системах обработки показатели находились на уровне контроля. Выявлены более высокие коэффициенты структурности при отвальной глубокой системе обработки (контроль) – 2,54, комбинированной минимальной – 2,47, отвальной минимальной – 2,23 по предшественнику сидеральный пар (рапс); по сидеральному пару (донник) – 2,98 (отвальная глубокая). При увеличении коэффициента структурности отмечено снижение показателя плотности сложения почвы, r = –0,3499 (R = 0,5760). Выявлена тенденция к снижению плотности сложения почвы до 0,98 г/см^3 по предшественнику сидеральный пар (рапс) при минимализации обработки почвы: комбинированной отвальной и минимальной отвальной; при отвальной глубокой (контроль) – 1,02 г/см^3. В результате корреляционного анализа установлено, что при увеличении плотности сложения почвы снижается содержание P_2O_5, r = –0,4898, K_2O, r = –0,2530.

Ключевые слова: яровая мягкая пшеница, система обработки почвы, предшественник, агрофизические свойства почвы, водопрочные макроагрегаты, плотность почвы, агрохимические свойства почвы

DEPENDENCE OF AGROCHEMICAL AND AGROPHYSICAL PROPERTIES OF LEACHED CHERNOZEM ON SOIL TREATMENT SYSTEM

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The results of research on the dependence of agrochemical and agrophysical properties of leached chernozem on the system of soil treatment are presented. The work was performed in 2015–2019 in a long-term stationary field experiment in crops of spring soft wheat Siberian Alliance. The soil of the experimental site is medium-powered medium-humus heavy-loamy leached chernozem. Wheat was preceded by clean fallow, green fallow (rape), green fallow (cloverleaf). The following tillage systems were studied: deep moldboard (control), deep combined, minimum combined, minimum moldboard. There is an advantage in nitrate nitrogen content in the soil before sowing, in the phase of tillering and earing of wheat on the preceding cereal fallow (rape) when using the minimum tillage system (in autumn the break crop BDT-3 is planted). The effect of the tillage system on the nitrate nitrogen content in the soil in the phase of bushing of wheat - 15,5%, conditions of the year - 12,9, the interaction of these factors - 20,1% was determined. A positive relationship between the content of nitrate nitrogen in the soil and the amount of mobile phosphorus on the precursor green fallow (rape), r = 0.7118-0.8917 (R = 0.9500), was detected. High P_2O_5 content (from 150 mg/kg and above) was recorded on average for 5 years during the earing phase of wheat - 145.0 to 165.6 mg/kg. Maximum P_2O_5 values were detected for green fallow (rape) under minimum combined and minimum moldboard systems. A significant increase in exchangeable potassium content over the control average for 2015-2019 was observed with the deep combined tillage system - 5.0 mg/kg (NSR_{05}). With the other tillage systems studied, the figures were at the control level. Higher soil pedality coefficients were revealed with a deep moldboard processing system (control) - 2.54, a minimum combined - 2.47, a minimum moldboard - 2.23 according to the predecessor green fallow (rapeseed); for green fallow (melilot) - 2.98 (deep moldboard). With an increase in the pedality coefficient, there was a decrease in the soil bulk density index, r = -0.3499 (R = 0.5760). A tendency was revealed towards a decrease in the soil bulk density to 0.98 g/cm^3 according to the predecessor green fallow (rapeseed) with minimization of soil cultivation: combined moldboard and minimum moldboard; with a deep moldboard (control) - 1.02 g / cm^3. As a result of the correlation analysis, it was found that with an increase in the soil bulk density, the content of P_2O_5, r = –0.4898, K_2O, r = –0.2530, decreases.

Keywords: spring soft wheat, soil tillage system, predecessor, soil agrophysical properties, waterproof macroaggregates, soil density, soil agrochemical properties

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INTRODUCTION

Agrochemical soil properties determine soil fertility [1,2].

Mineral nutrition is one of the main regulated factors used to target plant growth and development. A prerequisite for high crop productivity is an optimally balanced plant nutrition system [1–3].

During the mineralization of soil organic matter, nitrogen is mobilized through absorption by microflora and binding of ammonia [4, 5]. Nitrogen is one of the elements whose compounds play an enormous role in biomass creation, natural and anthropogenic systems functioning [6–8]. Optimization of mineral nutrition is closely linked to nitrogen uptake, transport and metabolism, which determines the size and quality of the crop. With sufficient nitrogen intake from the soil, plants accumulate considerable biomass during the tillering phase, when the numerical side of the crop is established during the 4th-5th stages of organogenesis in cereal crops (number of spikelets and flowers in the spike) [9].

Wheat experiences phosphorus deficiencies earlier than nitrogen deficiencies. It responds to additional phosphorus fertilization even before the tillering phase. If wheat is supplied with phosphorus before earing, its yield is not reduced even if no phosphorus fertilizer is applied in later phases[3].

The content of mobile forms of phosphorus and potassium is one of the most important agrochemical indicators of soil fertility. A good phosphorus supply improves carbohydrate metabolism, leads to the accumulation of sugars, which contributes to frost and winter hardiness, ensures economical use of moisture and increases drought tolerance of plants. A lack of available phosphorus slows down protein synthesis and increases nitrate nitrogen in plant tissues [10–12].

Optimum potassium availability in arable soils is one of the prerequisites for high crop productivity and sustainable agroecosystems [13, 14].

P.A. Chekmarev and P.V. Prudnikov, considering the role of potassium in farming, explain that fundamental, physiological-biochemical and ecological studies not only confirm the known, but also discover new functions of this element: it enhances the process of photosynthesis and assimilation of CO_2, promotes a greater accumulation of assimilants in the spare organs of plants [15].

Tillage in the farming system is regarded by many scientists as a powerful factor influencing its agrochemical and agrophysical properties. There are many examples of the effectiveness of minimum tillage systems and direct sowing in Russia. In the Novosibirsk region, the Rubin and Novomayskoye farms in Krasnozersky district and the Stepnoye farm in Iskitimsky district use the direct sowing technology on tens of thousands of hectares and produce high and stable yields annually [16].

Academician V.I. Kiryushin made a major contribution to the study of tillage methods and systems at different levels of intensification. Under his leadership at the Siberian Research Institute of Farming, stationary multifactorial experiments were set up in practically all soil and climate zones of the Novosibirsk Region[4].

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Generalization of the results of the conducted experiments has shown that under optimization of mineral nutrition of plants and phytosanitary situation the yield capacity of grain crops at different tillage from deep tillage to zero tillage on different types of soil (southern heavy loamy chernozem, ordinary heavy loamy chernozem, leached heavy loamy chernozem, meadow-chernozem soil) was not different[5].

The mechanical factors of structure formation are particularly strong during tillage. Tillage implements produce the greatest amount of macro-aggregate when the soil is physically ripe [17].

The purpose of the research is to study the dependence of agrochemical and agrophysical properties of leached chernozem on the tillage system.

MATERIAL AND METHODS

The work was carried out in a long-term stationary field experiment at the Kemerovo Research Institute of Agriculture, a branch of the Siberian Federal Research Centre of AgroBio-Technologies of the Russian Academy of Sciences.

The soil of the experimental plot is medium-powered medium-humus heavy-loamy leached chernozem with a humus content of 8.2% in the arable layer. The research was carried out in a four-field cereal fallow rotation (fallow - wheat - pea - barley) using the following tillage systems: mouldboard deep, combined deep, combined minimum, mouldboard minimum.

Tillage systems:

– mouldboard deep: annual main tillage for all crops - ploughing with plough PN-4-35 to a depth of 25-27 cm, spring moisture closure with BZT-1, C-11, pre-sowing cultivation with AKP "Leader-2,1";

– combined deep: annually for all crops shallow tillage to a depth of 25-27 cm with the KPG-250 subsurface cultivator, in spring moisture closure with BZT-1, C-11, pre-sowing cultivation with KPS-4,2;

– combined minimum: annually under all crops shallow main tillage to a depth of 12-14 cm with the KPG-250 subsurface cultivator, in spring moisture closure with BZT-1, C-11, pre-sowing cultivation with KPE-3,8;

– mouldboard minimum: annually, on forecrops, complete and green manure fallow autumn processing BDT-3, in spring direct sowing with a sowing complex.

Sowing in all variants was carried out with the Tom-5.1 seeding complex with a simultaneous application of 1.0 c/ha of ammophos ($N_{12}P_{52}$). Experimental plot area by tillage was 4720 m^2, record area - 100 m^2, four times repetition. The spring wheat variety Siberian Alliance was sown on three different predecessors: complete fallow, green fallow (rapeseed) and green fallow (melilot).

Soil moisture was determined by thermostatic weight method in a meter layer according to spring barley development phases[6], agrophysical properties of soil - according to N.A. Kachinsky method[7], bulk density or density volume (dv) - as the mass of absolutely dry soil (M) in the unit of soil volume (V) with all natural soil voids (g/cm^3) (dv = M/V). The density of the soil was set by layer, then calculated for a layer of 40 cm. The aggregate composition of the soil was determined by the method of N.I. Savvinov, which is based on the possibility of dividing the soil into fractions on sieves with holes of different diameters (see footnote 7).

Grain harvesting was carried out by solid harvesting using a Sampo-130 plot harvester. Grain yield figures are given for 100% purity and 14% moisture content according to GOST 13586.5-9368. Statistical processing of the obtained data was carried out by the method of analysis of variance according to B.A. Dospekhov[9] using computer programs of O.D. Sorokin[10].

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RESULTS AND DISCUSSION

Over the years of the study (2015-2019), the nitrate nitrogen content in spring soft wheat crops varied during the growing season (see Table 1). The specific behavior of nitrate nitrogen in the soil is such that its presence should be monitored annually before sowing. Nitrate nitrogen is in the soil solution, so its fluctuations in the arable layer during the growing season are significantly influenced by moisture conditions [18].

Over the years of the surveys, the average pre-sowing nitrate nitrogen content was 13.6 mg/kg soil in 2015, 2016 - 10.0, 2017- 21.8, 2018 - 12.0, 2019 - 11.9 mg/kg. The proportion of the influence of the conditions of the year on the nitrate nitrogen content before sowing - 48.6%, tillage system - 7.7% was detected.

Prior to sowing, $N\text{-}NO_3$ content averaged 10.6-17.5 mg/kg of soil in 5 years for the complete fallow preceding crop, with the advantage of minimum tillage systems - combined and mouldboard: 17.5 and 17.4 mg/kg of soil, respectively. This trend continues for the preceding green manure fallow (rapeseed) and green manure fallow (melilot). For rapeseed, a reliable advantage in $N\text{-}NO_3$ content was given by the minimum mouldboard tillage system, exceeding the control (deep tillage) by 2.1 mg/kg of soil (LSD_{05} = 1.83).

The content of nitrate nitrogen increased compared to the control for the forecrop with green manure fallow (melilot) at combined deep tillage by 2.1 mg/kg, combined minimum by 3.6 and mouldboard minimum tillage by 5.4 mg/kg.

The application of ammophos ($N_{12}P_{52}$) simultaneously with sowing and the nitrification processes in the soil increased the nitrate nitrogen content in the soil by the tillering phase of spring soft wheat. The highest content of $N\text{-}NO_3$ was noted for the forecrops of green manure fallow (melilot) and green manure fallow (rapeseed) when using the minimum tillage

Табл. 1. Содержание $N\text{-}NO_3$ в посевах яровой мягкой пшеницы Сибирский Альянс в слое почвы 0–40 см (2015–2019 гг.), мг/кг почвы

Table 1. The content of $N\text{-}NO_3$ in crops of spring soft wheat Siberian Alliance in the soil layer is 0-40 cm, mg/kg of soil (2015-2019)

Soil tillage system	Before sowing	Tillering phase	Earing phase
Complete fallow forecrop			
Deep mouldboard (control)	10,6	16,3	15,4
Deep combined	14,5	22,0	11,7
Minimum combined	17,5	22,2	14,3
Minimum mouldboard	17,4	21,8	14,9
Green manure fallow (rapeseed grass)			
Deep mouldboard (control)	12,5	19,9	14,5
Deep combined	13,7	20,6	14,5
Minimum combined	13,5	19,3	15,5
Minimum mouldboard	14,6	28,3	16,8
Green manure fallow (melilot)			
Deep mouldboard (control)	10,3	19,1	12,2
Deep combined	12,4	19,8	11,7
Minimum combined	13,9	21,7	13,6
Minimum mouldboard	15,7	27,9	11,9

Average by factors, $N\text{-}NO_3$, mg/kg of soil; tillage system: deep mouldboard - 14.5, deep combined - 15.7, minimum combined - 16.8, minimum mouldboard - 18.8; development phases: pre-sowing - 13.9, tillering phase - 21.6, earing phase - 13.9; forecrop: complete fallow - 16.5, green manure fallow (rape) - 17.0, green manure fallow (melilot) - 15.9; LSD_{05} by factors, mg/kg soil: tillage system - 1.83, forecrop - 1.59, development phases - 1.59.

system (in autumn the BDT-3 was embedded in the green manure fallow) - 27.9 and 28.3 mg/kg of soil, respectively.

Increased nitrate nitrogen content in the tillering phase was observed in 2015-2019 when combined deep and minimum tillage systems were used: for the forecrop complete fallow - 22.0-22.2 mg/kg soil, green manure fallow (rapeseed) - 20.6 and 19.3, green manure fallow (melilot) - 19.8 and 21.7 mg/kg respectively. In the mouldboard deep tillage system, the $N\text{-}NO_3$ content is 16.3-19.9 mg/kg of soil, depending on the predecessor. The effect of the tillage system on the nitrate nitrogen content in the soil during the tillering phase of spring soft wheat was 15.5%, the effect of the conditions of the year was 12.9, and the interaction of these factors was 20.1%.

The influence of the year's conditions was largely determined by moisture availability. A positive correlation has been established between the hydrothermal coefficient (HTC) during the vegetation period and the nitrate nitrogen content during the waxy maturity phase of spring soft wheat. For the complete fallow forecrop this correlation was observed in 2015-2018: r = 0.5315-0.9736* (* - hereafter in the text means above the confidence threshold), for rapeseed in 2017-2018 r = 0.3204-0.8690, for melilot in 2015-2016 r = 0.7313-0.9730*.

According to the 5-year averages (2015-2019), reliably high content of productive moisture in the soil layer 0-20 cm in the period of sowing was noted in the forecrops complete fallow and green manure fallow (rapeseed) at mouldboard minimum tillage - 29.7 mm, at mouldboard deep tillage (control) - 26.3 and 27.4 mm respectively (see Table 2).

According to the average values for 2015-2019 the highest content of productive moisture in the 0-20 cm layer of the soil was noted in the tillering phase for the forecrop green manure fallow (rapeseed) at mouldboard minimum tillage system (27,3 mm) compared to the control (mouldboard deep tillage, 22,7 mm), for the complete fallow forecrop at combined minimum - 25.4 mm (control - 20,2 mm). For complete fallow, the reserves of productive moisture in the minimum tillage system are higher by 3.2 mm compared to the control. For green manure fallow (melilot), stocks of productive moisture in all tillage systems are at the control level - 23.9-24.2 mm (control - 20.3 mm, LSD_{05} = 4.69). The results of the analysis of variance showed that the highest (21.3%) influence on the content of productive moisture in the root layer of the soil was caused by tillage systems, the influence of the forecrop was not established.

The annual precipitation in the phase of earing of spring wheat in the northern forest-steppe of the Kuznetsk Depression was noted. The content of productive moisture in the root layer of the soil on the average indicators for 2015-2019 is high enough for grain filling: 29.5 mm for complete fallow, 29.9 mm for green manure fallow (rapeseed), 31.0 mm for melilot. The influence of tillage system on the content of productive moisture in the tillering phase in the soil layer 0-100 cm - 4.6%, in the earing phase of this influence is not established.

The use of minimum technologies with the introduction of green crops and perennial grasses in the crop rotation, preservation of stubble backgrounds increases the biological activity of the soil in the rhizosphere, mineralization of organic matter with the release of available forms of nutrients, in particular nitrate nitrogen [19].

When spring soft wheat plants used nitrate nitrogen from heading stage to earing stage, its content decreased on average by 35.7% (from 21.6 to 13.9 mg/kg of soil). The effect of the tillage system on the nitrate nitrogen content in the soil during the earing phase was 10.7%, while the effect of the forecrop was not detected. The highest content of nitrate nitrogen was found in this phase with mouldboard minimum soil tillage system for rapeseed forecrop - 16.8 mg/kg of soil, control - 14.5 mg/kg.

The mobile forms of phosphorus practically do not move through the soil profile; therefore, its content in the root-containing soil layer (0-40 cm) is most important in assessing the availability of phosphorus in plants. Classification of soils in terms of the content of mobile phosphorus compounds in soils according to Chirikov is as follows: less than 20 mg/kg soil - very low content; 20 to 50 - low; 50 to 100 - medium;

Табл. 2. Запасы продуктивной влаги в посевах яровой мягкой пшеницы в слое почвы 0–20 см (2015–2019 гг.), мм

Table 2. Reserves of productive moisture in crops of spring soft wheat in the soil layer 0–20 cm (2015–2019), mm

Soil tillage system	Sowing	Tillering	Earing
Complete fallow forecrop			
Deep mouldboard (control)	26,3	20,2	27,7
Deep combined	25,8	21,4	31,1
Minimum combined	26,9	25,4	29,9
Minimum mouldboard	29,7	23,4	29,2
Green manure fallow (rapeseed grass)			
Deep mouldboard (control)	27,4	22,7	29,5
Deep combined	27,6	19,0	30,6
Minimum combined	27,7	21,3	30,8
Minimum mouldboard	29,7	27,3	28,8
Green manure fallow (melilot)			
Deep mouldboard (control)	24,8	20,3	30,4
Deep combined	25,5	23,9	30,5
Minimum combined	26,1	24,2	31,8
Minimum mouldboard	26,7	24,0	31,4

LSD_{05} by factors (sowing): tillage system - 2.0, forecrop - 1.74.
LSD_{05} by factors (tillering): tillage system - 4.69, forecrop - 4.06.
LSD_{05} by factors (earing): tillage system - 1.75, forecrop - 1.52.

100 to 150 - increased; 150 to 200 - high; over 200 mg/kg - very high [20].

The content of mobile phosphorus on average for 2015-2019 in the crops of spring soft wheat Siberian Alliance regardless of the forecrop is characterized as elevated: before sowing from 132.6 to 148.8 mg/kg soil, in the tillering phase from 137.4 to 150.0 mg/kg (see Table 3).

High P_2O_5 content (from 150 mg/kg and above) was recorded on average for 5 years during the earing phase, from 145.0 to 165.6 mg/kg. The maximum values were obtained for green manure fallow (rapeseed) with combined minimum soil tillage system - 160.6 mg/kg of soil - and mouldboard minimum - 165.6 mg/kg, with mouldboard deep (control) - 150.6 mg/kg. The share of the influence of the soil tillage system on the content of mobile phosphorus was 5.1% and that of the forecrop - 2.8%.

The high content of mobile phosphorus during earing stage - 161.6 mg/kg of soil (control - 151.0 mg/kg) was also observed with mouldboard minimum tillage system for the green manure fallow forecrop (melilot).

Correlation analysis based on our results showed a positive relationship between the content of nitrate nitrogen in the soil and the amount of mobile phosphorus on the forecrop of green manure fallow (rapeseed), r = 0.7118-0.8917 (R = 0.9500). In accordance with the increase of phosphorus availability, the microbiological activity of the soil increases and the content of nitrate nitrogen increases [21, 22].

The content of exchangeable potassium varied between the test variants. On average (2015-2019), the K2O content in mouldboard deep soil tillage system (control) was 107.8 mg/kg soil, combined deep tillage was 112.8, combined minimum tillage was 110.0, and mouldboard minimum tillage was 106.2 mg/kg (see Table 4).

A significant increase in the content of exchangeable potassium in comparison with the control was noted with the combined deep tillage system - 5.0 mg/kg (LSD_{05}), with the other

Табл. 3. Содержание P_2O_5 в посевах яровой мягкой пшеницы Сибирский Альянс в слое почвы 0–40 см по фазам развития растений (2015–2019 гг.), мг/кг почвы

Table 3. P_2O_5 content in spring soft wheat crops Siberian Alliance in soil layer 0–40 cm, mg/kg of soil, by plant development phases (2015–2019)

Soil tillage system	Before sowing	Tillering phase	Earing phase
Complete fallow forecrop			
Deep mouldboard (control)	132,6	137,4	154,8
Deep combined	140,0	143,0	152,4
Minimum combined	144,4	147,2	154,6
Minimum mouldboard	139,6	141,0	156,0
Green manure fallow (rapeseed grass)			
Deep mouldboard (control)	144,2	143,4	150,6
Deep combined	143,6	143,0	150,4
Minimum combined	147,0	147,6	160,6
Minimum mouldboard	139,8	147,2	165,6
Green manure fallow (melilot)			
Deep mouldboard (control)	148,8	149,2	151,0
Deep combined	141,6	142,4	145,0
Minimum combined	144,0	141,0	147,2
Minimum mouldboard	143,4	150,0	161,6

Average by factors, mg/kg of soil: P_2O_5, soil tillage system: mouldboard deep - -145.8, combined deep - 144.6, combined minimum - 148.2, mouldboard minimum - 149.4; development phases: pre-sowing - 142.4, tillering phase - 144.4, earing phase - 154.1; forecrop: complete fallow - 145.3, green manure fallow (rapeseed) - 148.6, green manure fallow (melilot) - 147.1; LSD_{05} by factors, mg/kg soil: tillage system - 3.23, forecrop -2.80, development phases - 2.80.

studied systems of cultivation indicators are at the control level. The influence of the tillage system on the exchangeable potassium content was 7.5%, that of the forecrop 18.5, and the interaction of these factors was 12.3%.

The content of exchangeable potassium increased during the vegetation period of spring soft wheat with the combined deep tillage system: by the forecrop complete fallow before sowing - 113.2 mg/kg, during tillering - 101.2, earing - 117.0 mg/kg, by the control - 108.8; 95.2; 106.2 mg/kg, respectively. The same tendency was found with the combined minimum tillage system: the excess to the control was 3.8-7.6 mg/kg of soil. For green manure fallow (rapeseed), the increase in exchangeable potassium content compared to the control was either absent or negligible under all tillage systems.

M.L. Tsvetkov and A.F. Kolesnikov note from their studies that the roots of melilot plants are able to assimilate hard-to-reach forms of plant mineral nutrients (potassium and phosphorus) from deep soil layers due to a well-developed root system. The content of mobile phosphorus and exchangeable potassium in the soil increases when sowing in the crop rotation on the preceding green manure fallow (melilot) [23].

According to the content of K_2O before sowing spring soft wheat on the green manure fallow (melilot) forecrop the advantage had the combined deep tillage system - by 4.2 mg / kg, the mouldboard minimum - by 6.4, the combined minimum - by 12.4 mg / kg (in the control - 107.6 mg / kg) in the tillering phase - by 6.6; 12.2; 8.0 mg / kg, respectively (control - 106.2 mg / kg).

Changes in the agrophysical parameters of the soil characterize the processes occurring in the soil under the influence of the system of its cultivation. When assessing the structural state of the soil, it was revealed that the average indicators for the content of agronomically valuable aggregates most resistant to the erosion effect of water (1-3 mm), depending on the conditions of the year, varied within insignificant limits: 2015 - 33.1%, 2016 - 34, 2, 2017 - 34.5, 2018 - 35.5, 2019 - 33.8% (see Table 5).

Табл. 4. Содержание K_2O в посевах яровой мягкой пшеницы Сибирский Альянс в слое почвы 0–40 см по фазам развития растений (2015–2019 гг.), мг/кг почвы

Table 4. K_2O content in spring soft wheat crops Siberian Alliance in soil layer 0–40 cm, mg/kg of soil, by plant development phases (2015–2019)

Soil tillage system	Before sowing	Tillering phase	Earing phase
Complete fallow forecrop			
Deep mouldboard (control)	108,8	95,2	106,2
Deep combined	113,2	101,2	117,0
Minimum combined	112,6	102,8	110,0
Minimum mouldboard	105,2	92,4	104,2
Green manure fallow (rapeseed grass)			
Deep mouldboard (control)	102,0	116,4	111,6
Deep combined	108,6	120,8	113,6
Minimum combined	105,6	104,0	110,4
Minimum mouldboard	89,0	105,0	111,0
Green manure fallow (melilot)			
Deep mouldboard (control)	107,6	106,2	116,0
Deep combined	111,8	112,8	116,0
Minimum combined	120,0	114,2	110,8
Minimum mouldboard	114,0	118,4	116,6

Average by factors, mg/kg of soil: K_2O, tillage system: deep mouldboard -107.8, deep combined - 112.8, minimum combined - 110, minimum mouldboard - 106.2; developmental phases: pre-sowing - 108.2, tillering phase - 107.4, earing phase - 111.9; forecrop: complete fallow - 105.7, green manure fallow (rapeseed) - 108.2, green manure fallow (melilot) - 113.7; LSD 05 by factors, mg/kg soil: tillage system - 4.39, forecrop -3.80, development phases - 3.80.

The influence of the soil cultivation system on the content of agronomically valuable aggregates is noted - 10.1%, the interaction of the soil cultivation system and the predecessor enhances this effect to 40.6%.

On average for 2015-2019, depending on the tillage system, the figures for the content of agronomically valuable aggregates are as follows: mouldboard deep tillage - 36.0%, combined deep tillage - 31.9%, combined minimum - 35.1, mouldboard minimum tillage - 34.0%; by forecrops: complete fallow - 32.9%, green manure fallow (rapeseed) - 34.5, green manure fallow (milelot) - 35.3%.

There is now a clear trend towards minimal tillage and direct seeding [24]. Tillage minimization did not worsen the state of soil aggregate composition: with combined minimum and mouldboard minimum systems, the number of agronomically valuable aggregates was at the control level (mouldboard deep). Soil texture can be characterized not only by the number of valuable aggregates, but also by the texture coefficient, which shows the ratio of agronomically valuable aggregates to the sum of the clumpy and dusty fractions. Higher coefficients of structure with mouldboard deep system (control) - 2,54, combined minimum - 2,47, mouldboard minimum - 2,23 on preceding green manure fallow (rapeseed) (see table 6).

An increase in the coefficient of soil structure for the complete fallow forecrop was found when using combined and mouldboard minimum tillage systems - 2.21 and 2.11 respectively, when using mouldboard deep tillage (control) - 1.66. The effect of the tillage system on the soil structure coefficient was 19.3% and that of the forecrop - 3.65. The greatest influence is determined by the interaction of these two factors - 34.4%. By applying organic matter, the use of green manure crops improves soil structure. For the preceding complete fallow (rapeseed) when using mouldboard deep soil tillage the coefficient of structure was 2.54 and for melilot it was 2.98.

With the increase of the coefficient of structure there was a decrease of the density of the soil, r = -0.3499 (R = 0.5760), which is important in assessing its agrophysical properties.

Табл. 5. Содержание агрономически ценных агрегатов (1–3 мм), % от воздушно-сухой почвы
Table 5. Content of agronomically valuable aggregates (1–3 mm), % of air-dry soil

Soil tillage system	2015	2016	2017	2018	2019
Complete fallow forecrop					
Deep mouldboard (control)	32,8	30,7	23,0	31,2	31,9
Deep combined	31,8	32,6	32,3	33,3	32,2
Minimum combined	33,9	35,8	34,4	36,0	36,2
Minimum mouldboard	29,8	34,4	37,2	34,1	34,4
Green manure fallow (rapeseed grass)					
Deep mouldboard (control)	32,4	32,0	39,6	37,7	38,1
Deep combined	29,7	33,8	31,1	31,9	31,6
Minimum combined	37,5	40,0	34,8	35,2	36,9
Minimum mouldboard	29,7	28,5	35,2	37,0	37,7
Green manure fallow (melilot)					
Deep mouldboard (control)	40,5	42,2	48,5	46,2	33,2
Deep combined	30,4	33,2	30,5	33,4	30,8
Minimum combined	32,7	31,6	33,6	34,6	32,9
Minimum mouldboard	36,2	36,1	34,4	35,2	29,9

Average by factors, %: agronomically valuable particles 1-3 mm: soil tillage system: deep mouldboard -36.0, deep combined - 31.9, minimum combined - 35.1, minimum mouldboard - 34.0; forecrop: complete fallow - 32.9, green manure fallow (rapeseed) - 34.5, green manure fallow (melilot) - 35.3; research year: 2015 - 33,1, 2016 - 34,2, 2017 - 34,5, 2018 - 35,5, 2019 - 33,8. LSD 05 by factors, mg/kg of soil: tillage system - 2.4, forecrop -2.1, years - 2.7.

Табл. 6. Коэффициент структурности почвы
Table 6. Soil pedality coefficient

Soil tillage system	2015	2016	2017	2018	2019	2015–2019
Complete fallow forecrop						
Deep mouldboard (control)	2,1	1,55	1,34	1,70	1,60	1,66
Deep combined	1,94	1,58	1,78	1,75	1,57	1,72
Minimum combined	2,1	2,24	2,15	2,15	2,39	2,21
Minimum mouldboard	1,58	2,1	2,68	2,05	2,16	2,11
Green manure fallow (rapeseed grass)						
Deep mouldboard (control)	1,97	2,39	2,78	2,32	3,22	2,54
Deep combined	1,58	1,62	1,44	1,47	1,56	1,53
Minimum combined	2,87	3,03	1,90	1,86	2,69	2,47
Minimum mouldboard	2,60	1,57	2,26	2,26	2,45	2,23
Green manure fallow (melilot)						
Deep mouldboard (control)	2,82	3,01	3,89	3,20	1,98	2,98
Deep combined	1,59	2,12	1,69	1,72	1,98	1,82
Minimum combined	1,75	1,82	1,75	1,78	2,00	1,82
Minimum mouldboard	2,28	2,08	2,19	2,25	1,60	2,10

Factor average, coefficient of structure, soil tillage system: deep mouldboard -2.39, deep combined - 1.69, minimum combined - 2.16, minimum mouldboard - 2.14; forecrop: complete fallow - 1.93, green manure fallow (rapeseed) - 2.19, green manure fallow (melilot) - 2.17; year of research: 2015 - 2,10, 2016 - 2,09 , 2017 - 2,15, 2018 - 2,04, 2019 - 2,10. LSD 05 by factors: tillage system - 0.30, forecrop -0.34, year - 0.26.

Табл. 7. Плотность сложения почвы (2015–2019 гг.), г/см^3
Table 7. Soil bulk density (2015–2019)

Soil tillage system	Soil density in the soil layer 0-40 cm
Complete fallow forecrop	
Deep mouldboard (control)	1,00
Deep combined	1,01
Minimum combined	1,00
Minimum mouldboard	1,04
Green manure fallow (rapeseed grass)	
Deep mouldboard (control)	1,02
Deep combined	1,05
Minimum combined	0,98
Minimum mouldboard	0,98
Green manure fallow (melilot)	
Deep mouldboard (control)	1,00
Deep combined	1,07
Minimum combined	0,98
Minimum mouldboard	1,02

Average by factors, soil density: tillage system: deep mouldboard - 1.01, deep combined - 1.04, minimum combined - 0.99, minimum mouldboard - 1.01; forecrop: complete fallow, green manure fallow (rapeseed) -1.01, green manure fallow (melilot) - 1.02. LSD 05 by factors: tillage system - 0.05, forecrop - 0.04.

The optimum equilibrium bulk density for the main subtypes of chernozems is 1.00-1.25 g/cm^3. At these values, it is possible to use minimum tillage technologies [25].

The bulk density of the soil was between 1.00 and 1.04 g/cm^3 for the complete fallow crop. An increase of 0.04 g/cm^3 was noted with the mouldboard minimum tillage system (see Table 7).

There is a tendency to reduce the bulk density of soil to 0,98 g/cm^3 on the forecrop green manure fallow (rapeseed) at minimum tillage: combined and minimum mouldboarding, and at mouldboard deep (control) - 1,02 g/cm^3. An increase in soil bulk density by 0.01-0.07 g/cm^3 was recorded for all studied forecrops when using a combined deep tillage system. The conditions of the year had a significant impact on soil bulk density - 55.9 %, the tillage system - 11.1 %. As a result of the correlation analysis it was found that a decrease in P_2O_5 content, r = -0.4898; K_2O, r = -0.2530, occurs with increasing soil bulk density.

CONCLUSIONS

1. The highest content of nitrate nitrogen before sowing of spring soft wheat in the forecrop of green manure fallow (rapeseed), green manure fallow (melilot), complete fallow when using the mouldboard minimum tillage system exceeded the control (mouldboard deep tillage) by 2.1; 5.4 and 6.8 mg/kg of soil, respectively.

2. The advantage in the content of N-NO3 during the tillering period of spring soft wheat was noted in the forecrop of green manure fallow (melilot) and green manure fallow (rapeseed) with the use of the mouldboard minimum tillage system (in the autumn it was embedded in green manure fallow BDT-3) - 27,9 and 28,3 mg/kg of soil, respectively. The influence of the tillage system on the nitrate nitrogen content in the soil during the bushing stage of the spring soft wheat was 15,5%, the influence of the conditions of the year was 12,9, and the interaction of these factors was 20,1%.

3. When spring soft wheat plants used nitrate nitrogen from heading stage to earing stage, its content decreased on average by 35.7% in the

experiment (from 21.6 to 13.9 mg/kg of soil). The effect of the tillage system on the nitrate nitrogen content in the soil during the earing phase was 10.7%; the effect of the forecrop was not detected. The highest nitrate nitrogen content was recorded under mouldboard minimum tillage for forecrop rapeseed - 16.8 mg/kg, the control - 14.5 mg/kg.

4. High P_2O_5 content (from 150 mg/kg and higher) was found on average for 5 years during earing phase, from 145.0 to 165.6 mg/kg; maximum values were obtained for green manure fallow (rapeseed) with combined minimum tillage - 160.6 mg/kg and mouldboard minimum - 165.6 mg/kg, with mouldboard deep (control) - 150.6 mg/kg of soil. The share of the influence of the tillage system on the content of mobile phosphorus was 5.1% and that of the forecrop 2.8%. A positive relationship between the content of nitrate nitrogen in the soil and the amount of mobile phosphorus on the forecrop green manure fallow (rapeseed), r = 0.7118-0.8917 (R = 0.9500) was revealed.

5. A significant increase in the content of exchangeable potassium compared to the control average for 2015-2019 was observed with the combined deep tillage system - 5.0 mg/kg (LSD_{05}), with the other studied systems the indicators were at the control level. The effect of the tillage system on the exchangeable potassium content was 7.5%, that of the forecrop 18.5, and the interaction of these factors was 12.3%.

6. The effect of the tillage system on the content of agronomically valuable aggregates most resistant to the erosive action of water (1-3 mm) - 10.1% was noted. The interaction of tillage system and forecrop increases this effect by up to 40.6%. On average for 2015-2019, depending on the tillage system, the rates of agronomically valuable aggregates content were as follows: mouldboard deep tillage - 36.0%, combined deep tillage - 31.9%, combined minimum - 35.1%, mouldboard minimum tillage - 34.0%; by forecrop: complete fallow - 32.9%, green manure fallow (rapeseed) - 34.5%, green manure fallow (melilot) - 35.3%.

7. Higher coefficients of structure at mouldboard deep tillage (control) - 2.54, combined minimum - 2.47, mouldboard minimum - 2.23 on the forecrop green manure fallow (rapeseed), green manure fallow (melilot) - 2.98 (mouldboard deep tillage) were noted.

8. The effect of the tillage system on the soil structure coefficient was 19.3% and that of the forecrop 3.65%. The greatest influence is determined by the interaction of these two factors - 34.4%. With the increase of the coefficient of structure there was a decrease of the bulk density of the soil, r = -0.3499 (R = 0.5760), which is important in assessing its agrophysical properties.

9. A tendency has been revealed to reduce the bulk density of soil to 0.98 g/cm^3 for the forecrop green manure fallow (rapeseed) with minimum tillage: combined and minimum mouldboarding tillage, deep tillage (control) - 1.02 g/cm^3. An increase in soil bulk density by 0.01-0.07 g/cm^3 was recorded for all studied crops when using a combined deep tillage system. Annual conditions had significant influence on the soil bulk density - 55,9 %, and the tillage system - 11,1 %. As a result of correlation analysis, it was found that P_2O_5 content, r = -0.4898, K_2O, r = -0.2530 decreases with increasing bulk density of the soil.

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СОВМЕСТНОЕ ИСПОЛЬЗОВАНИЕ БИОПРЕПАРАТОВ И РЕГУЛЯТОРОВ РОСТА ДЛЯ ПОВЫШЕНИЯ УРОЖАЙНОСТИ СОИ И ТОМАТОВ

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Приведены результаты исследований влияния средств защиты растений на культуры томата и сои в условиях Приморья. Изучение препаратов производили на районированных сортах томата Новичок и сои Приморская 86. Оценена эффективность различных комбинаций биопрепаратов на основе штаммов бактерий *Bacillus subtilis* Бактофит, Гамаир и регуляторов роста Циркон, Мивал-Агро. Препараты применяли для обработки семян и опрыскивания вегетирующих растений. Комплексная обработка Бактофитом обеспечивала снижение проявлений септориоза на томате на 3,9%, биологическая эффективность составила 22,1%. Регулятор роста Мивал-Агро (обработка семян и растений) обеспечил эффективность против фитофтороза на 36,8%. Наибольшая урожайность томата отмечена при обработке семян и растений препаратом Гамаир (20,0 т/га), прибавка к контролю составила 4,9 т/га. Максимальная эффективность (29,7%) против септориоза на сое зафиксирована в варианте Гамаир + Мивал-Агро. По вариантам опыта биологическая эффективность против пероноспороза составила от 21% (комплексная обработка Гамаиром) до 25,4% (Бактофит + Мивал-Агро). Применение всех препаратов положительно сказалось на росте и развитии растений сои. Самый большой прирост высоты растений в фазу полной спелости отмечен в варианте с применением Бактофита и Мивал-Агро (73,1 см), в контроле – 61,8 см. При использовании биопрепаратов и регуляторов роста масса 1000 семян достоверно увеличивалась по сравнению с контролем (176,2 г) на 13,5–22,0%. Высокие показатели урожайности по сравнению с контролем (1,8 т/га) достигнуты в варианте Бактофит с Мивал-Агро (2,7 т/га), прибавка составила 0,9 т/га.

Ключевые слова: томаты, соя, биопрепараты, регуляторы роста, болезни, структура урожая, урожайность

COMBINED USE OF BIOPREPARATIONS AND GROWTH REGULATORS TO IMPROVE SOYBEAN AND TOMATO YIELDS

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The results of research on the effect of crop protection agents on tomato and soybean crops under Primorye conditions are presented. The study of preparations was carried out on zoned varieties of tomato Novichok and soybean Primorskaya 86. The effectiveness of different combinations of biological preparations based on *Bacillus subtilis* strains Bactofit, Gamair and growth regulators Zircon, Mival-Agro was evaluated. The preparations were used for seed treatment and spraying of vegetative plants. Complex treatment with Bactofit provided a 3.9% reduction of septoriosis manifestation on tomato, the biological efficiency was 22.1%. Growth regulator Mival-Agro (seed and plant treatment) provided 36.8% effectiveness against late blight. The highest tomato yield was observed with the treatment of seeds and plants with Gamair (20.0 t/ha) with an increase of

4.9 t/ha compared to the control. The maximum efficiency (29.7%) against septoriosis on soybeans was recorded in the variant Gamair + Mival-Agro. The biological efficacy against peronosporosis ranged from 21% (Gamair complex treatment) to 25.4% (Bactofit + Mival-Agro). The application of all preparations had a positive effect on the growth and development of soybean plants. The largest increase in plant height in the phase of full ripeness was noted in the variant with the use of Bactofit and Mival-Agro (73.1 cm), in the control - 61.8 cm. Thousand-kernel weight increased with certainty by 13.5 – 22.0% in comparison with the control (176.2 g) after the usage of biopreparations and growth-regulating chemicals. High yield was achieved in the Bactofit + Mival Agro variant (2.7 t/ha), in comparison the control was 1.8 t/ha, the addition amounted to 0.9 t/ha.

Keywords: tomato, soybean, biological products, growth regulators, diseases, crop structure, productivity

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INTRODUCTION

Intensive farming is gradually leading to environmental degradation. Fertilizer and pesticide transformation products, which have mutagenic and toxic effects on living organisms, are accumulating in soil and water [1].

The demand for organic products is now increasing everywhere. The term 'ecological products', i.e. products produced according to ecological agricultural environmental management standards, has been adopted worldwide. The products must be inspected and labelled in accordance with established rules. The production of organic products is based on biological farming methods. This implies the reduction or complete rejection of synthetic mineral fertilizers and chemical plant protection agents with the maximum use of biological factors to increase soil fertility, suppression of diseases, pests and weeds that do not have a negative impact on the state of the natural environment. In this connection, interest in the use of microbiological advances in agriculture has increased [2, 3].

The use of growth regulators can increase the plant's resistance to negative factors. These include natural and synthetic organic compounds that in small doses actively affect plant metabolism, resulting in visible changes in growth and development [4, 5].

The use of biological plant protection agents is one of the main elements of modern technologies for phytosanitary optimisation of vegetable agrocenoses. Bacteria belonging to the genus *Bacillus*, especially *Bacillus subtilis* strains, are effective for biological control of many plant diseases caused by soil pathogens. Preparations based on *Bacillus* strains are characterized by high activity against phytopathogenic fungi, do not have a negative impact on the environment, contribute to the conservation and development of beneficial soil microbiota. The antagonistic activity of *Bacillus subtilis* is shown against a large number of pathogens, which allows to protect agricultural crops, especially those for which there are practically no effective means of protection, such as vegetable crops, as they are used mainly in raw form [6–9].

The use of biopreparations and growth regulators is an environmentally friendly method of increasing yields and product quality.

The purpose of the work is to obtain experimental data on testing biological preparations against diseases and growth regulators for presowing treatment of seeds and vegetative plants of soybeans and tomatoes, to determine the effect on productivity and yield.

MATERIAL AND METHODS

The research was conducted in 2018, 2019 on zoned varieties of tomato Novichok and soybean Primorskaya 86. Employees of the Biomethod Department of the Far Eastern Research Institute of Plant Protection (DVNIIZR) studied the effectiveness of bacterial preparations based on *Bacillus subtilis* bacteria strains (Bactofit, Gamair) and growth regulators (Zircon and Mival-Agro).

Bactofit is a microbial preparation (fungicide and bactericide) containing spores and cells of *Bacillus subtilis* culture, strain IPM-215. Bacteria of this species synthesize substances with antibiotic properties as well as growth-regulating components that enhance plant growth[1].

Gamair is a biological bactericide based on natural bacterium Bacillus subtilis, strain M-22 VIZR, has antibacterial and antifungal effect. It suppresses root rot pathogens, protects from mass manifestation of tracheomycosis wilt, various leaf and stem diseases. It reduces pesticide stress in plants [10].

Mival-Agro is a complex preparation containing an analogue of phytohormones from the auxin group in addition to a biologically active organosilicon compound. It has properties of cryoprotector and adaptogen. It effectively stimulates protein and nucleic acid synthesis. It stimulates root formation, reduces the degree of root rot. It does not interact with fertilizers and pesticides [11, 12].

Zircon (natural mixture of hydroxycinnamic acids and their derivatives) is a disease resistance inducer, seed germination activator, flowering stimulator. It reduces susceptibility to stress factors, increases crop yields. The active ingredient of the product belongs to plant phenols, isolated from the medicinal plant Echinacea purpurea [13].

In the experiment on tomatoes the seeds were soaked in the working solution of the preparations for 2 hours, in the variant with Zircon - 3 hours. The working fluid consumption was 1 l/kg of seeds. Vegetation spraying with biopreparations was carried out three times during the season. The first one was done 10 days after seedling planting in the open ground, the next ones were done with 10 days interval. The working solution consumption rate was 400 l/ha. Growth regulators spraying was carried out 1-2 days before seedlings planting in the ground, in the phases of the beginning of budding and flowering of 1, 2 brushes. The consumption rate of the working solution is 300 l/ha.

The soil of the experimental plot was meadow-brown podzolized with humus content of 2.4%, N-NO_3 - 8.2 mg/kg, P_2O_5 - 21.2 mg per 100 g of soil, K_2O - 55 mg per 100 g of soil, pH of the salt extract 4.5. The plot area was 5,6 m^2. Five variants of the experiment were carried out; triple replication, systematic placement. The sowing was carried out manually.

All records and observations in the field experiments were carried out according to the current methods and guidelines[2–4]. Tomato harvesting was carried out separately for each plot and the fractional composition of the crop was determined. In the soybean experiment, the preparation was processed one day before sowing by hand in a semi-dry method. For this purpose, the preparation was diluted in clean water (at the rate of 10 l/t) and, without letting the suspension settle, applied it to the seeds, which were then thoroughly mixed until the preparation was evenly distributed. The spraying was carried out during the phase of full sprouts and during the phase of budding - the beginning of flowering.

The soil of the experimental plot is meadow-brown, heavy loam by texture. Agrochemical characteristics of the soil are as follows: humus content 3.08-3.13%, easily hydrolyzable nitrogen - 9.5 mg/100 g, P_2O_5 - 14.12 mg/100 g, pH of the salt solution - 5.3. Tillage: autumn plow-

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ing to a depth of 22 cm, early spring harrowing, two tillage and pre-sowing tillage. Grain was the forecrop. No fertilizer was applied. Sowing of soybeans was carried out by SKS 6-10 seeder. Seed rate was 90 kg/ha.

There were five variants in the experiment, repeated four times, and the area of the plot was 10 m^2. The arrangement was randomized. Agronomic techniques of soybean cultivation in the experiment were common for Primorsky Territory (see footnote 4). Harvesting was done manually by variants in one pass. Sheaf samples were collected from two 0.25 m^2 (0.35 × 0.71 m) plots on each plot. The yield structure was determined under laboratory conditions.

All records and observations in the field experiments were carried out according to the current methods and guidelines, preparations were used according to the instructions, and the results were processed by analysis of variance (see footnote 4)[5,6].

RESULTS AND DISCUSSION

The weather conditions in the years of study were contrasting. The summer months of 2018 were characterized by an abundance of precipitation, with an uneven distribution over ten-day periods. August was the wettest. Summer temperatures were in line with the long-term average. The weather conditions in 2019 were unfavorable for crops in terms of precipitation. Particularly low rainfall occurred in June and July, when crop formation took place, which affected crop yields. August was the wettest, with 226.5 mm of precipitation during the month, which resulted in waterlogging of land. Temperatures were 0.6-3.8°C above the long-term average for each month.

The phytosanitary situation of the experiment allowed the efficacy of biopreparations and growth regulators to be observed. During the work, such tomato diseases as septoriosis, or white spot disease (*Septoria licopersici Speg.*), phytophthorosis (*Phytophthora infestans De Bary*) were identified. Septoriosis turned out to be the most harmful; its development in the variants was from 13.7 to 15.1%, while in the control it was 17.6% (see Table 1).

It was found that the complex treatment with Bactofit biopreparation provides a 3.9% reduction of septoriosis manifestation on tomato, the biological efficiency was 22.1%. Phytophthora development by variants was from 6.0 to 6.9%. The most effective treatment of seeds and spraying of plants with growth regulator Mival-Agro, where the biological efficiency was 36.8% while the development of the disease in the control was 9.5%.

The research revealed a growth-stimulating effect of the preparations. The treatment of seeds with biopreparations and growth regulators resulted in 3 days earlier emergence of seedlings and 4 days earlier formation of buds compared to the control.

The main indicator for the effectiveness of any agricultural practice is yield. The application of biopreparations and growth regulators had an impact on the productivity of tomato plants. When growth regulators were used, the increase was 3.7 t/ha (LSD_{05} = 2.5). The highest yield was observed when seeds and plants were treated with the biological preparation Gamair (20.0 t/ha), while the yield of the control was 15.1 t/ha (see figure). The increase with the use of biological preparations was 4.1 to 4.9 t/ha.

The effect of biopreparations and growth regulators on soybean plants showed that the preparations have a positive effect on soybean growth and development, duration of phenophases, productivity and yield. The soybean plants grew more quickly in leaf mass, and the duration of the interphase periods was reduced by 2-3 days.

According to the results of analysis of the experiment data, treatment of seeds and spraying of vegetative plants with biological preparations and growth regulators had a positive effect on the main indicators determining plant productivity. There was a significant (7-12 cm) difference in plant height in the phase of full ripeness compared to the control (61.8 cm) (see Table 2). All experimental variants gave a

[5]System of agricultural production in the Primorsky Territory. Edited by Chaika A.K. Novosibirsk, 2001. 364 p.

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

Табл. 1. Влияние обработок препаратами на фитосанитарное состояние томата (среднее за 2018, 2019 гг.), %

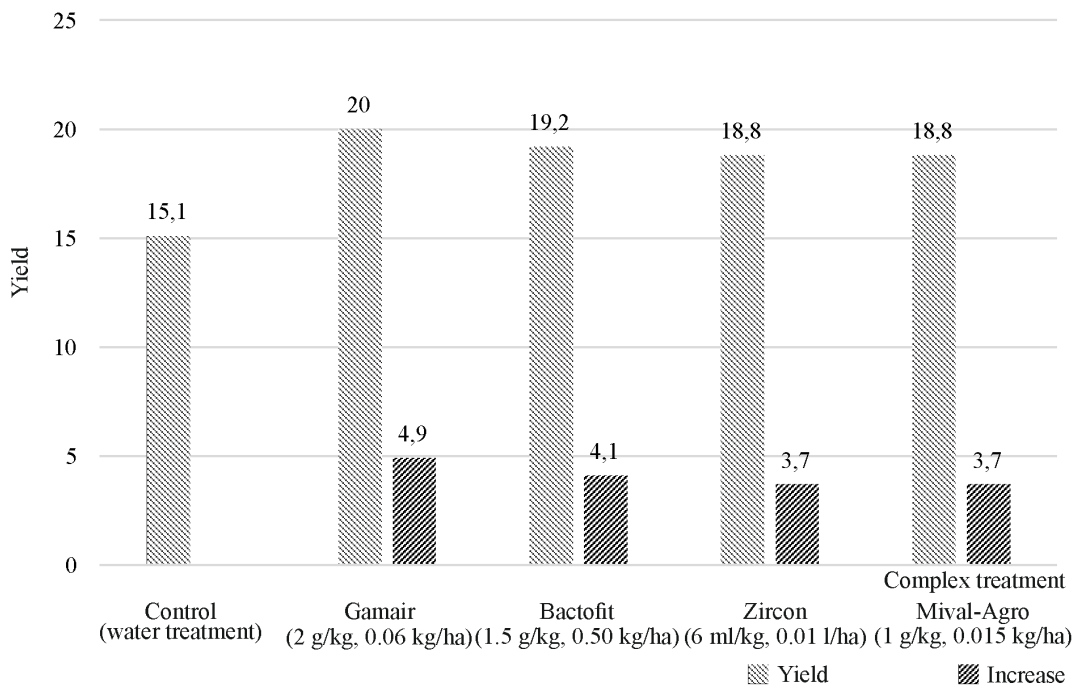
Table 1. The influence of preparation usage on phytosanitary state of tomato (mean value for 2018, 2019), %

Experiment option	Septoriosis		Phytophthora	
	Disease progression	Biological effectiveness	Disease progression	Biological effectiveness
Control (no treatment)	17,6		9,5	
Seed treatment (2 g/kg) and plant spraying with Gamair (0.06 kg/ha)	14,8	15,9	6,9	27,4
Seed treatment (1.5 g/kg) and plant spraying with Bactophyt (0.5 kg/ha)	13,7	22,1	6,3	33,7
Seed treatment (6 ml/kg) and plant spraying with Zircon (0.01 l/ha)	15,1	14,2	6,1	35,8
Seed treatment (1 g/kg) and spraying of plants with Mival-Agro (0.015 kg/ha)	14,1	19,8	6,0	36,8
LSD_{05}	1,5	2,0	1,7	0,9

significant increase in the number and weight of seeds compared to the control variant. The complex treatment with Bactofit stimulated an increase in the number of seeds per plant by 23 units and seed weight per plant by 2.0 g.

The 1000 seeds weight in all variants of the experiment reliably exceeded the indicator of the variant without treatment by 13.5-22.0% (LSD_{05} = 16.0 t/ha). The maximum weight was recorded in the variant with treatment of seeds with Bactofit and spraying of vegetative plants with Mival-Agro (215.0 g).

Simultaneously with the study of the effect on productivity, the preparations were evaluated for their ability to reduce the infestation of soybean plants with septoriosis (*Septoria gly-*



Урожайность томата при применении препаратов (среднее за 2018, 2019 гг.), т/га
Yield of tomato with preparation usage (mean value for 2018, 2019), t/ha

cines Hemmi) and peronosporosis (*Peronospora manshurica* (Naum.) Syd.) Treatment of soybean seeds with Gamair and spraying of Mival-Agro plants contributed to the reduction of septoriosis infestation by 8% (29.7% biological efficiency). Against peronosporosis the greatest biological efficacy had Bactofit + Mival-Agro (25.4%).

The yield record showed a significant increase in seed productivity of soybean in all variants of the experiment. The studied growth regulators and biological preparations provided increase of soybean yield due to increase of indicators of elements of yield structure and reduction of disease infestation. The increase of the soybean yield in comparison with the control amounted to 0.6-0.9 t/ha (see Table 3). The maximum soybean yield (2.7 t/ha) was obtained on the variant of complex application of Bactofit biopreparation with growth regulator Mival-Agro.

CONCLUSION

In the course of the research carried out under the conditions of Primorsky Territory, it was found that the use of biopreparations and growth regulators is promising for use on soybean and tomato plants. All the studied preparations inhibit the development of leaf spot disease during the growing season, have a positive effect on plant growth and development and significantly increase the crop yield. The highest yield of tomatoes was observed with the treatment of seeds and plants with the biological preparation Gamair (20.0 t/ha). The combined application of Bactofit with Mival-Agro promoted active plant growth and increased elements of structural analysis of soybean yield. The high indices of the yield were observed in the variant of treatment of the seeds with Bactofit with the spraying of the vegetative plants with the growth regulator Mival-Agro (2.7 t/ha) in comparison with the control (1.8 t/ha). The high efficiency of biological preparations was noted both when used together with growth regulators and when used separately.

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Табл. 2. Результаты структурного анализа продуктивности сои (среднее за 2018, 2019 гг.)
Table 2. The results of structural analysis of soybean productivity (mean value for 2018, 2019)

Experiment option	Plant height, cm	Number of seeds per one plant, pcs.	Seed weight per one plant, g	Weight of 1000 seeds, g
Control (no treatment)	61,8	43,3	4,4	176,2
Seed treatment (2.0 kg/t) and plant spraying (2 kg/ha) with Bactofit	70,4	65,7	6,3	213,7
Seed treatment with Bactofit (2.0 kg/t) and plant spraying with Mival-Agro (15 g/ha)	73,1	58,7	6,0	215,0
Seed treatment (30 g/t) and plant spraying (60 g/ha) with Gamair	68,8	60,1	6,0	208,7
Seed treatment with Gamair (30 g/t) and plant spraying with Mival-Agro (15 g/ha)	68,3	53,2	5,4	213,7
LSD_{05}	4,3	4,6	0,5	16,0

Табл. 3. Влияние биопрепаратов и регуляторов роста на урожайность сои (среднее за 2018, 2019 гг.)
Table 3. The influence of biopreparations and growth-regulating chemicals on soybean yield (mean value for 2018, 2019)

Experiment option	Yield, t/ha	Increase, t/ha
Control (no treatment)	1,8	
Seed treatment (2.0 kg/t) and plant spraying (2 kg/ha) with Bactofit	2,5	0,7
Seed treatment with Bactofit (2.0 kg/t) and plant spraying with Mival-Agro (15 g/ha)	2,7	0,9
Seed treatment (30 g/t) and plant spraying (60 g/ha) with Gamair	2,4	0,6
Seed treatment with Gamair (30 g/t) and plant spraying with Mival-Agro (15 g/ha)	2,5	0,7
LSD_{05}	0,1	

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АДАПТИВНЫЙ ПОТЕНЦИАЛ СЕЛЕКЦИОННЫХ ЛИНИЙ ЯРОВОГО ЯЧМЕНЯ В УСЛОВИЯХ КУЗНЕЦКОЙ КОТЛОВИНЫ

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Изучены адаптивные свойства ярового ячменя в условиях Кузнецкой котловины. Объекты исследований – пять среднеспелых селекционных линий ярового ячменя. Изучение селекционных линий проведено в питомнике конкурсного сортоиспытания в 2016–2020 гг. Почва опытного участка – выщелоченный чернозем, тяжелосуглинистый по гранулометрическому составу, средней мощности. Повторность четырехкратная, норма высева (оптимальная для ярового ячменя в зоне возделывания) – 450 шт./м^2. Срок посева 29 апреля – 5 мая, уборка комбайном Сампо 130 в фазу полной спелости образцов ярового ячменя (12–15 августа). Эксперимент проведен в сравнении со стандартным сортом Биом. Параметры экологической пластичности (b_i), стабильности (S^2d_i), индекс условий среды (Ij) рассчитаны по методике, разработанной S.A. Eberchart и W.A. Russel, где рассматривается положительный отклик генотипа на улучшение условий выращивания. При контрастных условиях выращивания ярового ячменя в годы проведения исследований установлено, что значительное влияние на урожайность имеет фактор среда – 82,6%, доля влияния генотипа составила 1,4%. Средняя урожайность за годы исследования ярового ячменя по питомнику конкурсного сортоиспытания составила 5,51 т/га, максимальный показатель средней урожайности имеет селекционная линия КМ-198/11 – 6,45 т/га. Выделены генотипы с наиболее высокими адаптивными свойствами: КМ-198/11 (b_i = 0,24, S_i^2 = 2,59), Nutans 12/16 (b_i = 0,24, S_i^2 = 2,18) при вариабельности урожайности 25,9–29,2% (стандарт Биом – 46,1%). Среднеспелая селекционная линия ярового ячменя КМ-198/11, имея адаптивные свойства выше средних показателей, подготовлена для передачи на государственное сортоиспытание в 2021 г. как сорт Кузбасский юбилейный. Выявлены основные достоинства сорта: высокая засухоустойчивость, устойчивость к полеганию и поражению головневыми грибами, высокая продуктивность (6,45–8,50 т/га), крупная зерновка (53,2 г), средняя степень реакции на стрессовые факторы (снижение продуктивности). Содержание сырого протеина в зерне 13,6–14,1%, пленчатость 8,4%, натурная масса 620 г/л.

Ключевые слова: яровой ячмень, селекционные линии, сорт, стабильность, пластичность, урожайность, агроэкологические условия

ADAPTIVE POTENTIAL OF BREEDING LINES OF SPRING BARLEY IN CONDITIONS OF KUZNETSK DEPRESSION

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Adaptive properties of spring barley in the conditions of the Kuznetsk depression have been studied. The objects of the research are five medium-ripening breeding lines of spring barley. The breeding lines

were studied in a nursery of competitive varietal trials in 2016-2020. The soil of the experimental plot is leached chernozem, heavy loam with a medium granulometric composition. The repetition was fourfold, the seeding rate (optimal for spring barley in the cultivation zone) 450 pcs / m^2. The sowing dates were April 29 - May 5, the harvesting was done with a Sampo 130 combine at the stage of full ripeness of spring barley samples (August 12-15). The experiment was carried out in comparison with the standard cultivar Biom. The parameters of environmental plasticity (bj), stability (S2dj), the environmental conditions index (Ij) were calculated according to the method developed by S.A. Eberchart and W.A. Russel, which examines the positive response of the genotype to the improved growing conditions. Under contrasting growing conditions of spring barley in the years of research, it was found that the environment factor had a significant influence on the yield - 82.6%, the share of genotype influence was 1.4%. The average yield over the years of the study of spring barley in the nursery of competitive variety trials was 5.51 t/ha, the maximum average yield has a breeding line KM-198/11 - 6.45 t/ha. Genotypes with the highest adaptive properties were identified: KM-198/11 (bi = 0.24, Si2 = 2.59), Nutans 12/16 (bi = 0.24, Si2 = 2.18) with yield variability of 25.9-29.2% (Biom standard - 46.1%). The medium-maturing selection line of spring barley KM-198/11, having above-average adaptive properties, is prepared for submission for state variety testing in 2021 as the variety Kuzbass Jubilee. The main advantages of the variety were revealed: high drought tolerance, resistance to lodging and blight, high productivity (6.45-8.50 t/ha), large grain size (53.2 g), medium reaction to stress factors (reduced productivity). Grain crude protein content was 13.6-14.1%, the film content 8.4%, the natural weight 620 g/l.

Keywords: spring barley, breeding lines, variety, stability, plasticity, yield, agroecological conditions

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INTRODUCTION

Spring barley is a key forage and fodder crop that generates higher yields than other cereal crops due to its early maturity and drought tolerance [1-3]. Barley grain is used for processing in the food and brewing industries [4, 5].

In Western Siberia with contrasting soil and climatic conditions it is necessary to cultivate varieties that can effectively use the bioclimatic potential in specific soil and climatic conditions [6]. Creation of high-yielding plastic varieties of spring barley will increase the efficiency of grain production, using the bioclimatic resources of the region [7].

Taking into account climatic factors and production demands, breeding for increased productivity and adaptability to local natural and climatic factors is currently relevant, especially in a changing climate [8–10]. The complex-

ity of yield formation lies in the interaction of multiple traits that appear during plant development under the influence of environmental conditions [11–13].

Successful varieties must be adapted to a wide range of environmental conditions in order to realize their genetic potential in a sustainable manner and to use their cultivation technology effectively. Differences in the response of varieties to changes in soil and climatic conditions are due to the interaction between the genotype and the environment. This interaction greatly complicates the process of selecting the best genotypes, so this information is of paramount importance in the breeding process [14, 15].

The aim of the research is to evaluate the breeding lines of spring barley for adaptability under the conditions of Kuznetsk Depression.

MATERIAL AND METHODS

The research was conducted in 2016-2020 at the Laboratory of Selection and Agrotechnics of Field Crops of the Kemerovo Research Institute of Agriculture - Branch of the Siberian Federal Scientific Centre of Agrobiotechnologies of the Russian Academy of Sciences (Kemerovo NIISKh - Branch of SFSCA RAS). The objects of the research are five medium-ripening breeding lines of spring barley. The breeding lines were studied in the nursery of competitive variety trials under the conditions of Kuznetsk Depression. Repeatability is fourfold, the location of plots is randomized, the accounting plot area is 15 m^2, the seeding rate (optimal for spring barley in the area of cultivation) is 450 pcs/m^2. The sowing date was 29 April - 5 May, harvesting by Sampo 130 combine in the phase of full ripeness of spring barley samples was conducted on 12-15 August. The counting and phenological observations of barley growth and development and yield accounting were conducted according to the method of M.A. Fedin, Y.A. Rogovsky, L.V. Isayev[1]. Statistical processing of the obtained data was carried out by methods of variation, correlation, variance analysis by the method of B.A. Dospekhov[2] in processing of computer programs by O.D. Sorokin[3].

The parameters of ecological plasticity (bj), stability (S2dj), environment index (Ij), theoretical yield (Xij) were calculated according to the methodology developed by S.A. Eberchart and W.A. Russel[4], which considers the positive response of the genotype to improved growing conditions.

The soil on which the research was conducted is leached chernozem, heavy loamy in granulometric composition, of medium thickness. The humus content is 8.0%, soil solution reaction is close to neutral, pH 6.0. N-NO_3 content in 0-40 cm horizon is 27.2 mg/kg, P_2O_5 is 128 mg/kg, K_2O is 98 mg/kg.

Spring barley yields are largely determined by the hydrothermal regime during the first vegetation period. In 2017, conditions during this period were defined as unfavorable (high temperatures and lack of moisture). Spring barley plants had a lack of moisture in the periods of sowing - sprouting and sprouting - emerging, HTC in May was 0.40, in June - 0.46 on the background of increased temperatures by one and three degrees, respectively (see Table 1). Precipitation in the second half of the growing season had a favorable effect on the further development of barley plants, HTC during earing - waxy ripeness is 1.8.

Unfavorable conditions in 2018 occurred during the growth and development of spring barley from sowing to full tillering with a decrease in average daily temperatures to 4.8 °C and a significant amount of rainfall (186% of the norm). A large overwetting was recorded in June and July, with HTC of 2.41 and 1.92, respectively. The harvesting period is characterized as favorable with low precipitation (33% of the norm, HTC = 0.42).

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Табл. 1. Метеоусловия в период вегетации ярового ячменя
Table 1. Weather conditions during the vegetation of spring barley

Indicator	Month				
	May	June	July	August	September
2017					
HTC	0,40	0,46	1,8	1,1	2,3
Precipitation amount, deviation from the norm, %	54	39	161	89	154
Average daily air temperature, deviation from the norm, °C	+1	+3	0	+1	–1
2018					
HTC	0,0	2,41	1,92	0,42	0,36
Precipitation amount, deviation from the norm, %	186	212	167	33	133
Average daily air temperature, deviation from the norm, °C	–3	+3	–1	0	+1
2019					
HTC	1,37	1,12	1,23	1,12	1,95
Precipitation amount, deviation from the norm, %	91	81	111	97	156
Average daily air temperature, deviation from the norm, °C	0	0	0	+2	+1
2020					
HTC	1,50	0,46	2,44	0,81	1,90
Precipitation amount, deviation from the norm, %	156	33	227	72	146
Average daily air temperature, deviation from the norm, °C	+4	–0,3	+0,4	+2,5	+0,6

Favorable conditions prevailed in 2019, with average daily temperatures in May, June and July in line with the long-term average.

In August, there was an increase in average daily temperatures by 2°C with moderate moisture content, HTC = 1.12-1.37. In 2020, lack of moisture was present during tillering - earing of spring barley, HTC = 0.46. In May, during the sprouting - heading period, high temperatures (4 °C above the norm) were accompanied by precipitation of 67 mm (156% of the annual average). During spring barley grain ripening period, significant overwatering was recorded, HTC = 2,44 (145 mm of precipitation) with average daily temperatures ranging from 16,7 to 21,4 °C (+0,4 °C to the norm).

RESULTS AND DISCUSSION

Under contrasting growing conditions of spring barley in the years of research, it was found that a significant influence on the yield has a factor of environment - 82.6%, the share of genotype influence was 1.4%. The analysis of environment indices revealed favorable years (2020 and 2019), when Ij was 1.09 and 1.96, and unfavorable years (2017 and 2018, Ij equal -2.7 and -0.33, respectively) (see Table 2). The average yield for the years of research of spring barley in the nursery of competitive variety trials was 5.51 t/ha, the maximum average yield has a breeding line KM-198/11 (6.45 t/ha). The average yield under different growing conditions characterizes the ability of plants to withstand the negative effects of the environment, i.e. the compensatory ability of genotypes, it is an indicator of genetic flexibility (GF) [16]. In agroecological conditions 2017-2020, breeding lines KM-209/11, Nutans 26/18 (GY = 5.52 t/ha), Nutans 12/16 (GY = 5.47 t/ha) have genetic flexibility, the Biom standard indicator is 5.00 t/ha. Compared with the standard, the KM-198/11 breeding line has the greatest genetic flexibility, with an excess in yield of 1.45 t/ha.

The regression coefficient bi was used to assess the adaptability of spring barley breeding lines. The selection line KM-198/11 had above-average adaptability, bi = 0.24, at high average yield in the experiment. The greatest responsiveness to improvement of environmental con-

Табл. 2. Влияние условий выращивания на продуктивность селекционных линий ярового ячменя
Table 2. Influence of growing conditions on productivity of breeding lines of spring barley

Variety, line	Yield, t/ha				Yield sum of the *i*-variety under *j*- conditions, $\sum Y_{i.}$ t/ha	Average variety yield in the j-year of experiment $Y_{i.}$ t/ha	Regression coefficient b_i
	Experiment year						
	2017	2018	2019	2020			
Biom, standard	2,0	4,4	7,0	6,6	20,0	5,00	0,31
KM-209/11	2,2	5,2	7,7	7,0	22,1	5,52	0,43
KM-198/11	4,9	5,3	7,1	8,5	25,8	6,45	0,24
Nutans 12/16	3,5	6,0	7,3	5,1	21,9	5,47	0,24
Nutans 26/18	1,8	5,6	7,8	6,9	22,1	5,52	0,47
Nutans 27/18	2,4	4,6	7,9	5,5	20,4	5,10	0,39
$\sum Y_{ij}$ (the yield sum of all varieties in the *j*- year of experiment)	16,8	31,1	44,8	39,6	132,3		
Yi – average variety yield in the j-year of experiment	2,80	5,18	7,47	6,60	22,0	5,51	
Ij – environmental index	–2,7	–0,33	1,96	1,09			

ditions was shown by samples KM-209/11 and Nutans 26/18, bi = 0.43 and 0.47, respectively.

The less variation in yield under the influence of external conditions, the higher the stress tolerance of the variety and the wider the range of its adaptive capacity. The response of breeding lines to external conditions was evaluated by the coefficient of variation (V, %). The breeding lines KM-198/11 (25.9 %), Nutans 12/16 (29.2%) and the standard Biom (46.1%) had the lowest rate of variability of yield in spring barley (see table 3). Yields in breeding line KM-198/11 ranged from 4.9 to 8.5 t/ha. The greatest influence of environment among breeding lines was observed in KM-209/11 (44.4%), Nutans 27/18 (44.6), Nutans 26/18 (47.8%). Stability coefficients (S_i^2) were calculated based on theoretical yield and deviations from actual yield values.

The high and most stable grain yield was observed in the breeding lines Nutans 12/16 and KM-198/11 (S_i^2 = 2.18 and 2.59 respectively), the Biom standard had S_i^2 = 4.23 (see Table 4).

The breeding line KM-198/11 with the highest yield among the genotypes studied has above-average adaptive properties (bi = 0.24, S_i^2 = 2.59).

The selection line of spring barley KM-198/11 has been prepared for state variety testing in 2021 as the variety Kuzbass Jubilee.

Spring barley Kuzbass Jubilee.

The variety of spring barley Kuzbass Jubilee was created in Kemerovo Research Institute of Agriculture (NIISKh) - a branch of SFSCA RAS. It was bred by individual selection from a hybrid population (KM-81 × Grosso) with breeding work on the selection of forms immune to dust brand with stable productiv-

Табл. 3. Вариабельность урожайности селекционных линий ярового ячменя
Table 3. Yield variability of breeding lines of spring barley

Variety, line	Parameter		
	Average variety yield in the j-year of experiment Yi, t/ha	Size of yield variation, (min-max), t/ha	Variation coefficient *V*, %
Biom, standard	5,00	2,0–7,0	46,1
KM-209/11	5,52	2,2–7,7	44,4
KM-198/11	6,45	4,9–8,5	25,9
Nutans 12/16	5,47	3,5–7,3	29,2
Nutans 26/18	5,52	1,8–7,8	47,8
Nutans 27/18	5,10	2,4–7,9	44,6

Табл. 4. Теоретическая урожайность и стабильность селекционных линий ярового ячменя
Table 4. Theoretical yield and stability of breeding lines of spring barley

Variety, line	Theoretical yield X_{ij}, t/ha				Deviation of the actual yield from theoretical $d_{ij,}$ t/ha				S_i^2
	Experiment year								
	2017	2018	2019	2020	2017	2018	2019	2020	
Biom, standard	4,16	4,90	5,60	5,34	–2,16	–0,5	+1,4	+1,26	4,23
KM-209/11	4,36	5,38	6,36	5,99	–2,16	–0,18	+1,34	+1,01	3,20
KM-198/11	5,80	6,37	6,92	6,71	–0,9	–1,07	+0,18	+1,79	2,59
Nutans 12/16	4,82	5,39	5,94	5,73	–1,32	+0,61	+1,36	–0,63	2,18
Nutans 26/18	4,25	5,37	6,44	6,03	–2,45	+0,23	+1,36	+0,87	4,33
Nutans 27/18	4,05	4,87	6,02	5,61	–1,65	–0,27	+1,88	–0,11	3,16

ity. The variety showed high resistance to dust brand (Ustilago nuda (Jens) Kell et Swing) and practical resistance to head smut (Ustilago hordei (Pers) Kell et Swing).

The variety belongs to the nutans variety group, a medium-maturing variety with a growing season of 85 days. The average yield is 6.45 t/ha and the maximum yield is 8.50 t/ha. The grain is large, the weight of 1,000 grains is 53.2 g, the number of grains in an ear is 20.9 units, productive tillering capacity is 1.9. It forms an aligned stem with a plant height of 86.8 cm, and is highly resistant to lodging and tilting of the ear (9 points). Crude protein content in grain: 13.6-14.1%; hoodness: 8.4%; natural weight: 620 g/l.

The main advantages of the variety are high drought tolerance, resistance to lodging and smut fungus, and high productivity. The variety reacts moderately to stress factors by reducing productivity.

CONCLUSION

As a result of a comparative study of spring barley selection lines in Kuznetsk Depression the most adaptive genotypes were singled out: KM-198/11 (bi = 0.24, S_i^2 = 2.59), Nutans 12/16 (bi = 0.24, S_i^2 = 2.18). The lowest rates of variability of the spring barley yield were observed for the selection lines KM-198/11 (25.9 %), Nutans 12/16 (29.2 %) and for the standard Biom - 46.1 %. The KM-209/11 (bi = 0,43) and Nutans 26/18 (bi = 0,47) samples had the greatest responsiveness to improvement of environmental conditions with a significant variation in yield depending on environmental conditions (V = 44,4-47,8%).

The selection line of spring barley KM-198/11 has been prepared for submission to state variety testing in 2021 as the Kuzbass Jubilee variety.

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Представлены результаты исследований по созданию нового сорта сои Горинская с использованием методов гибридизации и индивидуального отбора. В качестве исходного материала использованы сорта сои СибНИИК-315 (материнская форма) и Fiskebi V (отцовская). Исследования проведены в лесостепной зоне Западной Сибири (Новосибирская область). Соя Горинская относится к маньчжурскому подвиду. Растения имеют светло-коричневое (рыжеватое) опушение стебля, листьев, бобов. Характер роста и тип верхушки промежуточный, число ветвей – 1–3, угол отхождения ветвей – 20–30 град., куст сжатый. Высота до первого разветвления составляет 6–10 см, высота прикрепления нижнего боба 10–13 см. Бобы расположены равномерно по всему растению. Длина стебля равна 55–75 см, число междоузлий на стебле – 12–15. Соцветие представляет малоцветковую кисть из 3–5 цветков. Венчик имеет фиолетовую окраску. Бобы слабо изогнутые с заостренным кончиком, при созревании приобретают бурую окраску. Семена удлиненно-овальной формы, зеленовато-желтого цвета, без пигментации. Рубчик семени коричневый. Сорт зернового направления использования. Урожайность в конкурсном сортоиспытании достигала 29,4 ц/га. Масса семян с одного растения составляет 10–12 г, масса 1000 семян – 150–160 г. Число семян в бобе 2–3, среднее число бобов на один продуктивный узел – 2–3. Содержание белка в семенах составляет 35–38%, жира – 17–19%. Продолжительность вегетационного периода равна 100–105 дней. Сорт среднеустойчив к болезням, холоду, засухе, засолению почвы. В 2018 г. сорт сои Горинская включен в Государственный реестр селекционных достижений, допущенных к использованию в Российской Федерации по Восточно-Сибирскому региону.

Ключевые слова: соя Горинская, селекция, сорт, гибридизация, отбор

NEW CULTIVAR OF SOYBEAN GORINSKAYA

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The paper presents results of research into breeding of the new soybean cultivar Gorinskaya by the methods of hybridization and individual selection. Soybean varieties SibNIIK-315 (female parent) and Fiskebi V (male parent) were used as a starting material. The studies were carried out in the forest-steppe zone of the Western Siberia (Novosibirsk region). Soybean Gorinskaya belongs to the Manchu subspecies. The plants have a light brown (reddish) pubescence of the stem, leaves, beans. The growth pattern and the type of apex is intermediate, the number of branches is 1–3, the angle of branching is 20–30 degrees, the bush is compressed. The height to the first branch is 6–10 cm, the attachment height of the lower pod is 10–13 cm. The beans are distributed evenly throughout the plant. The length of the stem is 55–75 cm, the number of internodes on the stem is 12–15. The

inflorescence is a small-flowered raceme of 3-5 flowers. The corolla is purple in color. The pods are slightly curved with a pointed tip; when ripe, they acquire a brown color. The seeds are elongated-oval, greenish-yellow in color, without pigmentation. The seed hilum is brown. The cultivar is the grain variety for use. The yield in the competitive variety testing reached 29.4 c / ha. The mass of seeds per plant is 10–12 g, the mass of 1000 seeds is 150–160 g. The number of seeds per pod is 2-3; the average number of pods per 1 productive node is 2-3. The protein content in seeds is 35-38, fat – 17-19%. Duration of the vegetative period is 100-105 days. The cultivar is medium resistant to diseases, cold, drought, and soil salinity. In 2018, the Gorinskaya soybean variety was included in the State Register of Breeding Achievements Approved for Use in the Russian Federation for the East Siberian region.

Keywords: Gorinskaya soybean, breeding, cultivar, hybridization, selection

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The authors declare no conflict of interest.

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is the most common legume crop in the world, grown in more than 90 countries. It is an important source of protein and oil for food, feed and technical purposes and is therefore used in various industries [1-4]. The leaders in soybean production are the United States and Brazil, which grow two thirds of the world's soybean production [5].

At present, Russia's soybean production is clearly insufficient, as evidenced by the steady increase in soybean imports: from 65,000 tons in 2000 to 2.05 million tons in 2015. The reserves available in Russia are sufficient to increase the cultivated area to 5-6 million hectares, which will provide up to 7 million tons of commercial raw materials [6]. In the forest-steppe zone of Western Siberia, soybean can be cultivated on an area of about 250,000 ha and receive a guaranteed yield of 15 c/ha[1] [7-10]. As of 2020, 257 soybean varieties are registered in the State Register of Varieties of the Russian Federation, 13 of which are of Siberian selection. However, the current varieties do not fully meet the modern requirements of the agro-industrial complex. Growth of soybean production in Russia can be achieved not only by expanding the area under this crop, but also by creating new high-yield varieties.

Soybean varieties adapted to growing in the forest-steppe zone of Western Siberia are determined by the biological characteristics of the crop: requirements for thermal conditions, moisture supply, light, mineral nutrition. In addition, soil and climatic conditions are important for this crop. The forest-steppe zone of the West Siberian region is characterized by a short frostless period, a long duration (up to 17 hours) of the summer day, under which many soybean varieties significantly outgrow their generative development and lengthen the growing season, not having time to form a yield of mature seeds. Favorable average daily temperatures for germination of soybean seeds in the soil, emergence and growth of seedlings, budding and flowering, formation of beans and seeds, and maturation are provided in this region during the beginning of the third decade of May and the second decade of September. The duration of this period is about 115 days, the sum of temperatures above 10 °C is not less than 1800 ºC., i.e. the growing period from sowing to ripen-

[1]Kashevarov N.I., Gorin V.E., Polyudina R.I. et al. Cultivation of soybean in Western Siberia: recommendations. Novosibirsk, 1999. 74 p.

ing should not exceed 115 days. Varieties that do not reach full maturity before the onset of low positive average daily temperatures will be severely reduced or fail to yield mature seeds when regular frosts occur.

The main methods of variety development are intra-specific and distant hybridization and individual selection[2] [11–13].

The purpose of the research is to create a new high-yielding variety of soybean adapted to Siberian conditions.

MATERIAL AND METHODS

The research was conducted at the central experimental base of the Siberian Research Institute of Fodder Crops, SFSCA RAS, located in the forest-steppe zone of the Novosibirsk Region (Krasnoobsk settlement).

The soil of the experimental plots is medium-loamy leached chernozem, pH 6.6. The content of humus in the soil is 5.2%, easily hydrolysable nitrogen - 7.7 mg/100g soil, mobile phosphorus - 15.0, potassium - 16.0 mg/100g soil.

SibNIIK-315 and Fiskebi V soybean varieties were used as starting material. The main methods of creating promising breeding material were hybridization and individual selection.

Nurseries were planted according to generally accepted methods. In the hybrid and breeding nursery, the plants were sown and harvested manually and the number of plants per plot was counted.

In the control nurseries and competitive varietal trials, the plot area was 25 m^2, the arrangement was systematic, the repetition was four times. Sowing was carried out with a seeder CH-16. We sowed 700 thousand germinated seeds per 1 hectare by wide-row method. Plants were harvested by Sampo (Rostov) combine. Before harvesting, sheaf samples from 1 m^2 were taken from the trial sites. Seed productivity and its elements from each plant were determined. The standard was the variety SibNIIK-315.

Phytopathological surveys were carried out by the plant immunity group. Snedekor application software package was used for statistical data processing.

RESULTS AND DISCUSSION

Intraspecific hybridization of soybean to expand the genetic variability available for selection is an effective method in breeding this crop (see footnote 2) [11]. The study of flowering biology and improvement of hybridization technique allowed the use of this method of breeding to significantly expand the genotypic diversity of soybean breeding material by involving geographically distant forms in crosses. When selecting pairs for crossing, it should be taken into account that hybrids whose parental forms differ significantly in the maximum number of plant productivity elements give the highest rates of seed mass transgression from one plant[3].

According to the classification adopted in Europe and the USA, soybean varieties are divided into 10 groups according to the length of the growing season. When breeding soybeans for Western Siberia conditions, varieties with high adaptability and a vegetation period of no more than 110 days are of particular interest.

The duration of the germination-to-ripening period is determined to a large extent by the length of the germination-to-flowering period and to a lesser extent by the length of the flowering-to-ripening phase. The period from germination to flowering is noticeably longer with decreasing temperature sum, increasing relative humidity, increasing nitrogen nutrition, growing on a long bed and increasing the feeding area. In general, the phenotypic expression of the growing season size is 70% determined by hereditary characteristics of the variety and only 30% by all other factors[4]. According to G. Johnson and R. Bernard (cited in footnote 2), genetic and phenotypic correlations between growing season length and seed yield have a significant positive relationship.

[2]Enken V.B. Soybean. Moscow: Selkhozgiz, 1959. 619 p.

[3]Vashchenko A.P., Mudrik N.V., Fisenko P.P., Zaostrovnykh V.I. Soybean breeding in Primorye. Breeding and agrotechnics of field crops in Priamurye: Collection of scientific works. Novosibirsk, 1987 pp. 45-47.

[4]Korsakov N.I. Soybean (systematics and basics of breeding): thesis of Doctor of Science in Agriculture. L.: VIR, 1973. 44 p.

In order to create promising source material for breeding, crosses were carried out in 1994 where the best registered variety SibNIIK-315 was used as the female parent. The male component was represented by the variety Fiskebi V. Among the soybean varieties studied in the collection nursery, this variety was selected due to its high seed productivity and its constituent elements [14].

The first elite plants of this combination were isolated in a hybrid nursery in 1997. In 1998-2001, their study was continued in breeding nurseries. Selections were carried out in the field and laboratory conditions on the complex of traits: seed productivity and its constituent elements, the duration of the growing season, resistance to adverse environmental factors. Much attention was paid to the traits determining the manufacturability of soybean cultivation: the height of the bottom bean, resistance to bean bursting, lodging of plants, etc. Then, the study of the line named SNK-147 was continued in the control and competition nurseries, where it also showed high indicators of economically useful and morphobiological traits and properties (see Table 1).

Grain yields in 2010-2020 ranged from 16.0 to 29.4 c/ha, consistently exceeding the standard by 7-26%. The duration of the growing season ranged from 88 to 120 days, exceeding the standard by 5-17 days. On average, this line matured in 107 days during the 11 years of study, thus falling into the early maturing group (see the figure).

Increasing the protein and oil content of soybean seeds is one of the main focuses of breeding programs. Due to the quality and quantity of proteins, their balance in amino acids, high digestibility, and low cost of production, soybean ranks among the world's top protein-oil crops in terms of seed production. Soybean oil is similar in nutritional value to sunflower oil, but slightly inferior to cow's oil. The line we have created exceeds the standard in protein and fat production by 0.9 and 0.6 c/ha, respectively, or 14 and 17% (see Table 1).

Diseases are a major detriment to soybean yields. Only highly resistant varieties can ensure low disease incidence and a natural increase in soybean productivity. Infestation of soybean plants with downy mildew (peronosporosis) can reduce seed yields by up to 50%. This disease was first detected in the fields of the Siberian Research Institute of Fodder Crops in 2004. The reduction in soybean grain yield when affected by pustular bacteriosis reaches 22%, and by bacterial spot 27%[5].

A phytopathological study of the variety SNK-147 in the nurseries of competitive variety trials showed that it was more resistant to major fungal and bacterial diseases compared with the standard (see Table 2).

Thus, the use of individual selection in splitting generations has proven effective in creating high-yielding soybean varieties that meet modern cultivation technology requirements.

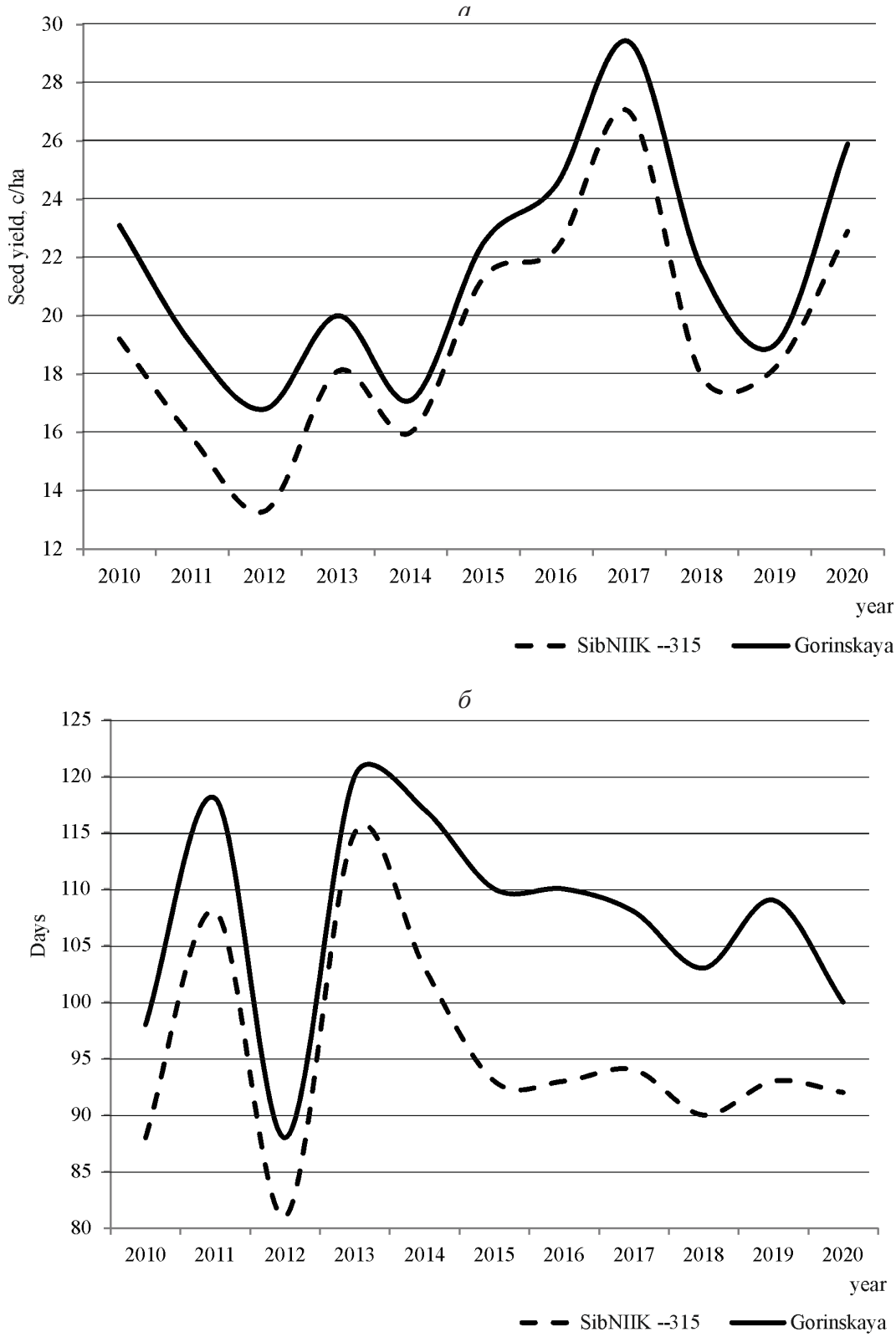
In 2013, the SNK-147 soybean line was submitted to state variety testing under the name

Табл. 1. Параметры нового сорта сои Горинская (2010–2012 гг.)
Table 1. Parameters of new soybean cultivar Gorinskaya (2010–2012)

Feature	Gorinskaya (SNK-147)	SibNIIK-315 (standard)	± to the standard, %
Grain yield, c/ha **	21,6 ± 1,3	18,9 ± 1,4	114*
Vegetation period, days	101 ± 8	92 ± 8	9*
Weight of 1000 seeds, g	133,1 ± 3,0	147,2 ± 5,7	90*
Crude protein content, %	36,4 ± 0,2	36,5 ± 0,1	100
Crude protein yield, c/ha	7,8 ± 0,7	6,9 ± 0,6	114*
Fat content, %	18,8 ± 0,4	18,2 ± 0,2	103
Fat yield, c/ha	4,1 ± 0,6	3,5 ± 0,4	117*

* Reliable at the 5% level.
** Grain yield given for 2010-2020

[5]Ashmarina L.F., Gorobei I.M., Konyaeva N.M., Agarkova Z.V. Atlas of diseases of fodder crops in Western Siberia. Novosibirsk: Siberian Research Institute of Fodder Crops, 2010. 180 p.



Урожайность семян (*а*) и продолжительность вегетационного периода (*б*) нового сорта сои Горинская

Seed yield and maturity of new cultivar of soybean Gorinskaya

Gorinskaya. In 2018, the variety was included in the State Register of Breeding Achievements Approved for Use in the Russian Federation for the East Siberian region. The certificate of authorship No. 71916 dated 05.06.2018 and patent No. 9653 dated 05.06.2018b were obtained. The authors of the variety are: N.V. Balykina, A.V. Zheleznov, N.I. Kashevarov, N.N. Kashevarova, A.A. Polishchuk.

Gorinskaya soybean variety is for grain use. The yield in competitive variety trials in the forest-steppe zone of Western Siberia reached 29.4 c/ha. According to the State Variety Commission the average grain yield in the East Siberian region was 28.6 c/ha. The maximum yield (31.2 c/ha) was obtained at the Krasnoturansky State Crop Testing Site (SCTS) in the Krasnoyarsk Territory in 2016. Seed weight per plant is 10-12 g, weight of 1000 seeds - 150-160 g. The number of seeds in a pod is mainly 2-3, the average number of beans per productive node is 2-3, the maximum - 4-5. Seeds have 35-38% protein content and 17-19% fat content. Sprouting and flowering lasts 30 to 32 days; sprouting and maturation last 100 to 105 days. The variety is moderately tolerant to cold, drought, soil salinity.

Morphologically, Gorinskaya soybean belongs to the Manchurian subspecies (ssp. *manshurica* (Enken) Zel. et Koch.). The plants have light brown (reddish) pubescence on the stem, leaves and beans. The character of growth and the type of apex are intermediate, the number of branches 1-3, the angle of branching 20-30 degrees, the bush is compressed. The height to the first branching is 6-10 cm, the attachment height of the lower legume is 10-13 cm. The beans are evenly spaced throughout the plant. The stem is 55-75 cm long, with 12-15 internodes on the stem. The type of seed germination is hypogeic (the seedpods reach the ground). Because of the presence of anthocyanin, the coloring of the sub-cotyledon during germination is purple. The primordial leaves are broadly ovate. The leaves are ternate, with the middle leaflets oval-oblong and slightly pointed. Leaf coloring is green. The inflorescence is a low-flowered cluster of 3 to 5 flowers. The corolla is purple. Pods slightly curved with a pointed tip, turning brown when mature. Seeds oblong-oval, greenish-yellow, without pigmentation. The seed ridge is brown.

CONCLUSIONS

1. Using hybridization and individual selection methods, a new variety of soybean, Gorinskaya, was created.
2. The average grain yield of the variety Gorinskaya in the West Siberian region is 21.6 c/ha (114% of the standard), the maximum yield is 29.4 c/ha, raw protein yield is 7.8 c/ha, fat yield is 4.1 c/ha, which is 14 and 17% higher than the standard, respectively. The maximum grain yield in the East Siberian region was 31.2 c/ha.
3. In 2018, the variety was included in the State Register of Breeding Achievements Approved for Use in the Russian Federation for the East Siberian region.

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Табл. 2. Поражение болезнями нового сорта сои Горинская (2010–2012 гг.), %
Table 2. Diseases of new soybean cultivar Gorinskaya (2010–2012), %

Feature	Gorinskaya (SNK-147)		SibNIIK-315 (standard)		± to the standard, %
	Average	Limits	Average	Limits	
Pustular bacteriosis	2,9	0–5,9	3,0	0,4–5,6	–0,1
Downy mildew	3,5	0,1–7,0	18,5	0,0–37,0	–15,0
Bacterial spot	4,0	0,0–8,1	8,3	0,4–16,2	–4,3

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ИНФОРМАЦИЯ ОБ АВТОРАХ

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ОЦЕНКА ОБРАЗЦОВ ДВУКИСТОЧНИКА ТРОСТНИКОВОГО ДЛЯ РЕКУЛЬТИВАЦИИ УГОЛЬНЫХ ОТВАЛОВ

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Одним из надежных путей восстановления эродированных почв и техногенных земель является их рекультивация с посевом многолетних злаковых трав. Изучены и выделены образцы двукисточника тростникового, пригодные для рекультивации угольных отвалов Кемеровской области. Экспериментальная работа проведена в Томской области (58°11′с.ш., 83°00′в.д.) в 2017–2020 гг. Объекты исследований представлены отборами двукисточника тростникового, проведенными в 2016 г. Питомник изучения образцов, пригодных для рекультивации угольных отвалов, заложен в 2017 г. в количестве шести номеров – КМ-1, КМ-2, КМ-3, КМ-4, КМ-5 (Томская область), в качестве стандарта использовали сорт Витязь (Томская область). Почвы опытных участков дерново-подзолистые кислые супесчаные и суглинистые с содержанием гумуса в пахотном горизонте не более 2%. При оценке образцов основное внимание уделено изучению признаков и свойств, которые лимитируют их возделывание в условиях таежной зоны: густоте травостоя, высоте растений, облиственности, зимостойкости, устойчивости к полеганию, семенной продуктивности, урожайности зеленой массы, устойчивости к наиболее распространенным заболеваниям. За 3 года изучения отборов двукисточника тростникового по комплексу основных хозяйственно важных признаков выделен образец КМ-5. Данный образец обладает комплексом ценных признаков при создании адаптивного сорта, пригодного для рекультивации угольных отвалов (облиственность – 61,4%, урожайность зеленой массы – 38,5 т/га, сухого вещества – 11,9, семян – 0,21 т/га). Выделившийся номер имеет ежегодные достоверные прибавки к стандарту по урожайности зеленой массы 8,5 т/га, сухого вещества – 3,3, семян 0,04 т/га. Образцы КМ-1, КМ-5 проявили высокую устойчивость к данным заболеваниям: поражение гельминтоспориозом – 6,0–6,1%, септориозом – 2,6–4,2%.

Ключевые слова: рекультивация, двукисточник тростниковый, урожайность, адаптивность, селекция

EVALUATING REED CANARY GRASS SAMPLES FOR RECLAMATION OF COAL DUMPS

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One reliable way to restore eroded soils and technogenic land is to reclaim it by sowing perennial grasses. Samples of reed canary grass suitable for reclamation of coal dumps in the Kemerovo region have been studied and identified. Experimental work was carried out in the Tomsk region (5811 N, 8300 E) during the period of 2017-2020. The research subjects are represented by samples of reed canary grass taken in 2016. A nursery of study samples suitable for reclamation of coal dumps was laid in 2017 with six numbers - KM-1, KM-2, KM-3, KM-4, KM-5 (Tomsk region), the variety Vityaz (Tomsk region) was used as a standard. The soils of the experimental plots were sod-podzolic acidic loamy sandy loam and loamy with a humus content of no more than 2% in the arable horizon. When evaluating the samples, the main attention is paid to studying the traits and properties that limit their cultivation under taiga conditions: grass density, plant height, foliage,

winter hardiness, lodging resistance, seed productivity, green mass yield, resistance to the most common diseases. Over a 3-year study of selections of reed canary grass based on a set of the main economically important traits, the KM-5 sample has been identified. This specimen has a complex of valuable features in creating an adaptive variety suitable for reclamation of coal dumps (foliage - 61.4%, green matter yield - 38.5 t/ha, dry matter - 11.9, seeds - 0.21 t/ha). The selected number has annual reliable additions to the standard in terms of green matter yield of 8.5 t/ha, dry matter yield of 3.3, and seed yield of 0.04 t/ha. Samples KM-1, KM-5 showed high resistance to these diseases: helminthosporiosis - 6.0-6.1%, septoriosis - 2.6-4.2%.

Keywords: reclamation, reed canary grass, productivity, adaptability, selection.

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INTRODUCTION

At present, the processes of anthropogenic disturbance of the vegetation cover, including in Western Siberia, are becoming global. The mining industry has a negative impact on all components of the natural environment, causing undesirable changes. Disturbed lands become focal points of atmospheric, water and soil pollution, adjacent lands, worsen sanitary and hygienic living conditions of the population. In order to restore the ecological integrity of disturbed areas, it is necessary to carry out reclamation works[1] [1–3].

Overgrowth of waste dumps is an example of primary succession occurring under specific edaphic conditions. The rate of self-vegetation on waste dumps varies from site to site. Phytomelioration significantly accelerates the process of self-restoration [4].

One of the reliable ways to restore eroded soils and technogenic lands is their reclamation with sowing of perennial grasses [5, 6]. The reed canary grass[2] is important for the restoration of disturbed areas [7].

The reed canary grass (*Phalaroides arundinacea* (L.) Rausch.) is a cosmopolitan perennial forage plant on intrazonal excessively wet soils in all continents except Antarctica. It is a perennial loose rootstock cereal for forage and erosion control use. Biological features of reed canary grass include wide adaptability to excessively humid areas, longevity, resistance to long-term flooding (up to 90 days), and high photosynthetic capacity. Longevity of economic use is 9-12 years, there is evidence of herbage more than 30 years old. The bicarbonate plays an important role as a fixer on landslide sites and a phytoremediator on sites of soils polluted with heavy metals [8]. The aim of the research

[1]Technologies of reclamation and arrangement of disturbed lands in Western and Eastern Siberia: monograph / Zenkov I.V., Nefedov B.N., Baradulin I.M., Yuronen Y.P., Voken V.N., Kiryushina E.V. Krasnoyarsk, 2015. 308 p. [Electronic resource]: URL: http://www.knigafund.ru Accessed 20.04.2021.

[2]Lamanova T.G., Sheremet N.V., Doronkin V.M. Collections of the Central Siberian Botanical Garden as a source of biodiversity restoration at overburden dumps of Kuzbass [Electronic resource]: URL: https://elar.urfu.ru/ bitstream/10995/32729/1/ brimnz_2012_27.pdf. Accessed 20.04.2021.

is to study and isolate samples of reed canary grass suitable for reclamation of coal dumps in the Kemerovo region.

MATERIAL AND METHODS

Experimental work was carried out in the Narym Department of Breeding and Seed Production at the Siberian Research Institute of Agriculture and Peat - Branch of the Siberian Federal Scientific Center of AgroBioTechnologies RAS, located in Kolpashevo, Tomsk Region (58°11′N, 83°00′E) in 2017-2020. The objects of the research are represented by the sampling of reed canary grass conducted by Kemerovo State University in 2016. The nursery garden for the study of samples suitable for reclamation of coal dumps was laid in 2017 in the amount of six numbers - KM-1, KM-2, KM-3, KM-4, KM-5 (Tomsk region), the standard - variety Vityaz (Tomsk region). Experimental work was carried out in natural field conditions.

The technology of laying a field experiment is generally accepted for perennial grasses in Western Siberia. Evaluation, observations and recordings were carried out in accordance with the methodological guidelines for perennial grasses breeding[3] and the methodology of the State Variety Testing Commission[4].

Samples were sown manually using dibbling along marker traces with a row spacing of 70 cm in the first days of June. The method of sowing was wide-row to a depth of 1-2 cm, seeding rate 0.6 g/m^2 (at 100% economic validity of seeds), plot area - 2 m^2. Sowing care consisted of 3-4 times weeding with simultaneous loosening of the row spacing.

The climate in the study area is sharply continental with long, harsh winters and short but hot, often arid summers. Snow cover lasts for about 7 months (usually from October to April). The frost-free period is short. Annual precipitation is about 500 mm, including more than 300 mm during the growing season. The sum of air temperatures above 10°C is 1300-1600°C.

Soils of the experimental plots are sod-podzolic acidic (pH_{salt} 4.3-4.9) sandy loam and loamy by granulometric composition with humus content in the arable horizon not exceeding 2% (by Tyurin). The nutrient supply of mobile nitrogen is low - 0,20-0,22 mg/100 g of air-dry soil (according to disulfo-phenolic acid), exchangeable potassium is medium - 8,3-13,9 mg/100 g of air-dry soil (by Peiva), mobile phosphorus is high - 12,1-18,1 mg/100 g of air-dry soil (by Kirsanov), aluminum content is high - 4,4-9,6 mg/100 g of soil (by Sokolov).

Grass density was measured in the first year of the study at full sprouts and before going into winter, in the second and subsequent years - at spring growth, by cutting and before going into winter on a 5-point scale. Plant height was measured in the phase of mass earing for green mass and at the beginning of seed ripening for seed. Plants were measured from the soil surface to the apex of the inflorescences at five locations.

Winter hardiness (percentage of plants surviving the overwintering period) was determined by counting the number of live and dead plants in the plot in autumn and spring at the beginning of the growing season.

In the study of resistance to leaf infections, counts were conducted during the period of maximum disease development according to the methodological guidelines of the VIR, VIC[5,6]. To determine the degree of infestation, 25 leaves from each plot were collected in the field and then compared with the Peterson scale tables [9].

The green mass productivity of reed canary grass was recorded under a two-crop system: the first cut was made in the phase of full lodging, and the second cut was made when the grass reached its maturity (height of the herbage). Before taking into account, the herbage was assessed by eyeballing in terms of density and alignment, disease infestation, and height. The herbage was then mowed and a sample sheaf was taken along the length of the swath in

[3]Methodological guidelines for breeding perennial grasses. MOSCOW: VIC. 2012. pp. 35-46.

[4]Methodology of state variety testing of agricultural crops. M., 1985. pp. 49-57, 120-125.

[5]Methodological guidelines for the study of cereal grass resistance to fungal pathogens for the conditions of the Non-Chernozem zone of the RSFSR. M.: VNIIR, 1976. 65 p.

[6]Guidelines for breeding perennial grasses. Moscow: Publishing House Of RSAU-MAA, 2012. 51 p.

various places by handfuls of 1 kg to determine the dry matter yield.

The leaf coverage was determined by analyzing the sample sheaves as the ratio of leaf weight to the total dry weight of the sample, expressed as a percentage. Seed productivity of the breeding material was determined by sowing the samples in pure form according to the optimal agricultural technique. Grass vegetation was mowed from the whole recording area with a sickle. The threshed seeds were brought to the condition of purity and germination.

Experimental material was processed according to B.A. Dospekhov[7] using an application software package[8].

RESULTS AND DISCUSSION

The evaluation of the samples focused on the traits and properties that limit their cultivation under taiga conditions: winter hardiness, yield of fodder mass and seeds, resistance to the most common diseases.

The growing season is an important biological trait that reflects the adaptation of plants to growing conditions. The natural and climatic conditions of the taiga zone in Western Siberia allow cultivated plants, in particular reed canary grass, to form a good herbage and conditioned seeds during a short summer.

Under our conditions, spring sprouting in 2018 was recorded on 10 May, the beginning of earing on 25 June, full earing on 27 June, mass flowering on 2 July, and mass seed ripening on 19 July. In 2019, regrowth occurred on 7 May, beginning of earing on 23 June, full earing on 27 June, mass flowering on 2 July, and mass seed ripening on 20 July. Thanks to an early and warm spring in 2020, germination started on 20 April, heading emergence on 8 June, complete heading on 12 June, mass flowering on 18 June, and mass seed ripening on 14 July. The duration of the growing season in 2018 was 70 days (74 days in 2019, 85 days in 2020). The end of the growing season in 2018 was on 29 October, in 2019 on 20 October and in 2020 on 10 November.

The density and thickness of the herbage of the studied numbers was 4-5. These estimates correspond to the state of the grass stand of the samples before the winter. All studied samples had high winter hardiness (100%), foliage (5 points), resistant to lodging (5 points). Plant height varied from 136 to 145 cm during the mass earing phase and from 151 to 162 cm during flowering (average data for 2018-2020).

Thanks to the high snow cover in the winter of 2017/18, 2018/19 and 2019/20, the reed canary grass specimens overwintered well, with a winter hardiness of 100%. The plants went into the winter in a well-developed condition. Mowing and harvesting of crop residues was carried out one month before the onset of permanent frost, so no fallout was observed on the crops.

Reed canary grass grows early in spring and is characterized by fairly intensive growth. Spring regrowth begins at a temperature of about 2-3°C. At the end of May, the grass can reach a height of 7-10 cm. In the phase of seed ripening in the conditions of Western Siberia, the reed canary grass grows to 200 cm in height. Plant height during the mass earing phase ranged from 136 to 145 cm, during flowering from 151 to 162 cm (average data for 2018-2020). All reed canary grass specimens were highly resistant to lodging (4-5 points).

Cereal grasses are affected by a large number of fungal diseases. The importance of one or another disease varies depending on the species of cereal, the environmental conditions and the way it is used. The most widespread are leaf diseases: helminthosporiosis, septoriosis and rust. Severely weakened plants poorly tolerate extreme conditions of heat, drought or low temperature. In the conditions of the Tomsk region, reed canary grass is most often affected by Helminthosporiosis (*Helminththosporium bromi* Died.) and septoriosis (*Septoria* sp.).

At the stage of maturity of seeds helminthosporiosis affection of samples was 6,0-7,6%, septoriosis - 2,6-7,0% (for standard - 3,0 and 2,9% respectively). Samples KM-1, KM-5 showed high resistance to these diseases: dam-

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

[8]Sorokin O.D. Applied statistics on computer. Novosibirsk, 2007. 206 p.

Характеристика образцов двукисточника тростникового в питомнике отбора (двухукосное использование) (средние данные за 2018–2020 гг.)
Characteristics of reed canary grass samples in the selection nursery (two-cuts use) (average data for 2018–2020)

Variety (Tomsk region)	Yield									Leaf coverage, %
	herbage			dry matter			seeds			
	t/ha	% to the standard	± to the standard	t/ha	% to the standard	± to the standard	t/ha	% to the standard	± to the standard	
Vityaz (standard)	30,0	100,0	0	8,6	100,0	0	0,17	100,0	0	52,8
KM-5	38,5	128,3	+8,5	11,9	138,4	+3,3	0,21	123,5	+0,04	61,4
KM-3	35,3	117,7	+5,3	10,3	119,8	+1,7	0,12	70,6	–0,05	51,7
KM-4	32,7	109,0	+2,7	9,0	104,7	+0,4	0,11	64,7	–0,06	52,0
KM-1	30,7	102,3	+0,7	9,8	114,0	+1,2	0,17	100,0	0	53,9
KM-2	29,2	97,3	–0,8	8,7	101,2	+0,1	0,11	64,7	–0,06	52,3
LSD_{05}			0,7			1,2			0,02	1,3

age by helminthosporiosis was 6.0-6.1%, septoriosis 2.6-4.2%.

Yield of green matter (dry matter) is the main indicator of the value of varieties. In haying, productivity was recorded in two-crop use: the first cutting was done in the full-thickness phase on July 5 (2018), June 27 (2019), June 8 (2020), the second on July 18 (2018), July 30 (2019), July 20 (2020).

The average green matter yield of the studied samples in two cuttings in 2020 was 23.5-42.0 t/ha, air-dry - 5.6-14.1 t/ha. The average green matter yield for 2018-2020 was 29.2-38.5 t/ha, air-dry 8.6-11.9 t/ha. All selections except KM-2 stood out on these traits. The excess over the standard variety was 2,3-28,3% for green mass yield and 1,2-38,4% for dry matter. Leaf coverage of the studied samples on the average over the 3 years changed in the first cut from 51,7% (KM-3) to 61,4% (KM-5).

In terms of seed yield in both 2020 and the 3-year average, the KM-5 selection stood out. The excess over the standard was 50.0 and 23.5%, respectively.

The results of the study of reed canary grass samples in the selection nursery are shown in the table below.

The criterion for the adaptability of selected genotypes in breeding is the level of their yield. Preference is given to samples that have maximum environmental adaptability. The selected number has annual reliable additions to the standard in terms of green matter yield of 8.5 t/ha, dry matter yield of 3.3, and seed yield of 0.04 t/ha.

CONCLUSION

As a result of studying the selection of reed canary grass in the taiga zone of the Tomsk region, a sample of KM-5 has been isolated, which possesses a set of valuable features (leaf coverage - 61.4%, green matter yield - 38.5 t/ha, dry matter - 11.9, seeds - 0.21 t/ha) that is used in breeding work to create an adaptive variety suitable for reclamation of coal mines.

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ЭФФЕКТИВНОСТЬ БИОЛОГИЧЕСКОЙ ЗАЩИТЫ КАПУСТЫ ОТ ВРЕДИТЕЛЕЙ В УСЛОВИЯХ ПРИМОРСКОГО КРАЯ

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Представлены результаты использования энтомофага и биопрепаратов для регуляции численности вредителей капусты (капустной совки *Mamestra brassicae* L., капустной белянки *Pieris brassicae* L., репной белянки *Pieris rapae* L., капустной моли *Plutella xylostella* L.). Исследования проведены в условиях Приморского края в 2018–2020 гг. Осуществлена оценка эффективности применения *Trichogramma ussuricum* Sorokina на различных сортах капусты. Эффективность энтомофага против капустной совки варьировала от 33,3 до 66,6%, против репной белянки – от 32,6 до 70,2%. В полевых экспериментах изучена эффективность биологических препаратов Фитоверм, КЭ (0,09 л/га), Акарин, КЭ (1,6 л/га), Проклэйм, ВРГ (0,3 кг/га), Битоксибациллин, Ж (10 л/га), Битоксибациллин, П (2 кг/га), Лепидоцид, СК (2 л/га), Лепидоцид, П (2 кг/га) против капустной моли. Растения капусты опрыскивали препаратами однократно. Учеты численности вредителя проводили до обработки и после обработки на 5, 10, 15-е сутки в соответствии с утвержденными методиками. Высокую эффективность 93–100% на 5–10-е сутки показал биоинсектицид Проклэйм. Эффективность препаратов на основе аверсектина С и акарина N составила 65,0–88,6%. При использовании биопрепаратов Битоксибациллин и Лепидоцид наблюдали снижение численности капустной моли относительно контроля на 61,2–97,5 и 65,0–78,0%.

Ключевые слова: капуста, вредители, энтомофаг, трихограмма, биологическая защита, биоинсектициды, биопрепараты, эффективность

EFFECTIVENESS OF BIOLOGICAL PROTECTION OF CABBAGE AGAINST PESTS IN THE CONDITIONS OF THE PRIMORSKY TERRITORY

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The results of the use of entomophages and biological products to regulate the number of cabbage pests (cabbage moth *Mamestra brassicae* L., cabbage butterfly *Pieris brassicae* L., turnip butterfly *Pieris rapae* L., diamondback moth *Plutella xylostella* L.) are presented. The study was carried out in the Primorsky Territory in 2018-2020. The efficiency of *Trichogramma ussuricum* Sorokina applications was assessed on cabbage varieties. The effectiveness of the entomophage against the cabbage moth varied from 33.3 to 66.6%, against the turnip butterfly - from 32.6 to 70.2%. In field experiments the effectiveness of biological products Fitoverm EC (0.09 l/ha), Akarin EC (1.6 l/ha),

Proclaim WG (0.3 kg/ha), Bitoxibacillin (10 l/ha), Bitoxibacillin P (2 kg/ha), Lepidocid SC (2 l/ha), Lepidocid P (2 kg/ha) against diamondback moth are studied. Cabbage plants were sprayed with the preparations once. Pest counts were carried out before treatment and after treatment on the 5th, 10th and 15th day in accordance with the approved methods. Bioinsecticide Proclaim showed a high efficiency of 93.0-100% on the 5-10th day. The effectiveness of preparations based on aversectin C and avertin N was 65.0-88.6%. Using the biological product Bitoxibacillin and Lepidocid a decrease the number of diamondback moth relative to the control by 61.2-97.5 и 65.0-78.0% was registered.

Keywords: cabbage, pests, entomophage, Trichogramma, biological protection, bioinsecticides, biological products, effectiveness

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INTRODUCTION

Cabbage is one of the most important vegetable crops in the Primorsky Territory in terms of food value and area occupied. Throughout the growing season, cabbage is damaged by leafhoppers such as diamondback moth (*Plutella xylostella* L.), cabbage moth (*Mamestra brassicae* L.), cabbage butterfly (*Pieris brassicae* L.) and turnip butterfly (*Pieris rapae* L.). Chemical control measures are carried out in the region. This leads to a significant accumulation of pesticides in food crops and has a negative effect on useful entomofauna. Biocenotic relationships are disrupted, resulting in an increase in numbers of some pest species and the development of resistance of populations to pesticides in others. Increasing crop productivity and improving crop quality are the most pressing problems of modern crop production, which can be solved by effectively optimizing the phytosanitary state of agroecosystems based on the use of environmentally low-hazard plant protection products [1]. An important part of environmentally safe systems of protection of vegetable crops is the use of agronomic methods that reduce the rate of pest reproduction and increase the resistance of plants to damage [2]. Biorational preparations based on the products of microorganisms are increasingly being used in agriculture. Fitoverm, EC, a bioinsecticide based on natural metabolites of *Streptomyces avermitilis*, shows sufficient effectiveness against leaf-eating pests [3]. The preparations based on the bacterium Bacillus thuringiensis (Bt) are effective and widely used insect pest control agents [4-8]. Entomophages play a special role in regulating the number of phytophages on cabbage [9, 10]. In the Primorsky Territory, 17 species of parasites damaging cabbage belong to five families according to their systematic position: Ichneumonidae, Braconidae, Tachinidae, Pteromalidae and Trichogrammatidae. Efficacy is 40-61% at the beginning of the growing season and 60-90% at the end[1].

One of the most important natural enemies of lepidopteran pests is Trichogramma (Hymenoptera, Trichogrammatidae). Under the conditions of the Primorsky Territory, work has been carried out to identify local Trichogramma species. The effectiveness of *Trichogramma evanescens* Westw. against pests on cabbage was established [11]. In the process of research, a new species *Trichogramma ussuricum* Sorokina was identified from the infected cabbage moth eggs. The richness of the parasite fauna

[1]Potemkina V.I. Cabbage pests and control measures using biological means. Ussuriysk, 2003. 59 p.

and the detection of local Trichogramma gives grounds for the development of a set of methods of biological control of lepidopteran pests using entomophages and entomopathogens.

The aim of the research was to evaluate the effectiveness of preparations of biological origin and the regulatory role of *Trichogramma ussuricum* in reducing the number of pests on cabbage.

MATERIAL AND METHODS

Studies on cabbage protection against major pests were conducted in the Primorsky Territory (Vozdvizhenka village) in 2018-2020. Research objects: cabbage varieties, pests of Lepidoptera order, *Trichogramma ussuricum* Sorokina. Experimental seedlings were grown in greenhouses. Planting in the open ground was carried out in the I decade of June. Studies to determine the biological efficacy of T. *ussuricum* entomophage were conducted on white cabbage varieties Podarok, Slava, Iyunskaya, Kazachok. The size of experimental plots was 8.4 m^2. Replication was carried out three times. Entomophage breeding was carried out on the eggs of grain moth *Sitotroga cerealella* Oliv. To determine the timing of trichogramma release, the number of pest eggs was counted by visual inspection of 10 plants. Point releases of the parasite were conducted in June-August at intervals of 5-7 days (at the rate of 300,000 individuals/ha). Ten releases were conducted in 2018, seven in 2019 and six in 2020. Trichogramma efficacy was determined by the degree of infestation of eggs by the entomophage, by the number of pest caterpillars.

The study of the effectiveness of the preparations was carried out on a medium-ripening white cabbage variety Slava 1305. We used Fitoverm, EC (aversectin C, 50 g/l) at the rate of 0.09 l/ha (NBC Pharmbiomed Ltd.); Akarin, EC (avertin N, 2 g/l. avertin N, 2 g/l) - 1.6 l/ha; Proclaim, WG (amamectin benzoate, 50 g/kg) - 0.3 kg/ha; Bitoxibacillin, G (Bacillus thuringiensis, strain BtH1) - 10 l/ha (FSBSI VNIISKHM); Bitoxibacillin, P (Bacillus thuringiensis var. thuringiensis) - 2 kg/ha; Lepidocid, P (Bacillus thuringiensis var. kurstaki) - 2.0 kg/ha; Lepidocid, SC (Bacillus thuringiensis var. kurstaki) - 2.0 l/ha (IA Sibbiofarm Ltd.). The cabbage plants were sprayed with the preparations once. Repeatability is three times. Plot area was 11.2 m^2. Pests were counted by visual inspection of 10 plants in each repetition before treatment and after treatment on the 5th, 10th and 15th days according to the approved methods[2]. Biological efficacy of the preparations was determined by pest reduction, corrected for control, and calculated using the Henderson and Tilton formula (see footnote 1). Statistical processing of the data was carried out according to B.A. Dospekhov[3].

RESULTS AND DISCUSSION

Natural Trichogramma in the Primorsky Territory conditions is not significant in limiting the number of cabbage pests. In our experiments *Trichogramma ussuricum* was used by the method of seasonal colonization. The identification of local Trichogramma species and study of their efficiency is very promising, because it helps to solve the problems of entomophage selection with wide ecological plasticity and adaptability to abiotic and biotic factors of the area.

In order to obtain a high effect from the application of Trichogramma egg parasite release was timed to coincide with the initial egg-laying period of the pests. Cabbage moth and cabbage butterfly had no economic importance during the years of study. Infestation of cabbage by cabbage butterflies was low (3.3-5.2%). Single butterfly egg clutches were recorded in 2018 and 2020 on the variety Slava. The biological efficacy of Trichogramma against this pest was recorded at 37.0%. First generation cabbage moths preferred early maturing (Iyunskaya, Kazachok) and medium maturing varieties (Slava) for egg laying. The number of eggs per plant varied from year to year. In the variety Iyunskaya there were 0.9 to 1.5 eggs/plant at the beginning of vegetation (1.3 on average)

[2]Methodological guidelines for registration trials of insecticides, acaricides, molluscicides and rodenticides in agriculture. SPb.: VIZR, 2009. 321 p.

[3]Dospekhov B.A. Methodology of field experience. Moscow: Kolos. 1985. 336 p.

and 1.5 to 2.5 in mid vegetation (2.0 on average), in the variety Slava - 1.3 to 3.3 eggs/plant. Trichogramma efficacy (33.3%) was observed only on the variety Kazachok (see Table 1). In 2018 cabbage moth eggs were 100% infested, in 2019 and 2020 the efficiency averaged 56 and 44%.

Oviposition of the second generation of moths was observed in the varieties Slava and Podarok with 1.6 and 3.5 eggs/plant, respectively. Against the second generation of the cabbage moth the greatest effect was obtained when the entomophage was released (from 50.0 to 66.6% of egg infestation). Oviposition of turnip butterfly was found on plants throughout the growing season. For egg laying, turnip moths more often chose the leaves of plants of varieties Iyunskaya, Slava and Podarok. A lower number of eggs was observed in the variety Kazachok during the years of study. Infestation of turnip butterfly eggs by Trichogramma spp. was observed in July; entomophage efficiency in white cabbage varieties of different ripeness groups averaged 32.6% to 43.7% in 3 years, in August - 36.5% to 70.2%. Surveys of cabbage leaf-eating pests showed low abundance of 0.03 (cabbage moth) to 0.09 (turnip butterfly) caterpillars/plant.

Among leaf-eating lepidopteran cabbage pests, the cabbage moth was the most abundant during the years of study. This phytophage is currently a dangerous pest of cabbage crops in Russia[4]. Infestation of cabbage plants by the pest in the years of study was observed in the third decade of June (in 2018 at the beginning of the decade, in 2019 and 2020 at the end of the decade). In 2018, cabbage moth abundance during the growing season was low (0.2-0.5 caterpillars/plant), limited by precipitation, with 75.4-138.8 mm in June-July. Optimum precipitation conditions during the second and third generations of the pest were between 30-45 mm. Hydrothermal conditions in 2019, 2020 were more favorable for the cabbage moth.

According to the results of field trials (see Table 2), the bioinsecticide Proclaim has a strong toxic effect on cabbage moths. Caterpillar mortality on the 5th day after treatment was 93.0%. The maximum effect (100%) was achieved on the 10th day. Proclaim provided plant protection on the 15th day, the phytophage population was 0.1 caterpillars/plant, while the control - 0.5 caterpillars/plant. Under Fitoverm application the number of caterpillars decreased by 7.0-11.6 times. The efficiency of

Табл. 1. Эффективность *Trichogramma ussuricum* против вредителей капусты (среднее за 2018–2020 гг.)

Table 1. Effectiveness of *Trichogramma ussuricum* against cabbage pests (average for 2018–2020)

Variety	Cabbage moth			Turnip butterfly		
	Period					
	June	July	August	June	July	August
Average number of eggs per plant						
Iyunskaya	1,3 ± 0,20	2,0 ± 0,34	0	0,9 ± 0,06	2,0 ± 0,23	1,6 ± 0,34
Kazachok	0	1,2 ± 0,30	0	0,2 ± 0,06	0,8 ± 0,13	0,8 ± 0,06
Slava	2,3 ± 0,68	0	1,6 ± 0,13	0	2,1 ± 0,47	2,3 ± 0,27
Podarok	0	0	3,5 ± 1,16	0	2,0 ± 0,27	1,5 ± 0,47
Trichogramma infestation, %						
Iyunskaya	0	0	0	0	43,7 ± 10,5	55,5 ± 10,5
Kazachok	0	33,3 ± 8,1	0	0	30,6 ± 1,43	46,0 ± 8,55
Slava	0	0	50,0 ± 12,2	0	34,0 ± 4,33	70,2 ± 2,72
Podarok	0	0	66,6 ± 19,0	0	32,6 ± 4,09	36,5 ± 6,13

[4]Opiakin P.Ya., Dolzhenko V.I., Ivanova G.P. Modern insecticides for protection of cabbage white cabbage from cabbage moth. Scientific support of development of agroindustrial complex in the conditions of import substitution: materials of international scientific and practical conference. SPb. pp. 59-62.

the preparation was registered at the level of 75,0-88,6%. Significant differences in the effect of these preparations on cabbage moth caterpillars on the 10th day after treatment were noted. The efficacy of Avertin N-based Akarin was significantly lower (65.0-72.0%). When using microbial preparations based on *Bacillus thuringiensis*, the greatest reduction in caterpillar numbers was observed in the variant with Bitoxibacillin, P (80.0-97.5%). The efficacy of Bitoxibacillin, G was significantly lower, the reduction in the number of caterpillars did not exceed 67.2%. The bacterial preparation Lepidocide showed low efficiency of 65.0% on the 5th day. Strengthening of the toxic action was observed by the 10th day after the treatment, and the decrease in the number of caterpillars was 70,8-78,0%. The effectiveness of bacterial insecticides depends on the preparative form[5]. The studies have shown that Lepidocid, SC was more effective against cabbage moths than Lepidocid, P.

CONCLUSION

As a result of this research, the possibility of using the entomophage *Trichogramma ussuricum* Sorokina and biopreparations to regulate the number of cabbage pests has been established. Application of Trichogramma by dispersal in white cabbage plantations reduced the cabbage moth population by 33.3-66.6% and the turnip butterfly population by 32.6-70.2%. The level of efficacy of *Streptomyces avermitilis* metabolite complex-based preparations against cabbage moths was 65-100%. The bioinsecticide Proclaim showed high efficiency (93-100%). Microbiological preparations reduced the number of caterpillars by 65.0-97.5%. The highest efficiency (80,0-97,5%) was observed in application of Bitoxibacillin, P. The use of parasiticides, bioinsecticides and microbiological preparations in cabbage protection allows reducing the application of chemical pesticides and obtaining ecologically clean products.

Табл. 2. Эффективность биоинсектицидов против капустной моли (среднее за 2018–2020 гг., сорт Слава 1305)

Table 2. Effectiveness of bioinsecticides against diamondback moth (average for 2018–2020, of Slava cabbage 1305)

Option	Rate of application of the preparation, l/ha, kg/ha	Average number of caterpillars, individuals per plant				Decrease in pest numbers relative to the baseline, corrected for control after treatment by record days, %		
		before treatment	After treatment by record days					
			5	10	15	5	10	15
Control	–	0,7	0,5	0,4	0,5	–	–	–
Fitoverm, EC	0,09	0,7	0,06	0,1	0,1	88,6	75,0	80,0
Akarin, EC	1,6	1,0	0,2	0,2	0,3	72,0	65,0	80,0
Proclaim, WG	0,3	0,6	0,03	0	0,1	93,0	100	76,7
Bitoxibacillin, G	10,0	1,6	0,3	0,3	0,4	61,2	67,2	65,0
Bitoxibacillin, P	2,0	0,7	0,1	0,01	0,1	80,0	97,5	80,0
Lepidocid, SC	2,0	1,2	0,3	0,2	0,2	65,0	78,0	76,6
Lepidocid, P	2,0	0,8	0,2	0,1	0,2	65,0	70,8	65,0
LSD_{05}	–	–	–	–	–	9,3	7,8	10,5

[5]Dolzhenko T.V. Biologization and ecological optimization of the assortment of means of protection of agricultural crops from pests: thesis of Doctor of Science in Biology. SPb; Pushkin, 2017. 301 p.

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ХАРАКТЕРИСТИКА ЛИНИЙ ПОРОДЫ КРУПНОГО РОГАТОГО СКОТА СИБИРЯЧКА ПО ГЕНАМ *CSN*3, *BLG, LALBA, LEP* И ИХ СВЯЗЬ С МОЛОЧНОЙ ПРОДУКТИВНОСТЬЮ

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Представлены результаты исследований по продуктивности и генотипической структуре коров ведущих линий породы крупного рогатого скота Сибирячка, ассоциативным связям генотипов *CSN3, BLG, LALBA, LEP* с экономически важными признаками. Сравнительная оценка показала, что наиболее высокий удой имели коровы линии быка Рефлекшн Соверинга – 6851 кг, содержание жира – 4,05%, белка – 3,15%. Формируемые сибирские линии быков Франка 937, Урагана 27 и Курса 1949 уступают им по удою, содержанию жира и белка с показателями 5246–5504 кг, 3,92–3,94%; 3,10–3,12% соответственно. Выявлена генотипическая структура стада и ведущих линий. Линия быка Вис Бэк Айдиала характеризуется более высокой частотой $CSN3^{AA}$ и LEP^{TT} генотипов – на 18,2 и на 11,0% по сравнению с линией Рефлекшн Соверинга. По другим генотипам различия не достигают порога достоверности. Средний уровень гомозиготности по исследованным генам варьирует от 51,2 до 73,4%. Наиболее высокая гомозиготность отмечена по *CSN*3 гену в линии Вис Бэк Айдиала – 79,6%. Число эффективно действующих аллелей составляет 1,66–1,72; степень генетической изменчивости – 40,2–42,7%. Коровы с $CSN3^{AB}$ генотипом имели удой на 544,0 кг выше по сравнению с гомозиготными животными по аллелю А ($p < 0,05$). Наиболее высокий удой отмечен у животных BLG^{AA} – 6790,1 кг, что выше, чем у коров с альтернативным генотипом BLG^{BB}, на 947,2 кг ($p < 0,01$). Животные с LEP^{CC} генотипом превосходили по удою коров с LEP^{TT} на 718,7 кг. По гену *LALBA* приоритетных генотипов не выявлено. Также не установлена связь между генотипами и качественными показателями молока.

Ключевые слова: крупный рогатый скот, линия, генотип, гомозиготность, продуктивность

CHARACTERISTICS OF THE LINES OF THE SIBIRYACHKA CATTLE BREED BY GENES *CSN3, BLG, LALBA, LEP* AND THEIR RELATIONSHIP WITH DAIRY PRODUCTIVITY

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The results of studies on productivity and genotypic structure of cows of the leading lines of Sibiryachka cattle breed, associative links of CSN3, BLG, LALBA, LEP genotypes with economically important traits are presented. Comparative evaluation showed that Reflection Sovering bull cows had the highest milk yield

of 6851 kg, fat content of 4.05% and protein content of 3.15%. The Siberian bull lines Frank 937, Uragan 27 and Kursa 1949 which are being shaped are inferior to them in milk yield, fat and protein content with values of 5246-5504 kg, 3.92-3.94%; 3.10-3.12% respectively. The genotypic structure of the herd and the leading lines is identified. The Vis Back Aydiala bull line is characterized by a higher frequency of $CSN3^{AA}$ and LEP^{TT} genotypes by 18.2 and 11.0%, in comparison with the Reflection Sovering line. For other genotypes, the differences do not reach the confidence threshold. The average level of homozygosity for the genes studied varies from 51.2% to 73.4%. The highest homozygosity was found for the CSN3 gene in the Vis Back Aydiala line at 79.6%. The number of effectively acting alleles is 1.66-1.72; the degree of genetic variability is 40.2-42.7%. The cows with $CSN3^{AB}$ genotype had 544.0 kg higher milk yield than homozygous animals for the A allele ($p < 0.05$). The highest milk yield was observed in BLG^{AA} animals - 6790.1 kg, which is 947.2 kg higher than in cows with the alternative BLG^{BB} genotype ($p < 0.01$). Animals with the LEP^{CC} genotype outperformed LEP^{TT} cows in milk yield by 718.7 kg. No priority genotypes were identified for the LALBA gene. Also, no connection has been established between genotypes and the quality indicators of milk.

Keywords: cattle, line, genotype, frequency, homozygosity, productivity.

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INTRODUCTION

The productivity of the black-and-white breed of cattle on farms in the Siberian region is increasing largely due to the use of bull breeders with high genetic potential, effective breeding and pedigree work, and an increased level of feeding that meets the needs of the animal. The new cattle breed Sibiryachka (patent No. 9498 of 08.02.2018) has good dairy productivity and extensive longevity [1]. To further improve the breed, it is advisable to use molecular genetic markers along with traditional breeding methods to ensure earlier prediction of genetic potential, efficient selection and selection of animals.

Currently, there is a steady trend in animal breeding towards the spread of the Holstein breed through the intensive use of imported breeding products. This leads not only to changes in phenotypic traits, but also to the impoverishment of the gene pool of local breeds and the risk of increased homozygosity [2, 3]. It should be noted that changes in genotypic structure, monitoring of homozygosity, inbredness in a number of generations on the example of a single herd have not been sufficiently studied. Polymorphic structural genes detected by PCR-RFLP method serve not only as potential genetic markers of economically important animal traits, but can also be used to characterize the ongoing changes in breeding and genetic parameters in the herd.

The most informative dairy cattle genes include CSN3, BLG, LALBA, LEP, where CSN3 occupies a special place, due to the proven influence of its B allele on increased protein content in milk and better cheese suitability [4–6].

Another equally important milk protein, beta-lactoglobulin (β-LG), belongs to the serum proteins of ruminants and is characterized by acid resistance with an optimum pH of 6.5. The β-LG content in goat and cattle milk is about 4 g/l, or 13 and 11% of total protein, respectively, and in serum up to 50% of all serum proteins

[7]. Thirteen allelic variants of the BLG gene have been identified and confirmed. The A and B alleles are the most common in cattle and are more widely studied [8]. A number of studies have shown an association of BLG^{BB} with fat and protein content in milk, and BLG^{AA} with high milk yield in cows [9, 10].

Leptin gene and its derivatives proteins of the hormone leptin are produced by adipose tissue cells and play an important role in the regulation of energy metabolism, affecting the synthesis of adipose tissue in animals and humans [11, 12]. In beef cattle breeding, the LEP gene is considered as a potential marker of fat accumulation in the carcass of an animal, associated with meat quality, its marbling [13, 14]. In dairy cattle breeding, an associative association of some genotypes with dairy performance and milk quality composition has been revealed[1] [15].

Lactalbumin alpha (LALBA) is an important mammalian serum protein encoded by the LALBA gene. A study [16] shows that α-lactalbumin is a protein that regulates lactose production in milk in almost all mammals. It plays a functional role in changing the volume of synthesized milk, so it is of interest for evaluation and prediction of milk productivity of cows.

The purpose of the study was to identify the genetic structure of the Sibiryachka cow herd and individual genealogical lines using CSN3, BLG, LALBA, LEP genes, to determine homozygosity of other breeding and genetic parameters as well as desirable genotypes of dairy productivity.

MATERIAL AND METHODS

The object of the study was Sibiryachka cows from Kirzinsky herd (Novosibirsk region) with milk yield of 6376 kg, fat and protein content in milk of 4.11 and 3.13% respectively. The service period was 135 days and calf yield was 81%.

Molecular genetic studies of cows were performed in the laboratory of biotechnology at the Siberian Research Institute of Animal Husbandry (SibNIPTIZh) of the Siberian Federal Scientific Centre of AgroBioTechnologies of the Russian Academy of Sciences. Genomic DNA was isolated from blood using the "Ampli-Prime DNA-sorb-B" clinical extraction kit according to the prescription of the manufacturer "Next-Bio" LLC (Moscow).

The quality and concentration of isolated DNA and identification of PCR-RFLP results were assessed in agarose gel by horizontal electrophoresis using an E-Box-CX5.TS-20.M gel documentation system in transmitted ultraviolet light by ethidium bromide fluorescence.

The polymorphisms of the CSN3, BLG genes were detected using the PCR-RFLP methodology developed at the All-Russian Research Institute of Animal Breeding[2]. LALBA gene polymorphism was determined using the PCR-RFLP methodology described in [17]. LEP genotyping of animals was performed according to the method [18].

The data were statistically processed using Microsoft Exel computer programs and generally accepted methods [19]. The compliance of the actual distribution of genotype frequencies with the theoretically expected frequency distribution was checked using the $\chi 2$ criterion [20].

RESULTS AND DISCUSSION

The genealogical structure of the Siberian herd is represented mainly by Holstein lines, among which the line of the bull Vis Back Aydial 1013415 accounts for 60,7% of cows, Reflection Sovering 198998 - 21,6%. The formed Siberian lines of bulls Frank 937, Uragan 27, Kurs 1949 are currently few in number and considerably inferior in productivity to Holstein lines (see Table 1). The highest milk yield (6851 kg) by the first lactation was noted in cows of the Reflection Sovering line, which was 1347-1605 kg higher than in the animals of Frank

[1]Zinnatova F.A., Shamsova A.R., Zinnatov F.F., Safiullina A.R., Khamitova L.L. The study of the relationship between leptin gene (LEP) with milk productivity in Holstein cows using PDRF-analysis. Fundamental science and technology - promising developments: materials of the XII scientific-international conference Kazan, 2017. pp. 1-3.

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937, Uragan 27, Kurs 1949 lines (p <0,001). The milk yield of cows of the Vis Back Aydial 1013415 bull line is slightly lower - 5995 kg, but it is higher than that of the animals of formed lines by 491-749 kg (p <0,5; p <0,001). In addition, cows of Holstein lines have milk with 0,11-0,13% higher fat content than that of Siberian lines (p <0,001). No significant differences were found in protein content between the lines.

Analysis of the genotypic structure of the Sibiryachka breed herd and the leading lines for the genes CSN3, BLG, LALBA, LEP revealed a mostly similar genotype ratio, except for CSN3^{AA} and LEP^{TT}, whose frequency in the Vis Back Aydial line is 18,2 and 11,0% higher than in the Reflection Sovering line (p <0,05) (see Table 2).

It should be emphasized that the ratio of CSN3 genotypes largely corresponds to the polymorphism of these genes in black-and-white breeds. As shown by the studies[3] [21, 22], the homozygous CSN3^{AA} genotype was detected in 55.2-73.2%, the heterozygous CSN3^{AB} genotype had 26.8-38.9% of animals, and the homozygous CSN3^{BB} genotype accounted for 5.6-10.2%. Similar frequency of CSN3 genotypes was observed in Simmental cows: CS-

Табл. 1. Молочная продуктивность коров основных линий
Table 1. Milk productivity of cows of the main lines

Line	Heads	First lactation		
		Milk yield, kg	Fat, %	Protein, %
Vis Back Aydial 1013415	334	5995 ± 55	3,97 ± 0,01	3,12 ± 0,002
Reflection Sovering 198998	119	6851 ± 98	4,05 ± 0,02	3,15 ± 0,006
Montwick Chiftein 95679	38	6221 ± 78	4,04 ± 0,02	3,14 ± 0,006
Frank 937	25	5504 ± 147	3,92 ± 0,01	3,11 ± 0,004
Uragan 27	22	5366 ± 178	3,94 ± 0,01	3,12 ± 0,004
Kurs 1949	12	5246 ± 235	3,92 ± 0,02	3,10 ± 0,01

Табл. 2. Генотипическая характеристика коров черно-пестрой породы СПК «Кирзинский» по гену *CSN3* с учетом линейной принадлежности
Table 2. Genotypic characteristics of black-and-white cows of the "Kirzinsky" APC by the *CSN3* gene with respect to linear affiliation

Genotype	Line			$\chi 2$
	Vis Back Aydial (n = 78)	Reflection Sovering (n = 46)	By herd	
CSN3^{AA}	76,9 ± 4,77	58,7 ± 7,26	71,0 ± 3,96	
CSN3^{AB}	23,1 ± 4,77	34,8 ± 7,02	26,7 ± 3,86	0,020
CSN3^{BB}	0 ± 0,00	6,5 ± 3,64	2,3 ± 1,31	
BLG^{AA}	29,5 ± 5,16	43,5 ± 7,31	35,9 ± 4,19	
BLG^{AB}	46,2 ± 5,64	39,1 ± 7,20	43,5 ± 4,33	1,555
BLG^{BB}	24,4 ± 4,86	17,4 ± 5,59	20,6 ± 3,53	
LEP^{CC}	35,9 ± 5,43	54,4 ± 7,34	48,9 ± 4,37	
LEP^{CT}	48,7 ± 5,66	41,3 ± 7,26	45,0 ± 4,35	1,367
LEP^{TT}	15,4 ± 4,09	4,4 ± 3,01	6,1 ± 2,09	
LALBA^{AA}	52,6 ± 5,65	43,5 ± 7,31	41,2 ± 4,30	
LALBA^{AB}	41,0 ± 5,57	52,2 ± 7,37	48,1 ± 4,36	0,555
LALBA^{BB}	6,4 ± 2,77	4,35 ± 3,01	10,7 ± 2,70	

$N3^{AA}$ = 0.626, $CSN3^{AB}$ = 0.306, and $CSN3^{BB}$ = 0.068 [23]. In general, the low frequency of the desirable $CSN3^{BB}$ genotype, whose associative link with protein content in milk and higher cheese suitability has been proved by many authors [3-5, 24], draws attention in the herd as a whole.

Our studies showed a BLG^{AA} frequency of 35.9%, a heterozygote frequency of 43.5, and a homozygous BLG^{BB} genotype of 20.6%. Variation in genotype frequencies was noted in the lines, but no significant differences were found due to insufficient sample size. The BLG genotypic structure of the black-and-white breed that we have identified is consistent with the findings of a number of authors. Studies [25-27] claim that about half of the animals are heterozygotes, with homozygotes with the BLG^{A} allele accounting for 24-27% according to various sources.

There is conflicting data on the frequency of LEP genotypes. In Holstein cows, the genotype frequency is as follows: LEP^{CC} - 10%, LEP^{CT} - 62, LEP^{TT} - 28% (see footnote 1). The distribution of genotypes in Holmogor cows of the Tatarstan type is somewhat different: LEP^{CC} - 25%, LEP^{CT} - 55,5, LEP^{TT} - 19,5% [15]. According to our data, the lowest share of cows is occupied by animals with the LEP^{TT} genotype - 6.1%, in the Reflection Sovering line - 4.4%. The LEP^{CC} homozygous genotype was detected in half of the animals in the herd as a whole, slightly less in animals belonging to the Vis Back Aydial line - 35.9%.

Analysis of LALBA gene genotype frequencies in black-and-white cows shows a low frequency of $LALBA^{BB}$ genotype, ranging from 3 to 20%, whereas the frequency of $LALBA^{AA}$ and $LALBA^{AB}$ genotypes is up to 50% [28, 29].

Based on genotype frequencies, breeding and genetic parameters were calculated: Ca - homozygosity, SH - homozygosity coefficient, Na - number of effective alleles, V - degree of genetic variability in the population. The average level of homozygosity for the studied genes ranged from 51.2 to 73.4%, with the highest homozygosity being recorded for CSN3 in the Vis Back Aydial line at 79.6%. The number of effective alleles and degree of genetic variability in the lines are approximately at the same level: 1.66-1.72 and 40.2-42.7% (see Table 3).

In studies on the use of genetic markers in breeding, the relationship between genotypes and performance is of particular interest. We found that heterozygous $CSN3^{AB}$ cows had the highest milk yield. The surplus was 544.0 kg compared to cows with the homozygous $CSN3^{AA}$ genotype ($p < 0.05$). Literature data on this issue is ambiguous.

The priority of the $CSN3^{AB}$ genotype for milk yield was established in the work [30]. Given the low frequency of the $CSN3^{BB}$ genotype in the herd, these animals were not considered in the productivity analysis (see Table 4).

Among cows with BLG genotypes, the highest milk yield was observed in BLG^{AA} animals - 6790.1 kg, which is 947.2 kg higher than in cows with the alternative BLG^{BB} genotype ($p < 0.01$). The association of this gene with milk production in black-and-white cows was found to be somewhat different. Cows with BLG^{AB}

Табл. 3. Селекционно-генетические параметры стада Сибирячка
Table 3. Breeding and genetic parameters of the Sibiryachka herd

Line	*n*	*Ca*, %				*SH*	N_a	*V*
		CSN3	*BLG*	*LALBA*	*LEP*			
Vis Back Aydial	78	79,6	50,2	52,2	60,6	0,100	1,66	40,2
Reflection Sovering	46	63,6	53,4	62,6	57,6	0,064	1,72	42,7
By herd	127	73,4	51,2	55,0	59,4	0,08	1,67	40,6

[3]Lihodeevkaya O.E., Lihodeevkiy G.A., Gorelik O.V. et al. Effect of genetic and paratypil factors on milk production in cattle // III International scientific conference: agritech-iii-2020: agribusiness, environmental engineering and biotechnologies. Volgograd, Krasnoyarsk, 2020. 82009 p.

Табл. 4. Продуктивность коров черно-пестрой породы в зависимости от носительства генотипа *CSN3* (первая лактация)

Table 4. Productivity of black-and-white cows depending on the carriage of the *CSN3* genotype (first lactation)

Genotype	*n*	Rate for the first 305 days of lactation		
		Milk yield, kg	Fat, %	Protein, %
$CSN3^{AA}$	70	6197,8 ± 164,80	4,00 ± 0,03	3,12 ± 0,01
$CSN3^{AB}$	21	6741,8 ± 207,70	4,03 ± 0,04	3,14 ± 0,02
BLG^{AA}	29	6790,1 ± 255,28	4,04 ± 0,04	3,13 ± 0,01
BLG^{AB}	40	6319,1 ± 209,88	4,01 ± 0,04	3,11 ± 0,01
BLG^{BB}	24	5842,9 ± 265,35	3,98 ± 0,03	3,12 ± 0,01
$LALBA^{AA}$	46	6404,2 ± 224,33	3,99 ± 0,03	3,11 ± 0,01
$LALBA^{AB}$	41	6248,8 ± 197,70	4,04 ± 0,04	3,13 ± 0,01
$LALBA^{BB}$	6	6519,2 ± 333,01	3,92 ± 0,03	3,12 ± 0,02
LEP^{CC}	39	6726,3 ± 193,73	4,06 ± 0,04	3,13 ± 0,01
LEP^{CT}	40	6086,8 ± 232,53	3,98 ± 0,03	3,12 ± 0,01
LEP^{TT}	14	6007,6 ± 300,98	3,94 ± 0,02	3,10 ± 0,01

had an advantage over their counterparts with BLG^{AA} and BLG^{BB} genotypes by 295 and 178 kg of milk, in fat and protein content in milk by 0.09 and 0.05 % respectively [9].

When analyzing the association of LEP genotypes with milk production of cows in the analyzed herd, the milk yield of LEP^{CC} animals was found to be 718.7 kg higher than that of LEP^{TT} cows ($p < 0.05$). Similar results in prioritizing LEP^{CC} genotype for milk yield were obtained in the work [15].

No association between genotypes and milk performance was found in the LALBA gene. There is also no association between genotypes and milk quality parameters.

CONCLUSIONS

1. A comparative evaluation showed that the highest milk yield was achieved by cows of the Reflection Sovering bull line - 6851 kg, fat content was 4.05%, protein content - 3.15%. The Siberian lines Frank 937, Uragan 27 and Kurs 1949 were inferior to them in milk yield, fat and protein content: 5246-5504 kg, 3.92-3.94%, 3.10-3.12% respectively.

2. The frequency of CSN3, BLG, LALBA, LEP genotypes of the Sibiryachka breed is generally consistent with the black- and- white breed. A low frequency of $CSN3^{BB}$ genotype - 2.3% and a high $CSN3^{AA}$ genotype - 71.0% was detected. The ratio of genotypes in the BLG gene: $BLGA^{AA}$: BLG^{AB}: BLG^{BB} is 35.9: 43.5: 20.6%. In the LALBA and LEP genes, homozygous genotypes $LALB^{AB}$ and LEP^{TT} account for 6.1 and 10.7% respectively, while the occurrence of the other two genotypes is 41.2-48.9%. In the leading lines of the Sibiryachka breed the CSN3, BLG, LALBA, LEP found a relatively equal ratio of genotypes, except for $CSN3^{AA}$ and LEP^{TT}, whose frequency in the Vis Back Aydial line is 18.2 and 11.0% higher than in the Reflection Sovering line ($p < 0.05$).

3. The average level of homozygosity for the genes studied ranges from 51.2 to 73.4%, with the highest homozygosity observed for CSN3 in the Vis Back Aydial line at 79.6%. The number of effective alleles and degree of genetic variability in the lines are approximately at the same level: Na - 1.66-1.72, V - 40.2-42.7%.

4. Cows of the Sibiryachka breed with the heterozygous $CSN3^{AB}$ genotype had a 544.0 kg higher milk yield compared to cows with the homozygous $CSN3^{AA}$ genotype ($p < 0.05$). Cows with BLG genotypes had the highest milk yield of 6,790.1 kg in BLG^{AA} cows, which was 947.2 kg higher than in cows with the alter-

native BLGB genotype ($p < 0.01$). Cows with the LEP^{CC} genotype also had a 718.7 kg higher milk yield than cows with LEP^{TT} ($p < 0.05$).

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ИЗУЧЕНИЕ ЭКСПРЕССИИ ФУНКЦИОНАЛЬНО-ЗНАЧИМЫХ ГЕНОВ ПРИ ТЕРАПИИ КОРОНАВИРУСНОЙ ИНФЕКЦИИ У ЦЫПЛЯТ

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Изучен уровень экспрессии противовоспалительных цитокинов NF-kB, IL-6, INF-γ, Caspasa-3, Fc у кур в легких и кишечнике при моделировании инфекционного бронхита. Для моделирования коронавирусной пневмонии вакцину вводили индивидуально, 10 доз на голову перорально. Цыплятам 1-й опытной группы скармливали препарат Люманце в расчете 3 кг/т корма, 2-й опытной – препарат Глицевир в расчете 200 мкг/0,3 мл на голову. Цыплята контрольной группы препараты не получали. Выявлено, что противовирусные препараты в опытных группах подавляли разрушение эпителиальных клеток в кишечнике. Это не всегда может свидетельствовать о позитивном характере, поскольку в случае апоптоза происходит разрушение не только пораженных вирусными частицами клеток кишечника, но и здоровых. Отмечено снижение количества активных макрофагов в кишечнике опытных групп относительно контрольной. Количество вырабатываемого интерферона также находилось ниже контроля, что свидетельствует о пониженной активности иммунной системы. Выявлена более высокая провоспалительная активность в респираторной системе цыплят при использовании Глицевира. Она заключается в повышенном уровне экспрессии генов IL-6, интерферона-гамма, рецептора макрофагов к Fc фрагментам антител, фактора регуляции воспаления NF-kB в сравнении с препаратом Люманце, обладающим противовоспалительной активностью, но и в сравнении с цыплятами контрольной группы, не подвергавшихся лечению. Сделан вывод о возможности прогнозирования риска развития обострения инфекционного процесса в легких на фоне локального снижения вирусной нагрузки в кишечнике. Необходим комплексный подход при терапии коронавирусных инфекций, включающий или противовирусные препараты системного действия, или противовоспалительные средства.

Ключевые слова: ген, интерлейкин, коронавирус, Люманце, Глицевир, цыплята

STUDY OF THE EXPRESSION OF FUNCTIONALLY RELEVANT GENES IN THE TREATMENT OF CORONAVIRUS INFECTION IN CHICKENS

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The level of expression of anti-inflammatory cytokines NF-kB, IL-6, IFN-y, Caspasa-3, FC in chickens in the lungs and intestines during the modeling of infectious bronchitis in chickens was

studied. To simulate coronavirus pneumonia, the vaccine was administered individually, 10 doses per head orally. The chickens of the 1st experimental group were fed with the Lyumantse preparation at the rate of 3 kg / t of feed, the 2nd experimental group received the Glitsevir drug at the rate of 200 μg / 0.3 ml per head. The chickens of the control group did not receive the preparations. It was revealed that antiviral drugs in the experimental groups suppressed the destruction of epithelial cells in the intestine. This may not always be an indication of a positive character, as in the case of apoptosis, not only the intestinal cells affected by the virus particles but also healthy cells are destroyed. There was a decrease in the number of active macrophages in the intestines of the experimental groups relative to the control. The amount of interferon produced was also below the control, which indicates a decreased activity of the immune system. A higher pro-inflammatory activity in the respiratory system of chickens was detected when Glicevir was used. It consists of increased expression of IL-6, interferon-gamma, macrophage receptor to Fc antibody fragments and inflammatory regulatory factor NF-kB genes compared to Lumantse with anti-inflammatory activity, but also compared to untreated control group chickens. It is concluded that it is possible to predict the risk of an exacerbation of an infectious process in the lungs against the background of a local decrease in the viral load in the intestine. An integrated approach is needed in the treatment of coronavirus infections, including either systemic antiviral drugs or anti-inflammatory drugs.

Key words: gene, interleukin, coronavirus, Lyumantse, Glitsevir, chickens

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INTRODUCTION

In modern science, pro-inflammatory and anti-inflammatory cytokines are considered as the most important factor of intercellular and systemic interaction in the body. Cytokines are a group of endogenous glycosylated polypeptide mediators of intercellular interaction involved in the formation and development of the body's defense reactions when pathogens are introduced and tissue integrity is compromised, as well as in the regulation of a number of normal physiological functions [1].

The state of the body's immune functions is largely determined by the ratio of pro- and anti-inflammatory cytokines. Functional antagonism between them has been shown to exist (2). An acute increase in circulating cytokine levels leads to the development of a protective systemic inflammatory response, often referred to as a cytokine storm. Pathologically high concentrations of pro-inflammatory cytokines can cause septic shock and death.

In situations in which cytokine levels exceed the physiological concentration for a prolonged period, they no longer mediate protection, but

become mediators of pathology [3-6]. This is also population-driven: the organism must be eliminated to prevent further spread of the pathology.

Interleukin 6 (IL-6) is an immunoregulatory cytokine with a broad spectrum of action: it regulates the processes of inflammation and cell division. IL-6 is synthesized from macrophages, T cells, fibroblasts, vascular endothelial cells, glial cells and epithelial cells after interaction with pathogenic molecules. In the formation of the immune response, interleukin 6 is involved in the production of antibodies. An excess of this cytokine leads to the development of an autoimmune reaction and tissue damage (7).

Caspases are a family of cysteine proteases that are involved in the cleavage of peptide bonds. The expression of caspases-3, -8, -9 is an indicator of the cytotoxicity of the apoptotic stimulus, making these markers an important part of research into the processes of apoptosis in the body [8].

Cells of the immune system interact with each other using cytokines - modulators of immune responses. Among these, interferons occupy an important place. They have antiviral and antibacterial effects and are involved in the anti-tumor immune response [9]. INF-γ, like most cytokines, has pleiotropic effects and plays an important role in the immune response. Initially, INF-γ was thought to be produced only by natural killer (NK) cells, CD4+ Th1-lymphocytes and cytotoxic CD+ T-lymphocytes. Later, it became known that B-lymphocytes, NKT cells and antigen-presenting cells (APCs) (macrophages, dendritic cells) are also able to secrete this cytokine [10].

NF-kB is found in almost all animal cell types and is involved in cellular responses to stimuli: stress, cytokines, free radicals, heavy metals, ultraviolet irradiation, oxidized LDL, and bacterial or viral antigens. NF-kB plays a key role in regulating the immune response to infection (11,12).

The antiviral effect of medicines is often detected by qRT-PCR [13–15], IFA [16, 17].

Several reports indicate that MDA5 signaling pathways and cytokines of innate immunity are activated following infection with IBV strain M41 [18]. The MDA5 signaling pathway is disrupted by cleavage of the adaptor protein MAVS in the IBV JS/2010/12 infection strain [19]. The INF type I response plays a crucial role in resistance to the IBV strain SAIBK2 [20]. The MDA5 signaling pathway and innate immunity cytokine (NF-kB and IRF3) were induced following infection with IBV-M41 strain [17]. Researchers found that mRNA expression levels of MDA5, MAVS, INF-α, INF-β, NF-kB, TNF-α and IL-6 were significantly increased following infection with IBV in vitro and in vivo [18].

The purpose of the study was to evaluate the expression of IL-6, Fc, NF-kB, Caspasa-3 and INF-γ genes during coronavirus infection in chickens.

MATERIAL AND METHODS

Chickens of the Shaver cross were vaccinated against infectious bronchitis in chickens being 14 days of age (IBC vaccine, strain Ma5, live dry). To simulate coronavirus pneumonia, the vaccine was administered individually, 10 doses per head orally. Chickens of experimental group 1 (n = 10) were fed Luymantse at the rate of 3 kg/t feed, and those of experimental group 2 (n = 10) - Glitsevir (glycyrrhizic acid derivative in chitosan nanoparticles) at the rate of 200 μg/0.3 ml per head. The concentrate was diluted by a factor of 3. Chickens of the control group (n = 11) did not receive the drugs.

On the 22nd day, the birds were slaughtered by cervical-cerebral dislocation and autopsied. RNA was isolated from internal organs by phenol-chloroform extraction, and RT-PCR was performed. The cDNA synthesis was performed using oligonucleotide N7.

To confirm the success of infection, the presence of IBK virus genomic RNA was tested by real-time RT-PCR, PCR was performed in a final volume of 20 μl containing 67 mM Tris.-HCl (pH 8.9), 16 mM (NH4) 2SO4, 2.4 mM MgCl2, 0.01% Tween 20, 0.2 mM dNTP, 0, 3 mM oligonucleotide primer solutions 5`-atgctcaaccttgtccctagca-3`5`tcaaactgcggatcacgt-3` and FAM probe tggaagtaggaccaac-BHQ, 1-2 units HotStart Taq-DNA polymerase. PCR was

performed on a CFX amplifier (BioRad) according to the following program: initial denaturation - 95 °C (15 min), then 40 cycles: denaturation - 95 °C (10 s), annealing - 60 °C (30 s).

RNA extractability from samples was monitored using real-time PCR specific to the housekeeping gene glyceraldehyde3-phosphate dehydrogenase (GAPDH) mRNA using the protocol above, using primers 5`cgtgaccccagcaacatcaa3` and 5` acttaccccagccttccat3` taqman ROX probe tggagtactggtcttccacc- BHQ2.

The expression of IL-6, Fc, NF-kB, Caspasa-3, INF-γ genes was assessed by the delta-delta Ct method relative to the expression level of housekeeping genes (see the table).

RESULTS AND DISCUSSION

The preparations Lyumantse and Glitsevir inhibited the destruction of epithelial cells in the intestines of the experimental groups (see Figure 1). This is not necessarily indicative of a positive character, since in the case of apoptosis, not only healthy but also infected cells are destroyed. A decrease in the number of active macrophages in the intestine relative to the control group was observed. The amount of interferon produced was also lower than the control, indicating a reduced activity of the immune system.

Glitsevir consists of nanoparticles, which are not absorbed by the intestine and have a local effect. Lyumantse can be absorbed as it contains salts of butyric acid and has a systemic effect in addition to its local effects. In the intestine, both preparations reduced the viral load.

Glitsevir provoked more intensive expression of genes involved in the immune response and inflammation, characterized by increased levels of NF-kB, IL-6, INF-γ (more T helper cells encountering viral particles), Fc (more macrophages) and Caspasa-3 (cells in the lungs are destroyed more intensively) (see figure 2).

The suppression of epithelial cell destruction by the experimental preparations is also evidenced by the reduced specific fraction of the Fc-fragment relative to the control group. Fc-receptor is present on macrophages and is responsible for antibody binding to macrophage. A decrease in the number of active macrophages in the intestine relative to the control group can be asserted. Caspases play an important role in the development and regulation of apoptosis and inflammation. In this case (as the coronavirus itself has no effect on cell destruction) there is destruction of the affected cells by immune agents such as T-killers.

Interferon gamma (INF-γ), which is a pro-inflammatory cytokine and activates many cells (T cells, B cells, etc.), is produced when T-helper cells interact with antigen. In the intestine the amount of interferon produced is reduced, this also indicates a reduced activity of the immune system.

Interleukin-6 is a pro-inflammatory cytokine, the amount of which directly affects the development of a cytokine storm. IL-6 creates

Нуклеотидные последовательности праймеров ПЦР для оценки экспрессии генов
PCR primer nucleotide sequences for assessing gene expression

Interleukin	Primer	Source reference	PCR program			
IL-6	5`-aaatccctcctcgccaatct-3` 5`-ccctcacggtcttctccataaa-3	[21]	1	95 °C	7 min	1 cycle
Caspasa-3	5`-ccaccgagataccggactgt-3` 5`-aactgcttcgcttgctgtga-3`	[22]				
INF-γ	5`-cactgacaagtcaaagccgc-3` 5`-accttcttcacgccatcagg-3`	[22]	2	95 °C	15 s	39 cycles
FcR	5`-cactgacaagtcaaagccgc-3` 5`-accttcttcacgccatcagg-3`	[22]				
NF-kB	5`-tcaacgcaggacctaaagacat-3` 5`-gcagatagccaagttcaggatg-3`	[22]	3	64,5 °C	30 s	
			END			

The data were processed by methods of variation and nonparametric statistics.

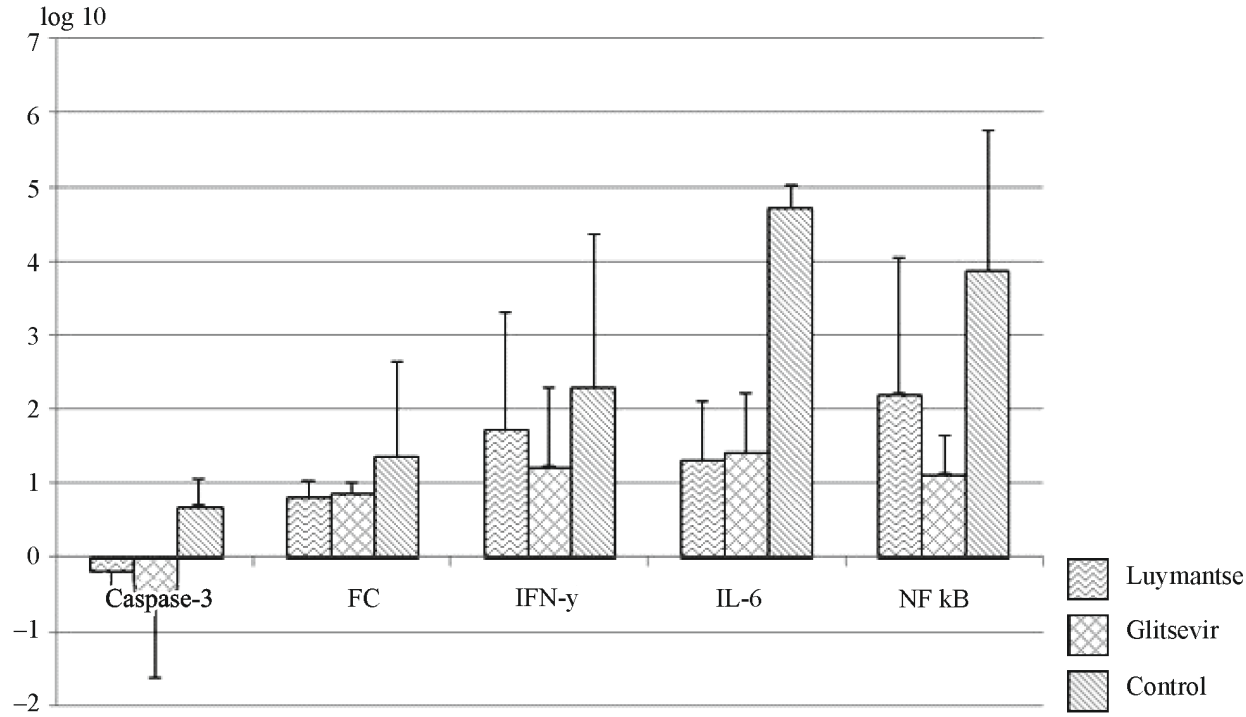

Рис. 1. Экспрессия генов в кишечнике у птицы опытной и контрольной групп, log10(ddCt) (относительно GAPDH)

Fig. 1. Gene expression in the intestine of birds in the experimental and control groups, log10(ddCt) (relative to GAPDH)

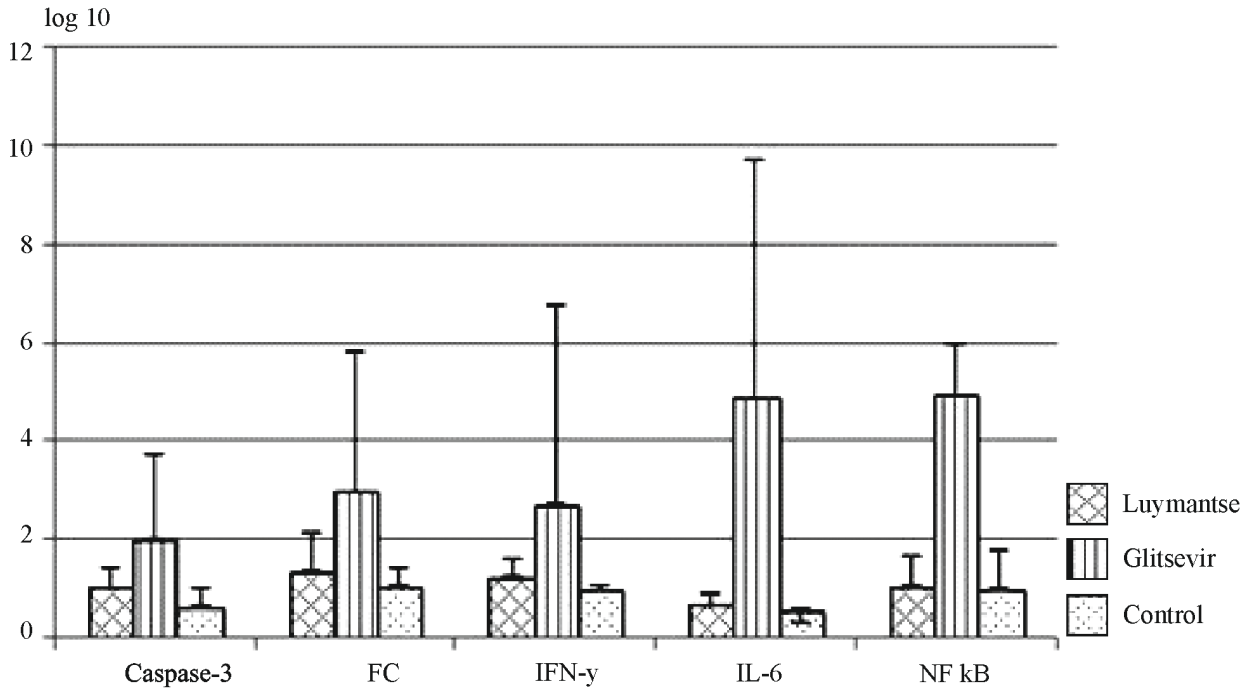

Рис. 2. Экспрессия генов в легких у птицы опытной и контрольной групп, log10(ddCt) (относительно GAPDH)

Fig. 2. Gene expression in lungs of poultry from experimental and control groups, log10(ddCt) (relative to GAPDH)

conditions in the body that overload the immune system and two pathways emerge: elimination of the pathogen in its entirety or elimination of the infected animal itself (7, 11). At the moment when viral antigens meet toll-like receptors, NF-kB is activated, which in turn is the trigger mechanism for both the innate immune response (macrophage migration, etc.) and adaptive immunity (antibody production, T-cell formation). NF-kB is the earliest factor and is most actively exploited in coronavirus infections. It is manifested by abnormally prolonged migration of neutrophils, granulocytes to the focus of inflammation, their activation, and increased proliferation, whereas in a normal infection there is only a short period of neutrophils fighting the primary focus of infection. This mechanism can subsequently lead to a leukotriene storm, subsequently to a cytokine one.

Glycyrrhizic acid has antiviral, anti-inflammatory, antipruritic and immunomodulatory effects, affects different types of virus DNA and RNA in vitro and in vivo, interrupts virus replication at early stages, causes virion exit from the capsid, preventing its penetration into cells, which is due to selective dose-dependent inhibition of phosphorylated kinase. Glycyrrhizic acid interacts with virus structures, changing different phases of the viral cycle, which is accompanied by irreversible inactivation of viral particles that are free outside cells, blocks the introduction of active viral particles inside cells, disrupts the virus ability to induce synthesis of new viral particles, induces interferon formation, which is a component of antiviral action, inactivates these viruses in nontoxic concentrations for normally functioning cells . The anti-inflammatory activity of glycyrrhizic acid is combined with a stimulating effect on humoral and cellular immunity factors[1].

The difference between the activity of drugs with a resorptive effect (Lyumantse) and those without (Glitsevir in chitosan nanoparticles) is the higher pro-inflammatory activity in the respiratory system with Glitsevir. It consists in increased expression of IL-6, interferon-gamma, macrophage receptor to Fc antibody fragments, inflammatory regulation factor NF-kB genes not only in comparison with Lyumantse, which possesses anti-inflammatory activity due to oily acid, but also in comparison with an untreated control group of chickens.

We propose two hypotheses about the effect of the drugs on the affected intestine:

– both drugs reduce inflammation in the intestine by suppressing immunoreactivity and therefore reducing the immune response;

– the drugs reduce the viral load, so there is less presentation of viral antigens and less production of immunocompetent cells.

In either hypothesis, Glitsevir had a suppressive effect on the inflammatory processes in the intestine without affecting the lungs (see Figure 1).

The main theory is a decrease in the activity of immunocompetent cells within the gastrointestinal tract, primarily Treg lymphocytes (active producers of the anti-inflammatory cytokine IL10) due to the suppression of the infection process locally, by the site of action of Glitsevir, i.e. in the intestine.

This assumption is supported by the suppression of IL-6 gene expression activity, a direct antagonist of the pro-inflammatory cytokine IL10 and cells producing this interleukin. All blood and lymph from the gastrointestinal tract necessarily pass through the lungs, i.e. virtually undiluted, so the contribution of the regulatory activity of the intestine immune system towards immunocompetent cells in the lungs must be substantial. Thus, the risk of an exacerbation of the infectious process in the lungs against the background of a local reduction of the viral load in the intestine can be predicted, which requires a comprehensive approach in the therapy of coronavirus infections, including either antiviral drugs of systemic action or anti-inflammatory drugs.

[1] Patent RF № 2044145 (Russian Federation). Di- and trinicotinates of glycyrrhizic acid and inhibitor of human immunodeficiency virus reproduction / G.A. Tolstikova, L.A. Baltina, K.P. Volcho, O.A. Plyasunova, A.G. Pokrovskii, N.F. Salakhutdinov. Published 10.08.2007. Bulletin number 22.

CONCLUSIONS

1. A statistically significant suppression of pro-inflammatory cytokine IL-6 expression ($p < 0.05$) in experimental groups of chickens treated with Lyumantse and Glitsevir was detected in a model of coronavirus infection.

2. The application of Glitsevir in chitosan nanoparticles was limited to local action, which was characterized by absence of suppression of proinflammatory cytokines in lungs and, on the contrary, differed from the Lyumantse action by increased dispersion of expression levels of the studied genes and average levels of increase in expression of IL-6, NF-kB, INF-γ (proinflammatory cytokines) and Caspasa-3, Fc-fragments in lung tissue.

3. To reduce the risks of acute pneumonia in coronavirus infections, the use of topical antiviral drugs in the intestine should involve the use of systemic anti-inflammatory drugs.

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МОНИТОРИНГ БОЛЕЗНЕЙ ОРГАНОВ ПИЩЕВАРЕНИЯ КРУПНОГО РОГАТОГО СКОТА НА ТЕРРИТОРИИ ЗАБАЙКАЛЬСКОГО КРАЯ

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Представлена динамика болезней органов пищеварения бактериальной этиологии среди крупного рогатого скота. Проанализированы статистические, лабораторные среднегодовые данные о зарегистрированных с этой патологией животных, о падеже и вынужденном убое скота за период 2016–2020 гг. Выяснено, что болезни органов пищеварения бактериальной этиологии распространены как у молодняка КРС (от 53,7 до 61,4%), так и у взрослого скота (43,1% от общего поголовья заболевших животных). На основании бактериальных методов исследований биологического материала выделены следующие возбудители: энтеропатогенная кишечная палочка *E. coli* (37,8% от общего числа заболевших животных) и стрептококки группы «D»-E. Faecalis (15,1%). У остального поголовья зарегистрированы ассоциативные формы инфекций (19,2%) и незаразные виды болезней органов пищеварения (27,9%). В результате проведенного мониторинга отмечен высокий уровень заболеваемости болезней органов пищеварения среди крупного рогатого скота в животноводческих хозяйствах следующих районов Забайкальского края: Акшинский, Красночикойский, Кыринский, Нерчинский, Оловянинский, Приаргунский, Хилокский, Шелопугинский, Агинский. Наименьшее распространение заболеваний крупного рогатого скота в организациях разных форм собственности зарегистрировано в крестьянско-фермерских хозяйствах края (6,8–10,9%). Средние показатели по численности зарегистрированных животных с данной патологией отмечены в сельскохозяйственных организациях (26,9–37,6%). Высокий процент данных заболеваний отмечен в хозяйствах населения (62,8%). При соблюдении в хозяйствах организации лечебно-профилактических мероприятий, правил гигиены содержания и кормления можно обеспечить сохранность и продуктивность скота, высокое качество и безопасность продукции скотоводства, проводить профилактику бактериальных заболеваний органов пищеварения.

Ключевые слова: крупный рогатый скот, мониторинг, болезни органов пищеварения, бактериальные болезни

MONITORING OF THE BOVINE DIGESTIVE DISEASES ON THE TRANSBAIKAL TERRITORY

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The dynamics of digestive diseases of bacterial etiology among cattle are presented. Statistical, laboratory and annual average data on registered animals with this pathology, mortality and forced slaughter of livestock were analysed for the period 2016-2020. It has been found that digestive diseases of bacterial etiology are prevalent both in young cattle (53.7% to 61.4%) and in adult cattle (43.1% of the total number of diseased animals). The following pathogens were identified on the basis of bacterial tests on biological material: enteropathogenic *E. coli* (37.8% of the total number of diseased animals) and group D streptococci, E. Faecalis (15.1%). The rest of the herd had associated infections (19.2%) and non-contagious digestive diseases (27.9%). As a result of this monitoring, a high incidence of digestive diseases among cattle in livestock farms in the

following districts of the Trans-Baikal Territory was recorded: Akshinsky, Krasnochikoysky, Kyrinsky, Nerchinsky, Olovyaninsky, Priargunsky, Khiloksky, Shelopuginsky, Aginsky. The lowest prevalence of cattle diseases in organizations of various forms of ownership has been recorded in peasant farms in the region (6.8-10.9%). The average number of registered animals with this pathology is recorded in agricultural organizations (26.9-37.6%). A high percentage of these diseases were recorded in households (62.8%). When farms follow the organization of therapeutic and prophylactic measures, housing and feeding hygiene rules, it is possible to ensure the safety and productivity of livestock, high quality and safety of livestock products and to prevent bacterial diseases of the digestive organs.

Keywords: cattle, monitoring, diseases of the digestive system, bacterial diseases

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INTRODUCTION

Respiratory and gastrointestinal diseases of young cattle are the most widespread at the present stage of livestock development. The reasons for this are that farms are staffed with "prefabricated livestock" from farms with different epizootic situations and non-compliance with the standard indicators of animal housing and feeding. High morbidity of young cattle leads to forced slaughter and death of a significant number of animals, to a decrease in live weight, which hinders the development of animal husbandry [1, 2].

Mass gastroenteritis in animals, in particular in newborn calves, is considered to be a factor-associated infection, etiologically determined by viruses, bacteria, protozoa and fungi. These diseases are epizootic in nature and are characterized by their stationarity, ubiquitous distribution and the presence of potentially virulent microbial associations [3-5].

Statistical and scientific data allow most gastrointestinal diseases of animals to be regarded as infectious diseases. They are caused by viruses (corona-, rota-, enteroviruses), bacteria (escherichia, clostridia, salmonella, etc.), protozoa, helminths (trichocephalus, strongyloides, etc.). Gastroenteritis of non-infectious etiology can also occur [2, 5].

The specific etiopathogenesis, clinical manifestation and course of the disease are determined by the interaction of macro- and microorganisms, the nature of the associations, the virulence of which is increased in the presence of unfavorable environmental factors [4–6].

The intestinal microflora, being in close relationship with the microorganisms, always reacts to changes in the conditions of housing, feeding and the presence of a pathological process. Any exposure caused by poor hygienic conditions within the production facility, improper transition to a new ration or stress can significantly affect the gastrointestinal ecosystem of calves [6-10]. In this regard, the issue of digestive diseases of bacterial etiology remains relevant.

The purpose of the research is to monitor digestive diseases of bacterial aetiology among cattle in the Trans-Baikal Territory.

MATERIAL AND METHODS

The material was cattle with signs of gastrointestinal diseases (including young cattle) from 10 districts of Trans-Baikal Territory (Aginsky, Akshinsky, Krasnochikoysky, Kyrin-

sky, Nerchinsky, Olovyaninsky, Priargunsky, Khiloksky, Chitinsky and Shelopuginsky). During monitoring, clinical and epizootological, statistical data on registered diseased animals in farms, veterinary reporting data (Form No. 2 - vet)[1] and laboratory tests results were taken into account. To clarify the diagnosis, sampling and examination of biological material (faeces, blood) from adult cattle and calves were carried out. Laboratory tests were conducted in the laboratory of laboratory and analytical studies of the Research Institute of Veterinary Science of Eastern Siberia - a branch of the Siberian Federal Scientific Center of AgroBioTechnologies of the Russian Academy of Sciences and the State Institution of the Regional Veterinary Laboratory. Bacteriological and biochemical tests were carried out in accordance with approved regulatory documentation[2].

RESULTS AND DISCUSSION

As a result of the data analysis of the examined livestock in 10 farms of Transbaikal Territory, digestive diseases take the leading place. In this connection, we took into account the data on registered sick animals, the number of fallen and forcedly killed cattle, including young cattle.

The number of diseased and dead animals from digestive diseases decreased by 21.8% and 66.3% respectively in cattle during the 5-year period compared to 2020 (see the table). In young animals, the morbidity rate was 33.4% and the mortality rate decreased by 66.3% of the total number of diseased animals with this pathology. To clarify the causes and factors of gastrointestinal diseases in cattle, such as colibacillosis, salmonellosis, streptococcosis and others, an analysis of laboratory tests for 2016-2020 was conducted. The figure shows the data on animals with digestive diseases of bacterial aetiology as a percentage of the total number of the diseased cattle in the region (29,599 heads in a 5-year period).

Statistical, laboratory and scientific data (2016-2020) show that digestive diseases of bacterial etiology are registered in young cattle (53.7% to 61.4%) and in adult cattle, with an average of 43.1% of the total number of animals suffering from digestive diseases over five years.

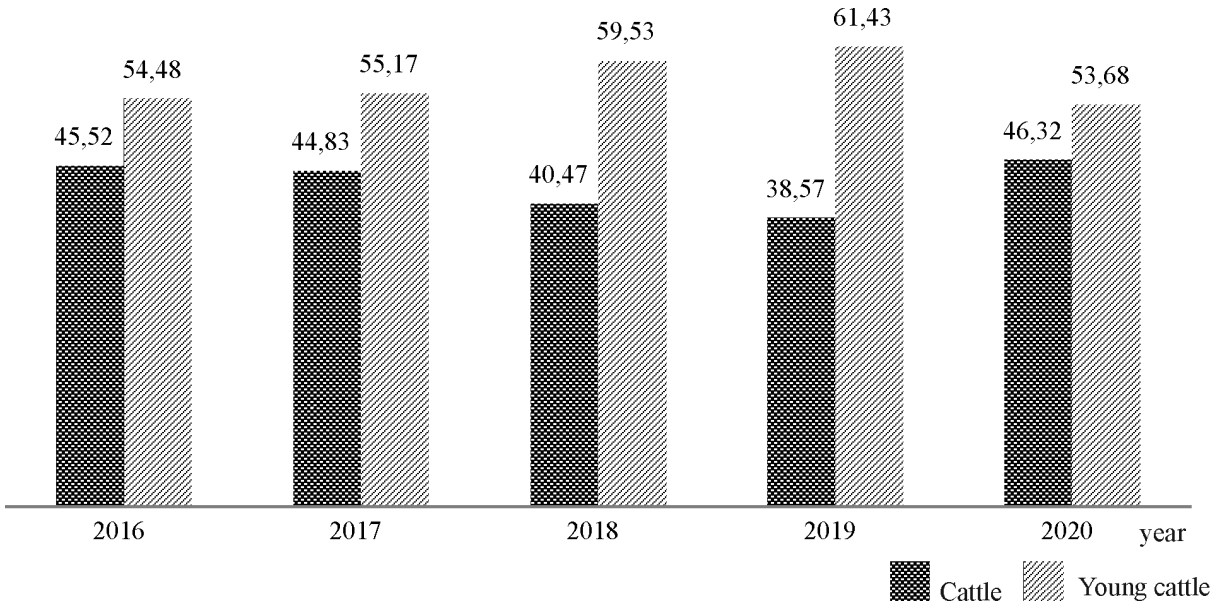
From biological material by bacteriological methods of investigation enteropathogenic *E. coli* was detected in 37.8% of the animals, group "D"-E.Faecalis in 15.1%, the rest of the animals had associated infections (19.2%) and

Данные об исследованных больных животных с болезнями органов пищеварения за 2016–2020 гг.
Data on the studied sick animals with diseases of the digestive system for 2016–2020

Year	Initially registered sick animals, heads		Of the reported sick animals, dead and compulsorily slaughtered, heads			
	bovine cattle	young cattle	bovine cattle		young cattle	
			dead	compulsorily slaughtered	dead	compulsorily slaughtered
2016	4577	2490	300	64	169	6
2017	4209	1887	186	77	102	0
2018	4127	1670	240	35	134	0
2019	3900	1504	178	48	85	5
2020	3578	1657	95	43	39	0

[1]Veterinary Reporting Form No 2 - vet "Information on non-communicable animal diseases" 2016-2020.

[2]MG 4.22723-10 and MG on bacteriological diagnosis of colibacillosis (escherichiosis) of animals, approved by the Department of Veterinary Medicine of the Ministry of Agriculture and Food of the Russian Federation No 13-7-2/2117 27.07.00. M., 2000. 54 p.



Динамика зарегистрированных болезней органов пищеварения бактериальной этиологии среди крупного рогатого скота, 2016–2020 гг.,%

Dynamics of reported digestive diseases of bacterial etiology among cattle from 2016–2020, %

non-infectious forms of digestive system diseases (27.9%).

As a result of this monitoring, a high level of disease incidence was noted among cattle in the following districts of Trans-Baikal Territory: Akshinsky, Krasnochikoysky, Kyrinsky, Nerchinsky, Olovyaninsky, Priargunsky, Khiloksky, Shelopuginsky, Aginsky.

Analysis of clinical and laboratory data shows that the incidence of gastroenteritis in newborn calves varies from single cases to 15-30%, lethality reaches 40-60% of the number of diseased animals, in addition to a decrease in meat productivity of 10-18% in over diseased animals.

In absolute numbers, losses from gastrointestinal diseases in 2016 were 2,465 heads, in 2017 and 2020 - 2008 and 1,826 heads, respectively. In 2020, in relation to 2016, the level of digestive diseases in young cattle increased by 6.5% and amounted to 55.7-62.8% of the total number of the diseased cattle.

The lowest percentage of diseased cattle with digestive diseases is registered in the farms of the region (6.8-10.9%). The average number of registered animals with this pathology is recorded in agricultural organizations (26.9-37.6%); the most frequent occurrence of these diseases is in household farms (62.8%).

CONCLUSION

According to monitoring of digestive diseases among cattle on a number of farms of various forms of ownership in Trans-Baikal Territory, the lowest incidence of the disease was recorded in peasant farms (6.8-10.9%). The average rate of registered animals with this pathology is noted in agricultural organizations (26.9-37.6%). A high percentage of these diseases was recorded in household farms (62.8%).

During bacterial diagnosis of biological material enteropathogenic *E. coli* was detected in 37.8% of cattle, group "D"-E. Faecalis - 15,1%, the rest of cattle (47,1%) have associated forms of infections and non-infectious forms of digestive diseases. Implementation in cattle farms of therapeutic and preventive measures, rules of hygiene of maintenance and feeding provides safety and productivity of livestock, high quality and safety of livestock products, prevention of bacterial diseases of digestive organs of animals.

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ВЛИЯНИЕ ЭКОЛОГО-ГЕОГРАФИЧЕСКОГО ФАКТОРА НА СОДЕРЖАНИЕ ТЯЖЕЛЫХ МЕТАЛЛОВ В ЛЕГКИХ ГЕРЕФОРДСКОГО СКОТА

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Изучена проблема загрязнения пищи тяжелыми металлами из-за накопления их в биосистемах вследствие антропогенных воздействий. Представлены результаты исследования содержания кадмия, свинца, железа и марганца у крупного рогатого скота из Новосибирской области и Алтайского края. Цель исследования – оценить влияние эколого-географического фактора на содержание тяжелых металлов в легких бычков герефордской породы. Пробы легких взяты от 31 клинически здорового бычка герефордской породы в возрасте 16–18 мес. Пробоподготовка осуществлена в соответствии с ГОСТами 26929–94 и 30178–96. Определение химического состава проб проведено методом атомно-абсорбционной спектрометрии с пламенной и электротермической атомизацией. Медианные значения по содержанию кадмия, свинца, железа и марганца в легких бычков находились в диапазоне 0,01–0,12; 0,07–0,11; 70,9–89,1 и 0,3–0,4 мг/кг соответственно. Фенотипическая изменчивость уровня железа и марганца отмечена относительно низкой, свинца и кадмия – высокой. Дисперсии уровней свинца и кадмия в изученных группах животных зарегистрированы гомогенными, марганца и железа варианты были разнородными. Влияние эколого-географического фактора характерно только для уровня кадмия. Для марганца, железа, свинца и кадмия рассчитаны референтные интервалы: 0–1,12; 0–148,1 и 0–0,170 мг/кг соответственно. Они могут служить ориентировочной нормой для скота герефордской породы, разводимого на территориях Краснозерского, Новосибирского, Маслянинского районов Новосибирской области и Целинного района Алтайского края.

Ключевые слова: герефордская порода, легкие, тяжелые металлы, кадмий, свинец, экология

INFLUENCE OF ENVIRONMENTAL AND GEOGRAPHICAL FACTOR ON THE HEAVY METAL CONTENT IN THE LUNGS OF HEREFORD CATTLE

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The problem of food contamination by heavy metals due to their accumulation in biosystems as a result of anthropogenic influences has been studied. The results of cadmium, lead, iron and manganese in cattle from the Novosibirsk Region and the Altai Territory are presented. The purpose of the study was to assess the impact of the ecological and geographical factor on the heavy metal content in the lungs of Hereford bulls. Lung samples were taken from 31 clinically healthy Hereford bulls aged 16-18 months. Sample preparation was carried out in accordance with GOST 26929-94 and 30178-96. The chemical composition of the samples was determined by atomic absorption spectrometry with flame and electrothermal atomization. The median values of the content of cadmium, lead, iron and manganese in the lungs of bull-calf were in the range of 0,01-0,12; 0,07-0,11; 70,9-89,1 and 0,3-0,4 mg/kg. The phenotypic variability of the level of iron and manganese was relatively low, while that of lead and cadmium was high. The dispersions of lead and cadmium levels in the animal groups studied were homogeneous, manganese and iron variants were heterogeneous. The influence of the ecological and geographical factor is characteristic only for cadmium levels. For manganese, iron, lead and cadmium the calculated reference ranges

are: 0-1.12; 0-148.1 and 0-0.170 mg/kg respectively. They can serve as a guideline for Hereford cattle bred in the territories of Krasnozersky, Novosibirsky and Maslyaninsky districts of the Novosibirsk region and the Tselinny district of the Altai Territory.

Keywords: Hereford breed, lungs, heavy metals, cadmium, lead, ecology

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INTRODUCTION

Livestock products are an important part of the human diet. In addition to their high protein and low carbohydrate content, meat products are rich in bioavailable essential micronutrients, amino acids and vitamins [1, 2]. Unlike other products, meat and by-products can accumulate large amounts of toxic elements [3-5]. The concentration of heavy metals in meat and by-products depends on the livestock production system [6]. In intensified livestock production, trace elements are supplied to the animals mainly in the form of premixes, which are added to concentrated feed. In addition, the mineral intake of livestock depends on the local environmental conditions [7-9]. Soil is an important source of trace elements, which are passed on to plants and through the food chain to animals and humans [10, 11]. Control of the concentration of toxic and essential trace elements in animal organs is necessary when raising livestock on large complexes [4, 12, 13]. This is necessary to ensure that heavy metals in food do not exceed the maximum levels established for human consumption. The results of the research are used to provide a balanced diet for animals in order to increase productivity and increase economically useful use [14]. Data on the content of heavy metals in animal organs and tissues provide important information on environmental pollution (natural or anthropogenic origin) and can be used to minimize the environmental impact of animal production [15, 16].

The purpose of the study was to assess the influence of the ecological and geographical factor on the content of heavy metals and to determine the reference intervals in the lungs of Hereford breed steers.

MATERIAL AND METHODS

Lung samples were taken from 31 Hereford steers aged 16-18 months bred in the Novosibirsk Region and the Altai Territory. The animals were bred in four districts: Krasnozersky (n = 4), Novosibirsky (n = 6), Maslyaninsky (n = 17) and Tselinniy (n = 4). The animals had no history of disease and were clinically healthy at the time of slaughter. Sampling was carried out after slaughter, followed by freezing and storage at -24°C until analysis.

The chemical composition of lung tissues was determined by atomic absorption spectrometry with flame (Mn, Fe) and electrothermal (Cd, Pb) atomization on a Shimadzu AA-7000 spectrometer in the biochemical laboratory of the Siberian Research Institute of Animal Husbandry of the Siberian Federal Scientific Center of AgroBioTechnologies of the Russian Academy of Sciences. Sample preparation was carried out in accordance with GOST 26929-94 and 30178-96.

Due to the small sample size in the groups, we calculated robust measures of descriptive statistics: median (Me), first and third quartiles (Q1, Q3), interquartile range (IQR), minimum and maximum values of the variable (Min, Max). Homogeneity of variance was assessed

using the Fliegner-Keelin test. To identify differences between districts in the concentration of heavy metals in the lungs of bulls, the Kraskell-Wallisle test was applied [17]. A posteriori analysis was performed using Dunn's test [18] with Hill's correction [19]. Reference intervals were calculated on the basis of the American Veterinary Clinical Society's Quality Assurance and Laboratory Standards Manual [20], taking into account the Clinical and Laboratory Standards Institute (CLSI) expert protocols[1]. Statistical processing of raw data was performed using the statistical programming language R and the data analysis environment RStudio, version 1.2.5033.

RESULTS AND DISCUSSION

Descriptive statistics on the content of heavy metals in the lungs of Hereford cattle, taking into account the breeding area, are shown in Table 1. Significant variability in iron and manganese levels was observed in cattle in the Maslyaninsky district. Intergroup phenotypic variability in cadmium levels was recorded as relatively low and in lead levels as high. Cadmium and lead concentrations in lung tissue of animals were generally comparable.

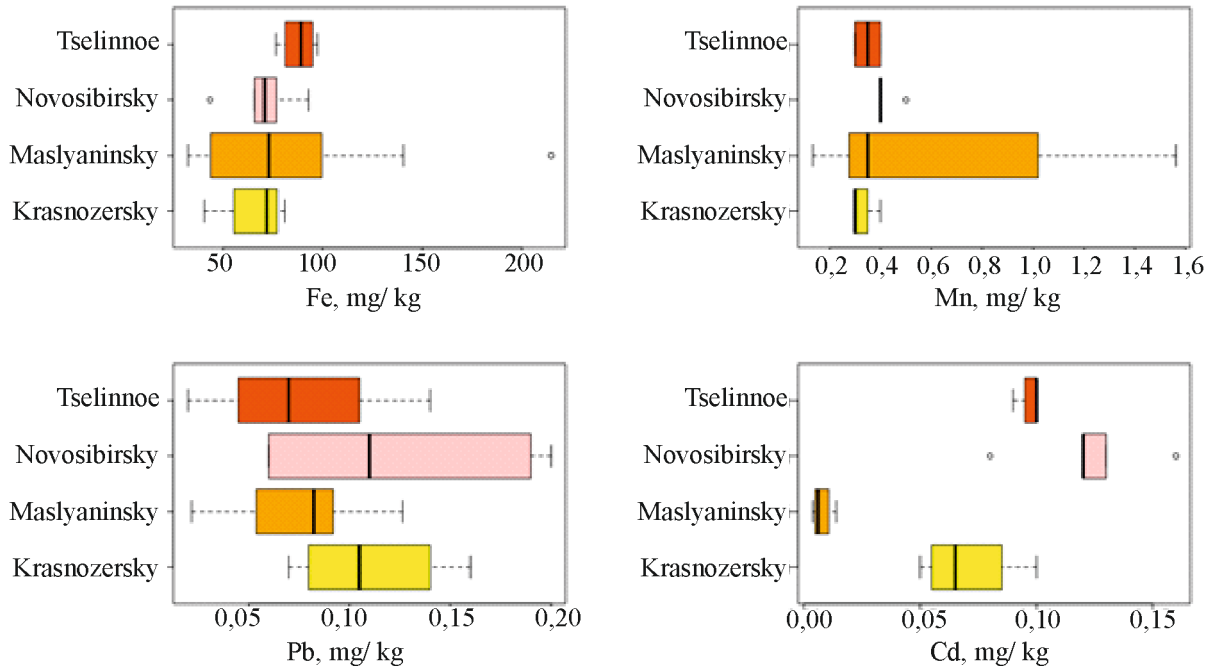
Concentrations of heavy metals were recorded fairly uniform across the studied areas (see the figure). Only cadmium level had rather high inter-group variability. Thus, cadmium level in Maslyaninsky district was more than 10 times lower relative to other districts. Concentration of heavy metals in cattle lungs is currently understudied. This is probably due to the fact that the levels of many trace elements are not normalized in the lungs. In addition, the lungs are not a widely consumed organ. Nevertheless, there are papers that have studied the accumulation of heavy metals in the lungs of animals.

Lead figures in similar studies [21-23] were 2-8 times higher than in our work. The minimum level of lead (0.004 mg/kg) was found in lung samples from calves reared on farms in Italy. Such a significant difference between our studies and those cited can only be explained by the early age of the animals from which the samples were taken [24]. Apparently, lead accumulates significantly with age and the difference between young and mature animals may

Табл. 1. Содержание ТМ в легких быков герефордской породы, мг/кг
Table 1. The content of heavy metals in the lungs of Hereford bulls, mg/kg

Factor	District	Me	Min	Max	Q_1	Q_3	IQR
Fe	Krasnozersky	71,9	40,6	81	53	77,9	24,9
Fe	Maslyaninsky	73	32,4	214,7	42,2	104	61,8
Fe	Novosibirsky	70,9	43,6	93,1	64	78,3	14,4
Fe	Tselinny	89,1	76,7	97,4	80,5	95,3	14,7
Mn	Krasnozersky	0,3	0,3	0,4	0,3	0,36	0,06
Mn	Maslyaninsky	0,35	0,13	1,56	0,27	1,03	0,76
Mn	Novosibirsky	0,4	0,4	0,5	0,4	0,41	0,01
Mn	Tselinny	0,35	0,3	0,4	0,3	0,4	0,1
Pb	Krasnozersky	0,11	0,07	0,16	0,08	0,14	0,07
Pb	Maslyaninsky	0,08	0,02	0,13	0,05	0,09	0,04
Pb	Novosibirsky	0,11	0,06	0,2	0,06	0,19	0,13
Pb	Tselinny	0,07	0,02	0,14	0,04	0,11	0,07
Cd	Krasnozersky	0,07	0,05	0,1	0,05	0,09	0,03
Cd	Maslyaninsky	0,01	0,004	0,014	0,005	0,01	0,005
Cd	Novosibirsky	0,12	0,08	0,16	0,11	0,14	0,03
Cd	Tselinny	0,1	0,09	0,1	0,09	0,1	0,01

[1]Defining, establishing, and verifying reference intervals in the clinical laboratory – 3th ed. CLSI Document C28-A3c. Approved guideline – Wayne, Pa, USA: CLSI, 2010. 59 p.



Содержание тяжелых металлов в легких герефордского скота по районам разведения
The content of heavy metals in the lungs of Hereford cattle by breeding area

be significant. Cadmium levels in our work are comparable with those of previously studied cattle lung samples [22]. A.A. Farmer and A.M. Farmer [23] showed that the concentration of this element in cattle lungs can vary in a wide range from 0.02 to 0.33 mg/kg depending on the breeding area. In our work, cadmium also showed the highest intergroup variability depending on breeding area. A single-factor analysis of variance had to be performed to identify the influence of the ecological and geographical factor. The raw data were checked to ensure that the conditions of the analysis were fulfilled. The null hypothesis of homoscedasticity of variance for manganese and iron concentrations can be rejected from the Fliegner-Keelin test (see Table 2). The intergroup variances of cadmium and lead pollutants were homogeneous. It is not possible to assess the distribution of traits for a Gaussian fit due to the small number of some groups. Therefore, it was decided to use the Kruskal-Wallis test. As a result, only in cadmium levels in the lungs of steers was a significant influence of the factor studied, in all other cases the differences were random (see Table 3).

A posteriori analysis showed that animals bred in Maslyaninsky district differed significantly in cadmium levels in lungs from cattle from other districts of the Novosibirsk Region and the Altai Territory (see Table 4). It is possible that these differences are caused by significant variability of cadmium, which is typical for homogeneous populations of cattle[2] and limited sampling from districts. It is necessary to continue monitoring cadmium levels in cattle and to identify individual factors that influence its variability.

Табл. 2. Оценка гомоскедастичности дисперсий тяжелых металлов в легких скота методом Флигнера-Килина

Table 2. Evaluation of the homoscedasticity of dispersions of heavy metals in cattle lungs by the Fligner-Kilin method

HM	χ^2	*df*	*p*
Cadmium	6,9092	3	0,07485
Lead	4,1719	3	0,2435
Iron	9,0672	3	0,02841
Manganese	12,429	3	0,00605

As a result of the experiment, the concentration of lead, iron and manganese was found to be homogeneous in the populations of cattle in the areas studied. Consequently, it is possible to combine the animals into one group and calculate the reference intervals. Data on the reference intervals for heavy metal concentrations in the lungs of Hereford cattle are presented in Table 5.

The reference values for lead levels were lower by a factor of 3 in the lower interval than those suggested by R. Puls [25]. Such differences may indicate a high variability of lead in different cattle populations, moreover, in the study of R. Puls [25] did not specify the breeding location, breed, age and sex of the cattle. These factors should be taken into account when developing regional standards for the content of heavy metals in animal organs and tissues.

Табл. 3. Влияние фактора районирования на уровень тяжелых металлов в легких животных герефордской породы

Table 3. The influence of the zoning factor on the level of heavy metals in the lungs of Hereford breed animals

Variables	*H*	*df*	*p*
Cadmium-District	21,513	3	0,0001
Lead- District	4,6744	3	0,1972
Iron- District	2,2547	3	0,5213
Manganese-District	3,3696	3	0,3381

CONCLUSION

In the course of the study a significant influence of the ecological and geographical factor on the cadmium content in the lungs of Hereford cattle has been established. In Maslyaninsky district the level of cadmium in Hereford cattle is 7-12 times lower than in Novosibirsk, Krasnozersky and Tselinnoe districts. No differences were found between the indicators of iron, manganese and lead content in the lungs of animals of the studied districts. Phenotypic variability of cadmium level in lungs is much higher than that of other heavy metals. The obtained reference values of iron, manganese and lead content in lungs can serve as a conventional norm for Hereford cattle bred in the territories of Krasnozersky, Novosibirsky, Maslyaninsky districts of the Novosibirsk region and Tselinnoe district of the Altai territory.

Табл. 4. Межгрупповое сравнение районов по содержанию кадмия в легких герефордского скота

Table 4. Intergroup comparison of areas by the content of cadmium in the lungs of Hereford cattle

District	Factor	Krasnozersky	Maslyaninsky	Novosibirsky
Maslyaninsky	Z p	2,379008 0,0347	–	–
Novosibirsky	Z p	–1,042339 0,4459	–3,973060 0,0002	–
Tselinny	Z p	–0,474417 0,6352	–2,689774 0,0179	0,461292 0,3223

Note. Z - criterion; p - level of significance including Holm correction.

Табл. 5. Референтные интервалы с 90%-ми доверительными интервалами (ДИ) для содержания тяжелых металлов в легких герефодского скота, мг/кг

Table 5. Reference intervals with 90% confidence intervals (CI) for the content of heavy metals in the lungs of Herefod cattle, mg/kg

Factor	Reference interval	Lower limit 90% CI	Top limit 90% CI
Mn	0–1,12	0–0	0,879–1,421
Fe	0–148,1	0–18,59	124,0–190,8
Pb	0–0,170	0–0,009	0,145–0,204

[2]Petukhov V.L., Syso A.I., Narozhnykh K.N., Konovalova T.V., Korotkevich O.S., Sebezhko O.I., Kamaldinov E.V., Osadchuk L.V., Soloshenko V.A., Myadelets M.A., Titova T.V., Tsygankova A.R., Saprykin A.I. Cadmium level in soil, coarse fodder, organs and tissue of cattle West Siberia // 18th International Conference on Heavy Metals in the Environment: Proceeding of Abstract, 12-15 September 2016. Ghent, Belgium, 2016. S10-P07.

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ПРОГНОЗИРОВАНИЕ СОДЕРЖАНИЯ НИТРАТНОГО АЗОТА В ПОЧВЕ С ИСПОЛЬЗОВАНИЕМ МАШИННОГО ОБУЧЕНИЯ

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Исследованы возможности и целесообразность применения Байесовской сети доверия и логистической регрессии для прогнозирования содержания нитратного азота в слое почвы 0-40 см перед посевом. Для обучения моделей использованы данные длительного многофакторного полевого опыта Сибирского научно-исследовательского института земледелия и химизации сельского хозяйства СФНЦА РАН за 2013–2018 гг. Опыт заложен на черноземе выщелоченном на территории центрально-лесостепной подзоны в 1981 г. в Новосибирской области. Учитывая особенности статистической выборки (данных наблюдений и анализов), определены основные предикторы моделей, влияющие на содержание нитратного азота в почве. Байесовская сеть доверия построена в виде ациклического графа, в котором обозначаются главные (основные) узлы и их взаимоотношения. Узлы сети представлены качественными и количественными параметрами рабочего участка (подтип почвы, предшественник, обработка почвы, погодные условия) с соответствующими градациями (событиями). В результате заполнения экспертами таблицы условных вероятностей с учетом анализа эмпирических данных сеть присваивает апостериорную вероятность наступления событий для целевого узла (содержание нитратного азота в слое почвы 0–40 см). Для проверки устойчивости работы сети проанализированы два сценария развития событий, получены удовлетворительные показатели. В результате построения логистической регрессии получены коэффициенты, характеризующие тесноту связи между зависимой переменой и предикторами. Коэффициент детерминации логистической регрессии равен 0,7. Это свидетельствует о том, что качество модели можно считать допустимым для прогнозирования. Дана сравнительная оценка прогностических возможностей обученных моделей. Общая доля правильных прогнозов для Байесовской сети доверия составляет 84%, для логистической регрессии – 87%.

Ключевые слова: Байесовская сеть, регрессионный анализ, нитратный азот, почва

PREDICTION OF NITRATE NITROGEN CONTENT IN SOIL USING MACHINE LEARNING

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The possibilities and feasibility of using the Bayesian network of trust and logistic regression to predict the content of nitrate nitrogen in the 0-40 cm soil layer before sowing have been investigated. Data from long-term multifactor field experience at the Siberian Research Institute of Farming and Agricultural Chemization of SFSCA RAS for 2013-2018 were used to train the models. The experiment was established on leached chernozem in the central forest-steppe subzone in 1981 in the No-

vosibirsk region. Considering the characteristics of the statistical sample (observation and analysis data), the main predictors of the models affecting nitrate nitrogen content in soil were identified. The Bayesian trust network is constructed as an acyclic graph, in which the main (basic) nodes and their relationships are denoted. Network nodes are represented by qualitative and quantitative plot parameters (soil subtype, forecrop, tillage, weather conditions) with corresponding gradations (events). The network assigns a posteriori probability of events for the target node (nitrate-nitrogen content in the 0-40 cm soil layer) as a result of experts completing the conditional probability table, taking into account the analysis of empirical data. Two scenarios were analyzed to test the sustainability of the network and satisfactory results were obtained. The result of the logistic regression is the coefficients characterizing the closeness of the relationship between the dependent variable and the predictors. The coefficient of determination of the logistic regression is 0.7. This indicates that the quality of the model can be considered acceptable for forecasting. A comparative assessment of the predictive capabilities of the trained models is given. The overall proportion of correct predictions for the Bayesian confidence network is 84%, for logistic regression it is 87%.

Keywords: Bayesian network, regression analysis, nitrate nitrogen, soil

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INTRODUCTION

Agriculture 4.0, as the fourth stage of its evolution, puts forward the requirements for creating and mastering modern information systems for decision support using a set of digital technologies [1]. Predictive analytics in these systems should take a leading position, because without predicting the transformation of conditions, objects and processes occurring in agriculture, it is difficult or almost impossible to make the right decision on its management [2, 3].

As in many other areas of human activity, the amount of information on agriculture is constantly increasing. Various machine learning algorithms are being used to evaluate information from a variety of sources in order to analyze data and assist agricultural professionals in solving specific problems, while improving efficiency. The application of machine learning in agriculture is currently accompanied by massive interest from the global scientific community. Various models are used in machine learning: regression, clustering, Bayesian and neural networks, support vector machines, decision trees, etc. The appropriateness of applying one or another machine learning model is determined by the different types of agricultural data and the problems to be solved [4-6].

One of the tools of artificial intelligence and the possibility of application in machine learning are considered to be Bayesian Belief networks (BBN). A review article [7] noted that the BBN method is suitable for research in agriculture, as BBN are able to reason with incomplete information and include new information, as well as solve problems under uncertainty, taking into account cause-effect relationships [8]. Examples of the application of the BBN apparatus in Russian-language publications are considered in medicine, ecology, risk analysis, sociology and other subject areas [9, 10], in the application to agriculture BBN have very limited application [11].

The most popular statistical method used for predictive modelling in agriculture is regression

analysis. This method is considered the easiest to use and understand, it allows to investigate the relationship between the dependent (target) and independent (predictor) variables, to identify significant patterns in general form, to determine the closeness of the relationship of the studied factors [12].

The purpose of the research is to train different models for the analysis of empirical data, to carry out a prediction of the nitrate nitrogen content in the soil before sowing, and to evaluate the accuracy of the predictive models.

MATERIAL AND METHODS

In model training, data from a long-term multi-factor stationary field experiment of the Siberian Research Institute of Soil Management and Chemicalization of Agriculture of SFSCA RAS were used. The experiment was conducted in 1981 on the territory of the farm "Elitnaya" - a branch of SFSCA RAS in the Novosibirsk region in the central forest-steppe subzone. The data include the results of research (2013-2018) of a four-field grain and fallow crop rotation (fallow - wheat - wheat - wheat). The experiments were carried out with different variants of the main tillage:

– ploughing (for the 1st and 3rd crops to a depth of 20-22 cm, for the 2nd - 25-27 cm);

– non-moldboard tillage (non-moldboard loosening with SibIME tines for the 1st and

3rd culture to a depth of 20-22 cm, under the 2nd - 25-27 cm);

– minimum tillage (stubble-mulch to a depth of 10-12 cm for all crops annually);

– zero tillage (no under-winter plowing).

The stationary soil is leached chernozem of medium-loam granulometric composition. Modelling was carried out using data on nitrate nitrogen content in the 0-40 cm soil layer before sowing.

The training of the BBN was carried out in the Netica software version "6.07", the logistic regression model was implemented in the SPSS module package version "26". In modelling, 80% of the original sample data were used for model training and 20% for testing (forecasting).

The dimensioning of the nitrate nitrogen level in the soil was set according to A.E. Kochergin's scale.

RESULTS AND DISCUSSION

BBN construction. BBN is an oriented acyclic graph, each vertex of which corresponds to a random variable, the arcs of the graph encode the conditional independence relations between these variables. The vertices can represent variables of any type, be weighted parameters, latent variables or hypotheses [13]. BBN are probabilistic because they are based on probability distributions and use probability theory to make predictions. Some data or expert knowledge (heuristics) are used to train and run a BBN. A prediction model is based on Bayes formula, which determines the probability of an event occurring, assuming that another event that is interdependent with it has already occurred.

The construction of a BBN begins with the definition of the graph structure, in which the main (main) nodes and their parameters are identified.

Based on the data structure, it is expertly assumed that the amount of nitrate nitrogen in the soil is dependent on weather conditions and farming practices.

The main nodes of the network are then represented by the qualitative and quantitative parameters of the working area (soil subtype, forecrop, tillage, weather conditions) with the corresponding gradations (events):

– soil sub-type - discrete variable with one gradation – Leached chernozem;

– soil tillage with four gradations – Plowing, Non-mouldboard tillage, Minimum tillage, Zero tillage;

– forecrop with four gradations – Fallow, fallow wheat 1, fallow wheat 2, fallow wheat 3;

– weather conditions with two gradations – Favorable, Unfavorable;

– nitrate nitrogen content in the 0-40 cm soil layer with two gradations - Less than 10 (less than 10 mg/kg soil) and More than 10 (more than 10 mg/kg soil). This node is the target node.

The next step was to construct an acyclic graph and arrange causal relationships to the target node, which is a prerequisite for further completion of the conditional probability table (CPT), taking into account the analysis of the

data obtained. The constructed graph consists of four main nodes (soil subtype, weather conditions, forecrop, tillage) and one target node (nitrate nitrogen content). At this stage, the system sets up a uniform probability distribution for all the nodes (see Figure 1).

Once the structure of the graph has been drawn up and the cause-and-effect relationships have been defined in the form of arrows from the main nodes to the target node, the CPT is constructed and completed according to the logic of the model (see Figure 2).

In CPT, the program automatically builds possible combinations of random events of the major nodes affecting the two events of the target node (nitrate nitrogen content - Less 10, More 10). In doing so, experts assign a priori probability of occurrence of each of the two events of the target node to each combination of random events of the main nodes, thereby training the model. The higher the percentage, the greater the probability that a given event will occur. In completing the CPT, the experts were guided not only by heuristics (knowledge of the problem) but also by empirical data from field experience. Once the CPT is fully constructed and populated, the BBN is compiled and the network is ready to use.

Before giving a forecast for 2021 for nitrate nitrogen content in the 0-40 cm soil layer, the

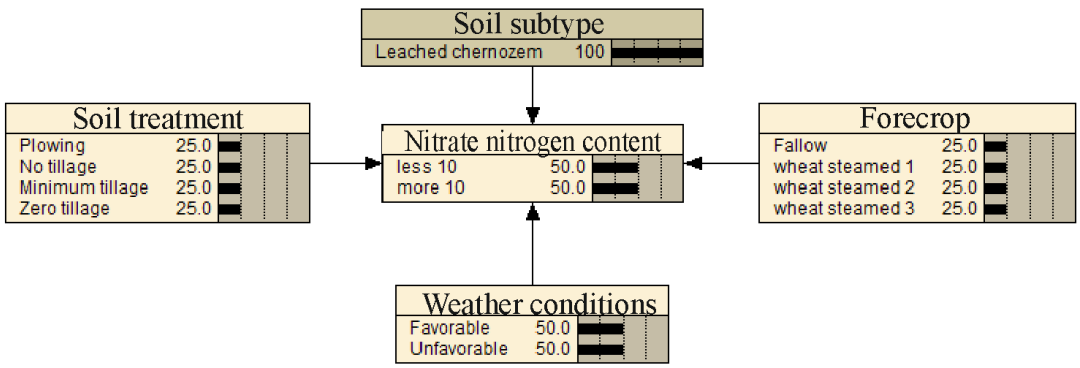
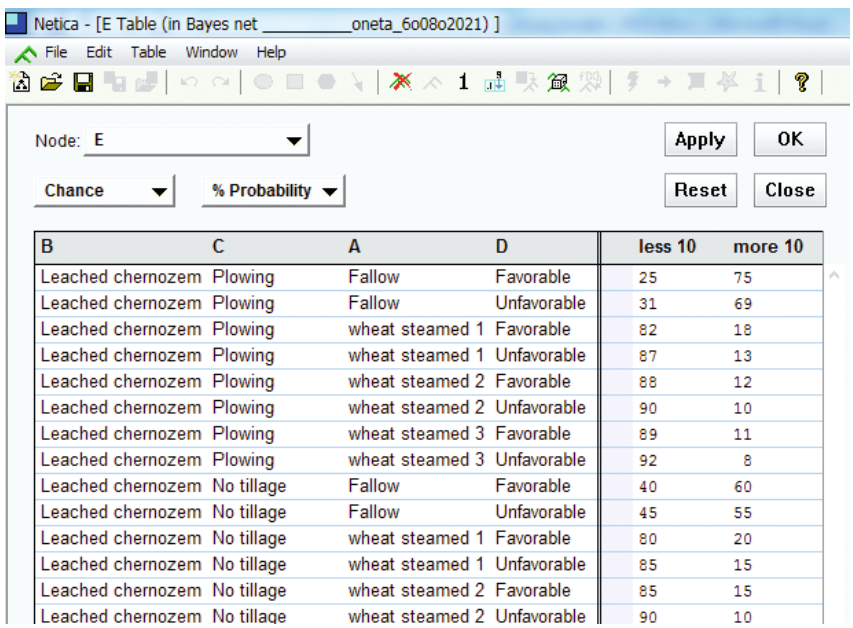


Рис. 1. Структура ациклического графа.
Fig. 1. The structure of an acyclic graph.



B	C	A	D	less 10	more 10
Leached chernozem	Plowing	Fallow	Favorable	25	75
Leached chernozem	Plowing	Fallow	Unfavorable	31	69
Leached chernozem	Plowing	wheat steamed 1	Favorable	82	18
Leached chernozem	Plowing	wheat steamed 1	Unfavorable	87	13
Leached chernozem	Plowing	wheat steamed 2	Favorable	88	12
Leached chernozem	Plowing	wheat steamed 2	Unfavorable	90	10
Leached chernozem	Plowing	wheat steamed 3	Favorable	89	11
Leached chernozem	Plowing	wheat steamed 3	Unfavorable	92	8
Leached chernozem	No tillage	Fallow	Favorable	40	60
Leached chernozem	No tillage	Fallow	Unfavorable	45	55
Leached chernozem	No tillage	wheat steamed 1	Favorable	80	20
Leached chernozem	No tillage	wheat steamed 1	Unfavorable	85	15
Leached chernozem	No tillage	wheat steamed 2	Favorable	85	15
Leached chernozem	No tillage	wheat steamed 2	Unfavorable	90	10

Рис. 2. Фрагмент таблицы условных вероятностей
Fig. 2. A fragment of the conditional probability table

network was trained to determine its behavior during changes in the events of the main nodes and to obtain the posterior probability of the target node. For this purpose, a situation was modelled (first scenario) in which the conditions on the working plot were as follows: forecrop - Fallow, tillage – Mouldboard Plowing, weather conditions - Unfavorable (see Figure 3).

In the first scenario, the BBN predicts with a 69% probability that the nitrate nitrogen content in the 0-40 cm soil layer will be more than 10 mg/kg.

In order to check the stability of the network, the second scenario was analyzed (node events changed): forecrop – fallow wheat 3, tillage - Zero tillage, weather conditions - Favorable (favorable) (see Figure 4).

Under the second scenario, the BBN predicts that there is a 95% probability that the nitrate nitrogen content in the 0-40 cm soil layer will be less than 10 mg/kg.

A sensitivity analysis has also been conducted for the BBN. A sensitivity analysis function is used to determine the magnitude and extent of the impact of the main nodes on the target node events in a descending order (see Table 1).

The mutual information between the two nodes indicates how dependent these nodes are on each other. If it exists, it shows how close their relationship is. The highest rate of mutual information is obtained for the forecrop node. This means that the node has the greatest influence on the target indicator (nitrate nitrogen content in the 0-40 cm soil layer). Weather conditions and soil tillage have much less influence on the target indicator.

Construction of a logistic regression model. To predict the target indicator (nitrate nitrogen content in the 0-40 cm soil layer), the relationship of this indicator (dependent variable) to the following independent variables (factors) was investigated: forecrop, tillage method, weather conditions (precipitation in April-May and September, average monthly air temperature for the same months).

The dependent variable can be categorized as a categorical variable when the values of nitrate nitrogen in the 0-40 cm soil layer take the form - Less 10 and More 10. In this case, the desired relationship can be obtained using a logistic regression model [14]. In this case, one of the categories of the dependent variable becomes the reference variable and the other is compared with it. The independent variables can be categorical or quantitative. The logistic regression equation predicts the probability of belonging to each category of dependent variable by the values of independent variables. The final selection of the predicted category for the dependent variable is made according to the rule of most likely membership.

Data generated in the form of a table of 72 observations (rows) and 9 factors (columns), including the dependent variable, were used to obtain the parameters (coefficients) of the logistic regression (see Figure 5).

The number of observations is distributed by the nitrate nitrogen content in the 0-40 cm soil

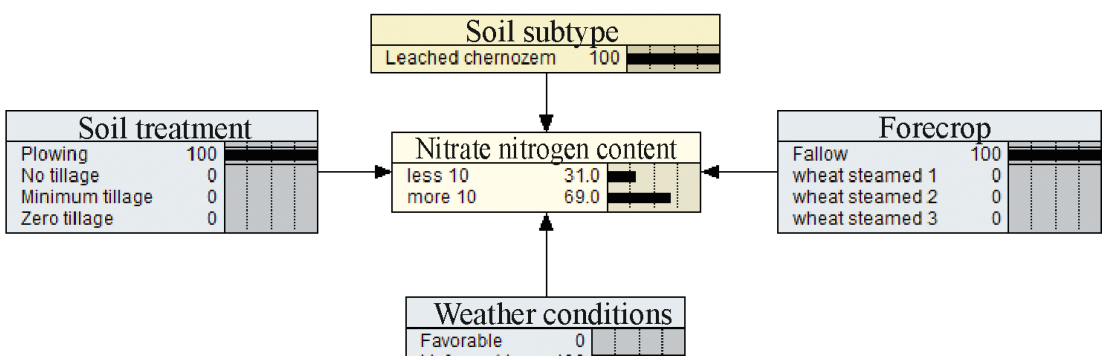


Рис. 3. Первый сценарий БСД

Fig. 3. The first DAG scenario

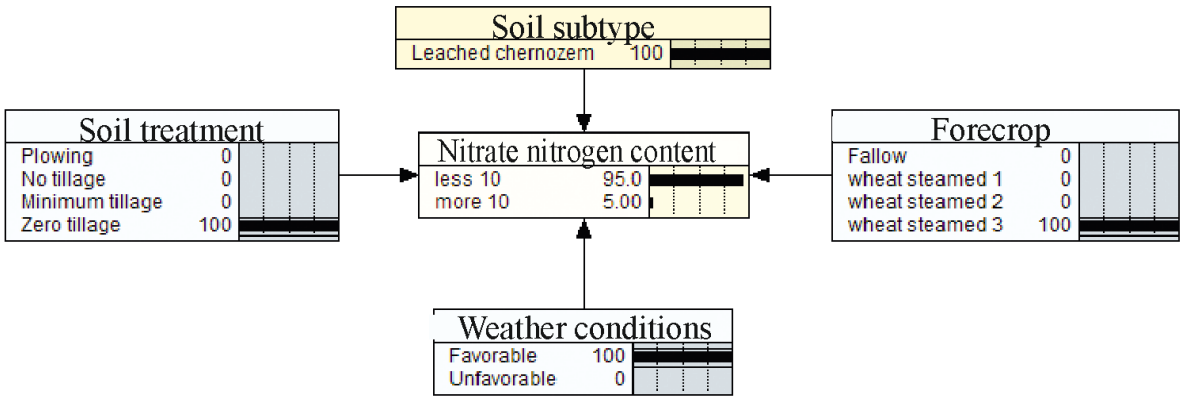


***Рис.* 4.** Второй сценарий БСД

***Fig.* 4.** The second DAG scenario

Табл. 1. Результаты анализа чувствительности узла содержания нитратного азота в слое почвы 0–40 см

Table 1. Results of the sensitivity analysis of the nitrate nitrogen content node in the 0–40 cm soil layer

Node	Mutual information	Percentage	Belief dispersion
Forecrop	0,308	33,9	0,08366
Weather conditions	0,00174	0,204	0,00048
Soil tillage	0,00084	0,0987	0,0002322
Soil subtype	0	0	0

layer as follows: Less 10 - 53, More 10 - 19. More 10 category was selected as a reference category.

Table 2 presents the coefficients obtained by means of logistic regression. Based on the logistic regression calculations, we can conclude that the strongest influence on the resulting variable is exerted by fallow as a forecrop. If the significance of the coefficient is $P < 0.05$, the relationship is statistically significant. A result of $P>0.05$ indicates that the relationship between the variables is weak or not detected. Third fallow wheat and zero tillage do not affect the nitrate nitrogen content in the 0-40 cm soil layer.

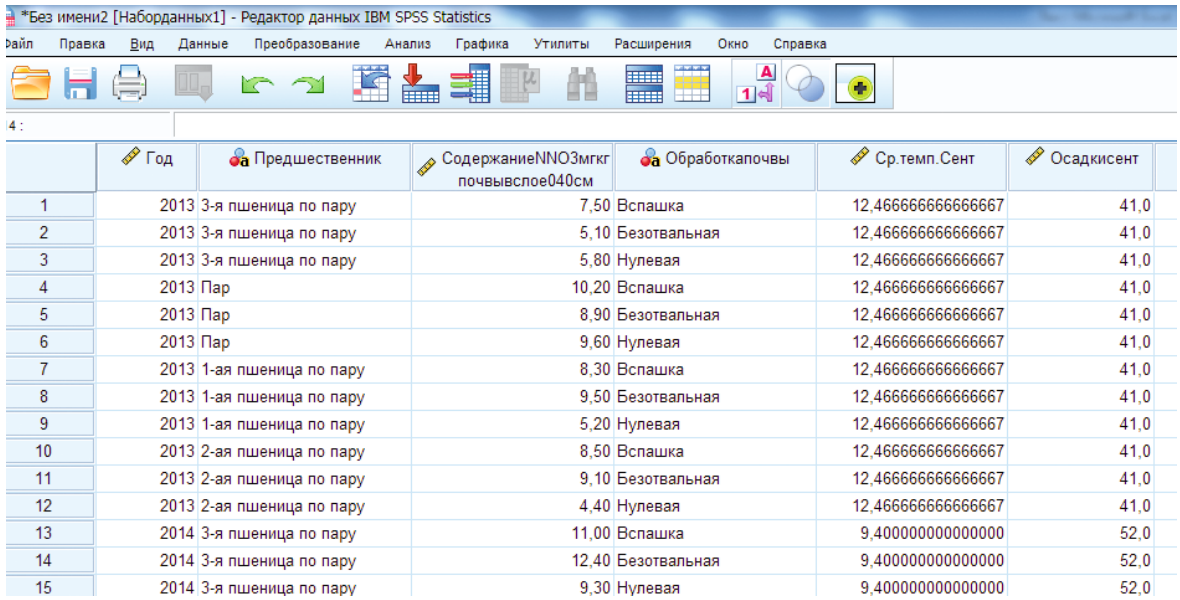
A measure of the adequacy (quality) of the constructed logistic regression model is the pseudo R-squared coefficient. In this case, the resulting variance on the Nagelkerke measure (usually the most used) is 70%, indicating the satisfactory predictive power of the model.

Unlike conventional regression, a logistic regression model does not predict the value of a numerical variable based on a sample of initial values. Instead, the value of the function is the probability that a given initial value belongs to a particular category.

Thus, in the course of the research, BBN and logistic regression models were built and trained, predicting nitrate nitrogen content in 0-40 cm layer of leached chernozem before sowing. The forecast for 2021 was carried out for the experiments presented in Table 3. The weather conditions this year were unfavorable.

The prediction made with the help of BBN shows accumulation of nitrate nitrogen in soil layer 0-40 cm for fallow precedence in all variants is more than 10 mg/kg (with 69% probability for ploughing, 55% for non-mouldboard, 65% for zero tillage). For all other variants, nitrate nitrogen content of less than 10 mg/kg is predicted. In contrast to BBN, logistic regression prediction shows nitrate nitrogen content in 0-40 cm layer in all variants not more than 10 mg/kg.

The deviation (error) of the actual nitrogen content from the predicted one was determined as a criterion for evaluating the predictive models. Table 4, 5 present comparative predictive capabilities of the models tested on the initial sample. The initial sample consists of 72 observations, including 53 observations with nitrate nitrogen content Less than 10 and 19 observa-



	Год	Предшественник	СодержаниеNNO3мгкг почвывслое040см	Обработкапочвы	Ср.темп.Сент	Осадкисент
1	2013	3-я пшеница по пару	7,50	Вспашка	12,466666666666667	41,0
2	2013	3-я пшеница по пару	5,10	Безотвальная	12,466666666666667	41,0
3	2013	3-я пшеница по пару	5,80	Нулевая	12,466666666666667	41,0
4	2013	Пар	10,20	Вспашка	12,466666666666667	41,0
5	2013	Пар	8,90	Безотвальная	12,466666666666667	41,0
6	2013	Пар	9,60	Нулевая	12,466666666666667	41,0
7	2013	1-ая пшеница по пару	8,30	Вспашка	12,466666666666667	41,0
8	2013	1-ая пшеница по пару	9,50	Безотвальная	12,466666666666667	41,0
9	2013	1-ая пшеница по пару	5,20	Нулевая	12,466666666666667	41,0
10	2013	2-ая пшеница по пару	8,50	Вспашка	12,466666666666667	41,0
11	2013	2-ая пшеница по пару	9,10	Безотвальная	12,466666666666667	41,0
12	2013	2-ая пшеница по пару	4,40	Нулевая	12,466666666666667	41,0
13	2014	3-я пшеница по пару	11,00	Вспашка	9,400000000000000	52,0
14	2014	3-я пшеница по пару	12,40	Безотвальная	9,400000000000000	52,0
15	2014	3-я пшеница по пару	9,30	Нулевая	9,400000000000000	52,0

Рис. 5. Фрагмент таблицы данных в SPSS для построения логистической регрессии

Fig. 5. A fragment of a data table in SPSS for constructing a logistic regression

Табл. 2. Оценка параметров (коэффициентов) логистической регрессии

Table. 2. Estimation of parameters (coefficients) of logistic regression

Factor	Coefficient of variables	Standard error	Coefficient significance (*P*)
Average monthly temperature (September)	–1,7	0,6	0,007
Average monthly rainfall (September)	– 0,16	0,068	0,023
Average monthly temperature (April to May)	–2,08	0,84	0,013
Average monthly rainfall (April to May)	–0,22	0,076	0,003
Forecrop – fallow	5,1	1,7	0,002
Forecrop – 1-st wheat on fallow	–0,613	0,8	0,48
Forecrop – 2-nd wheat on fallow	–1,5	1,03	0,167
Forecrop – 3-rd wheat on fallow	0	0	0
Tillage - ploughing	1,03	0,81	0,27
Tillage – non-mouldboard	–0,58	0,87	0,607
Tillage – zero	0	0	0
Constant	55,1	19,06	0,004

tions with nitrate nitrogen content More than 10.

In BBN, correct predictions for the Less 10 category are as high as 90%, with 48 observations predicted correctly and 5 incorrectly (see Table 4).

For the More 10 category in the BBN, the correct prediction rate is 68%. However, out of 19 observations, 13 were correctly predicted by the model and 6 were incorrectly predicted. For all observations, the overall proportion of correct predictions is 84%. The reliability of the predictions is lower than in logistic regression, but the efficiency of its predictive ability is quite high.

When comparing actual observations of nitrate nitrogen content in the 0-40 cm layer with predicted estimates using logistic regression, it can be noted that the obtained proportion of correct predictions is 94.3% for the category Less 10 (see Table 5). This model correctly predicted 50 observations, three observations were predicted incorrectly, falling into the category More 10.

For the sample of observations with nitrate nitrogen content More 10, the proportion of correct predictions was 68.4%, of which 13 observations were correctly predicted and 6 predictions were incorrect, falling into the category Less 10. The total proportion of correct predictions in all categories was 87%. Thus, given the small size of the statistical sample and the small number of predictors, the predictive properties of the tested models can be considered satisfactory.

CONCLUSION

Using machine learning techniques, models have been built and trained to predict the pre-sowing nitrate nitrogen content in the 0-40 cm soil layer with acceptable confidence. The difference in methodologies is that the BBN in predictive modelling allows for "what-if" scenario analysis, can combine patterns inferred from statistical data and expert knowledge derived from actual data, and is able to handle incomplete and different types of data.

In the future, it is planned to improve the quality of the models by adding other predictors affecting the resultant trait, to search for machine learning methods that allow analysis of small-scale data, and to verify the models with actual data. The possibility of using the built models to develop an expert system for the selection and maintenance of agricultural technologies, which will allow making competent decisions in relation to the objectives of agricultural production is being considered.

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Табл. 3. Прогноз содержания нитратного азота в слое почвы 0–40 см в 2021 г.
Table 3. Forecast of nitrate nitrogen content in the 0–40 cm soil layer in 2021.

Forecrop	Soil tillage	$N\text{-}NO_3$ content (forecast by DAG), mg/kg	N-NO3 content (logistic regression forecast), mg/kg
Fallow	Ploughing	More 10	Less 10
Fallow	Non-mouldboard	More 10	Less 10
Fallow	Zero tillage	More 10	Less 10
1-st wheat on fallow	Ploughing	Less 10	Less 10
1-st wheat on fallow	Non-mouldboard	Less 10	Less 10
1-st wheat on fallow	Zero tillage	Less 10	Less 10
2-nd wheat on fallow	Ploughing	Less 10	Less 10
2-nd wheat on fallow	Non-mouldboard	Less 10	Less 10
2-nd wheat on fallow	Zero tillage	Less 10	Less 10
3-rd wheat on fallow	Ploughing	Less 10	Less 10
3-rd wheat on fallow	Non-mouldboard	Less 10	Less 10
3-rd wheat on fallow	Zero tillage	Less 10	Less 10

Табл. 4. Классификационная таблица БСД
Table 4. DAG classification Table

Number of observations	Predicted		Percentage of correct predictions
	Less 10	More 10	
Less 10 (53)	48	5	90
More 10 (19)	6	13	68
Total share			84

Табл. 5. Классификационная таблица модели логистической регрессии
Table 5. Classification table of the logistic regression model

Number of observations	Predicted		Percentage of correct predictions
	Less 10	More 10	
Less 10 (53)	50	3	94,3
More 10 (19)	6	13	68,4
Total share			87

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СУТОЧНЫЕ КОЛЕБАНИЯ ДИАМЕТРА СТЕБЛЯ ТОМАТА КАК КРИТЕРИЙ УПРАВЛЕНИЯ ПОЛИВОМ

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Рассмотрен процесс суточного изменения диаметра стебля томата с целью обоснования использования этого параметра для управления капельным орошением. Изменение размеров отдельных частей растений зависит от обеспечения продукционного процесса водой, светом, теплом и элементами питания. Поэтому такие параметры растений, как температура листьев, скорость потока ксилемы, диаметр плода и стебля, могут быть индикаторами наличия необходимых ресурсов. Исследования проведены в Новосибирской области в июне – сентябре 2020 г. В качестве индикатора водного стресса растений использована величина диапазона суточных колебаний диаметра стебля, которая имеет тесную связь с относительной влажностью почвы. Источником информации послужили результаты измерений влажности почвы и прироста диаметра стебля томата. Эксперименты по оценке влияния водного дефицита на параметры стебля проводили на растении, высаженном в открытый грунт отдельно от остальных. Условия искусственного водного стресса создавали путем полива один раз в неделю. Сбор данных осуществляли с помощью фитомонитора РМ-11z, датчиков влажности почвы и диаметра роста стебля. Результаты измерений обрабатывали в программе Microsoft Office Excel. Установлено, что диапазон суточных колебаний прироста диаметра стебля зависит от наличия влаги. При влажности почвы ниже 30% растение испытывает водный стресс и диапазон колебаний диаметра стебля увеличивается. Максимальный рост диаметра стебля наблюдался в 7–10 ч, минимальный – в 13–15 ч местного времени. Разница между максимумом и минимумом суточного прироста диаметра стебля характеризует диапазон суточной разницы диаметра стебля, который тесно коррелирует с влажностью почвы. Коэффициент корреляции между ними составляет 0,72. Предельное значение суточной разницы диаметров стеблей составляет 0,025 мм при влажности почвы 30%. Превышение фактического значения этого параметра граничного значения может служить сигналом к включению системы орошения. Реализация данного подхода дает возможность автоматизировать технологический процесс полива и учесть показатель, сигнализирующий о водном стрессе растения.

Ключевые слова: продукционный процесс, диаметр стебля, водный стресс, фитомониторинг, датчик, полив

DAILY VARIATIONS IN TOMATO STEM DIAMETER AS A CRITERION FOR IRRIGATION MANAGEMENT

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The process of daily variation in tomato stem diameter is examined in order to justify the use of this parameter to control drip irrigation. Changes in the size of individual plant parts depend on the provision of water, light, heat and nutrients to the production process. Therefore, such plant parameters as leaf temperature, xylem flow rate, fruit and stem diameter can be indicators of availability of necessary resources. The research was carried out in Novosibirsk region in June - September 2020. The value of the range of daily variations in stem diameter, which has a close relationship to relative soil moisture, was used as an indicator of plant water stress. The source of the information is the results of measurements of soil moisture and stem diameter growth of tomato. Experiments to assess the effect of water deficit on stem parameters were carried out on a plant set out in the open ground separately from the rest. Artificial water stress conditions were created by

watering once a week. Data were collected using a PM-11z phytomonitor, soil moisture and stem diameter growth sensors. The results of measurements were processed in Microsoft Office Excel program. It was found that the range of daily fluctuations of stem diameter growth depends on moisture availability. When soil moisture is below 30%, the plant experiences water stress and the range of stem diameter fluctuations increases. The maximum growth in stem diameter was observed at 7-10 a.m. and the minimum at 13-15 p.m. local time. The difference between the maximum and minimum of the daily stem diameter increase characterizes the range of the daily stem diameter difference, which correlates closely with soil moisture. The correlation coefficient between them is 0.72. The limit for the daily stem diameter difference is 0.025 mm at 30% soil moisture. If the actual value of this parameter exceeds the limit value, the irrigation system can be activated. The implementation of this approach makes it possible to automate the irrigation process and to take into account the indicator that signals water stress of the plant.

Keywords: production process, stem diameter, water stress, phytomonitoring, sensor, irrigation

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INTRODUCTION

The productivity of agricultural plants is the result of a complex of natural processes that depend on the habitat. Negative effects of these influences are compensated by technological processes. The efficiency of cultivation depends on the correct and timely execution of all technological operations for crop cultivation. Currently, most research is focused on the application of high-tech controls for production processes and individual operations [1-3].

The basis for deciding whether or not to carry out a technological operation is information obtained by observing natural processes, the experience and intuition of plant specialists. The right choice of technological operation and its timing depends largely on the human factor. Reducing this dependence is one of the challenges that cannot be met without the digitalization of crop technology.

According to the laws of farming, the maximum yield can be obtained when all crop conditions are optimally combined. The limiting factor when growing tomatoes in Siberian conditions is heat. Application of cultivation facilities during the whole period of vegetation increases the air temperature in the zone of plant growth, so the next limiting factor is moisture supply [4-6]. Consequently, the timing of irrigation is an important condition for obtaining high yields of tomatoes.

The purpose of the study is to justify the choice of the parameter of daily variation of the tomato stem diameter as a criterion for assessing the necessity of performing the technological process of irrigation.

MATERIAL AND METHODS

The plant production process consists of photosynthesis and processes of organic matter transfer from leaves to other organs by xylem fluxes. The specificity of ecological and physiological studies is that the plant is considered as a single organism, the vital functions of which are closely interrelated and are implemented in constant interaction with changing environmental factors [7, 8]. Changes in the size of plant parts such as the stem and fruit depend on the provision of the production process with water, light, heat and nutrients. Such plant parameters as leaf temperature, xylem flux rate, fruit and stem diameter can be indicators of the availability of the necessary resources in the production process [9-11].

Daily variation measures in the stem diameter is an important indicator of water availability. Many factors influence the water requirements of plants: soil, climatic, physiological parameters of plants. Complex consideration of such parameters in the mathematical model allows solving the problem of operational control of drip irrigation systems [12-14]. The boundary conditions of the necessity of the irrigation operation are required to be determine for practical use of these parameters. The set problems are solved experimentally by measuring the increment of stem diameter of tomato at change of humidity of soil. The experiment was conducted in the Novosibirsk region from June 16 to September 10, 2020. A plant planted in the open ground separately from the others was used to assess the effect of water stress on stem parameters. Conditions of artificial water stress were created by watering once a week. The use of special modern phytomonitor systems and equipment (photosynthesis monitor RTM-48A and phytomonitor PM-11z [15] to study the variability and diversity of changes in the characteristics of CO2-gas exchange in response to environmental changes) allowed us to identify the optimal and threshold values of abiotic factors limiting the growth and development of plants [16].

An SMTE-3z soil sensor was placed in the rooting zone of the plant at a depth of 10-20 cm. It measured the temperature, humidity and electrical conductivity of the soil. The stem diameter growth sensor SD-5z was installed on the lower part of the stem to record the change in stem size relative to its diameter at the time of installation. The resolution was at least 0.002 mm. The fruit diameter sensor measured the actual fruit diameter. The resolution was at least 0.04 mm.

The sensor signals are transmitted via the radio module to the phytomonitor, stored in its memory and used for further computer processing. The interval for collecting sensor information is 15 minutes. The complex operates continuously throughout the vegetation period.

A DWS-11z weather station was used to measure environmental characteristics, and phytomonitoring sensors were used for plant and habitat characteristics (see Figure 1).

RESULTS AND DISCUSSION

The results of measurements of fruit diameter, stem growth and soil moisture are shown graphically in Figure 2. The graph shows that the limit value for soil moisture under the conditions of the experiment is a moisture content of about 30%. But this parameter can significantly depend on the mechanical composition of the soil and its other properties. Therefore, the reaction of the plant to changes in its moisture content is the most reliable criterion for assessing the need for the technological process of irrigation.

The stem diameter growth curve has two extremes daily: a maximum in the morning and a minimum in the afternoon. The maximum stem diameter increase was observed at 7-10 h and the minimum at 13-15 h local time. The difference between the maximum and minimum (hereafter referred to as the stem diameter difference) is a characteristic of the range of daily

Рис. 1. Приборы для измерения параметров растений и внешней среды обитания:
1 – почвенный датчик, *2* – датчик прироста диаметра стебля, *3* – датчик диаметра плода, *4* – радиомодуль

Fig. 1. Instruments for measuring the parameters of plants and the external environment:
1 – soil sensor, *2* – stem diameter growth sensor, *3* – fruit diameter sensor, *4* – radio module

variations in stem diameter, which is closely correlated with soil moisture. The correlation coefficient between the two is 0.72.

The dynamics of the soil moisture and stem diameter difference is shown in Fig. 3. The graph shows that there is an inversely proportional relationship between the soil moisture and the variation in stem diameter, as the variations occur in counter-phase. With a soil moisture of 30% the swing of the stem diameter is about 0.025 mm. Hence, it can be assumed that a stem diameter difference greater than 0.025 mm is a sign of tomato water stress. However, this assumption requires further testing and clarification of the effect of the plant age and other conditions.

CONCLUSION

An indicator of the presence of water stress in tomatoes is the amount of daily variation in stem diameter. The stem diameter difference, i.e. the difference between the morning maximum and the daily minimum of stem diameter growth, can be used as an indicator of plant water stress to control irrigation systems in digital tomato cultivation technology. According to the results of the study, the limit value of the stem diameter difference is 0.025 mm. Exceeding the actual value of this limit value parameter can serve as a signal to activate the irrigation system.

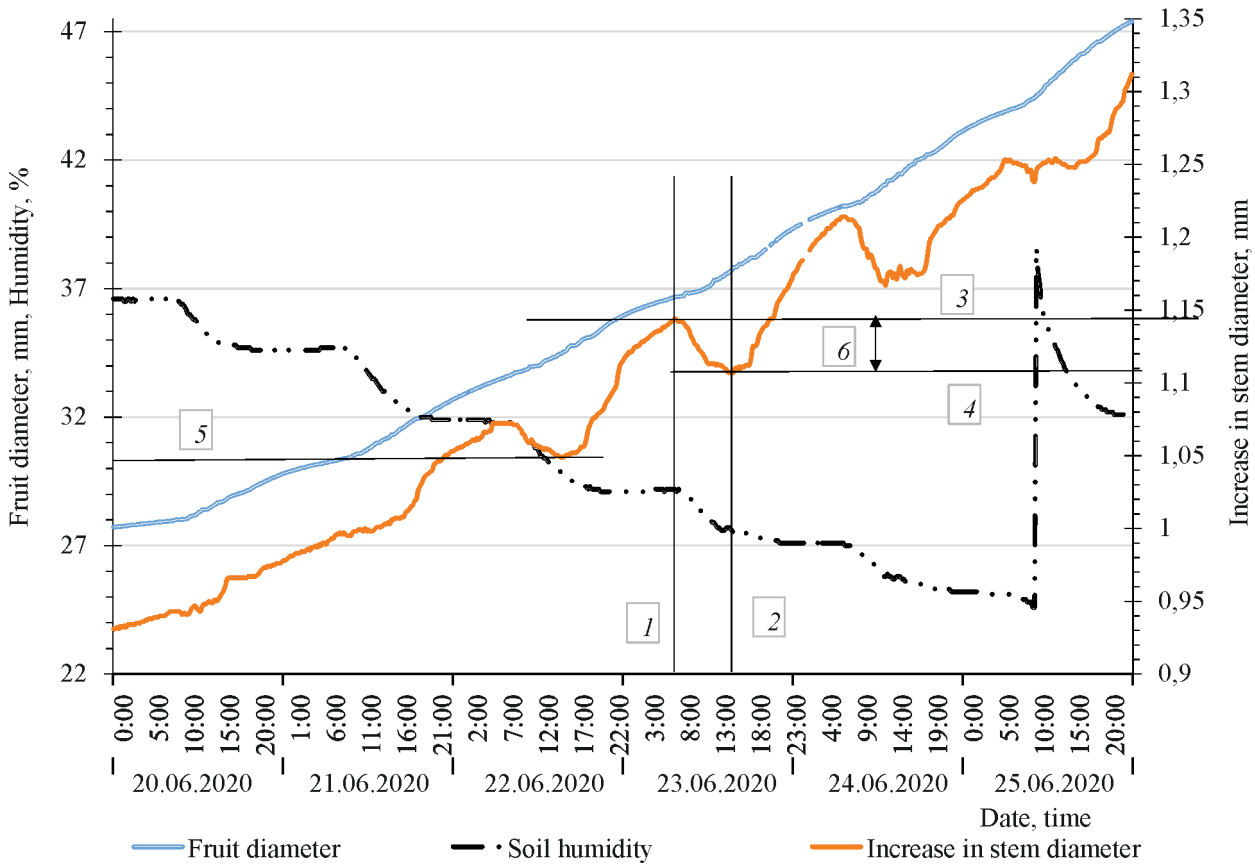

Рис. 2. Динамика изменения параметров почвы и растения при недостатке влаги

1 – время утреннего максимума, *2* – время дневного минимума, *3* – значение утреннего максимума, *4* – значение дневного минимума, *5* – допустимый минимум влажности почвы

Fig. 2. Dynamics of changes in soil and plant parameters with a lack of moisture

1 – time of the morning maximum, *2* – time of the daytime minimum, *3* – value of the morning maximum, *4* – value of the daytime minimum, *5* – permissible minimum soil moisture

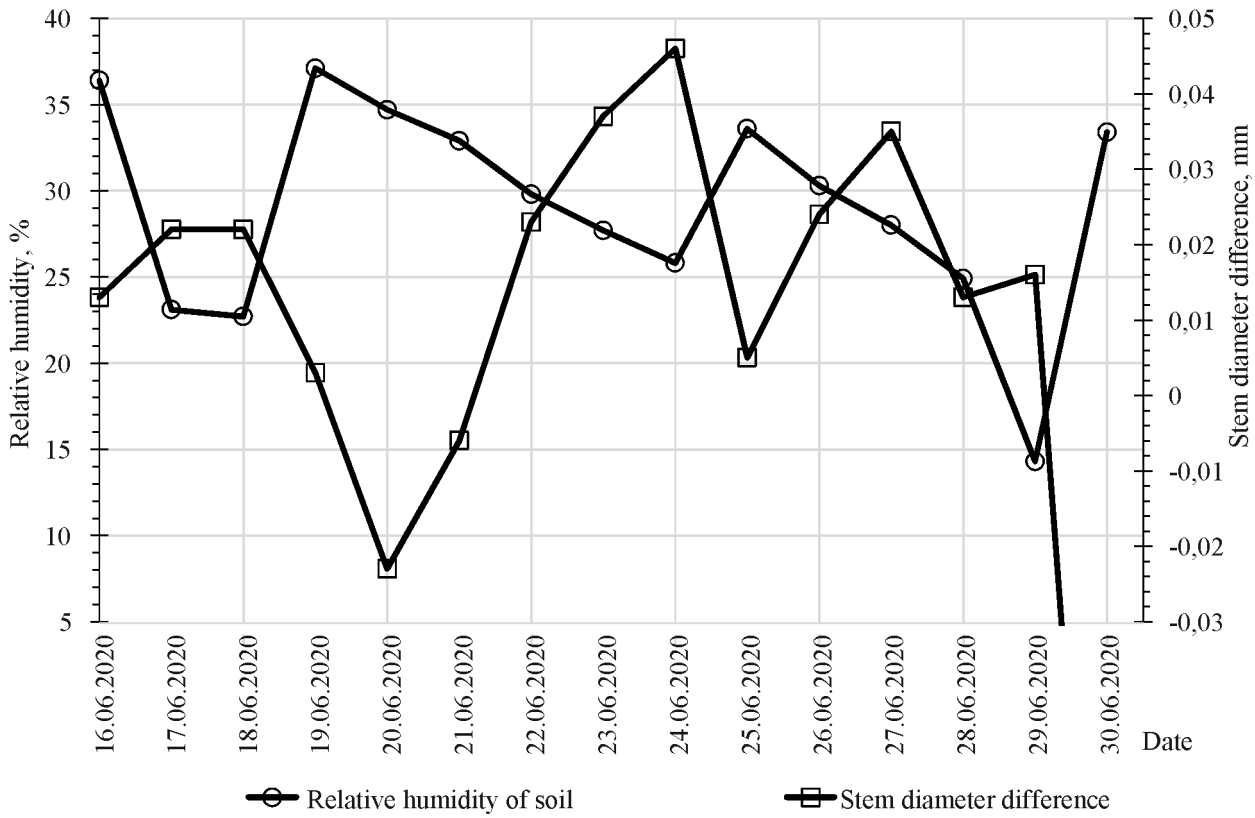

Рис. 3. Динамика изменения влажности почвы и перепада диаметра стебля
Fig. 3. Dynamics of changes in soil moisture and the difference in stem diameter

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ПАРАДИГМА ВЗАИМОДЕЙСТВИЯ СИБИРСКОЙ НАУЧНОЙ СЕЛЬСКОХОЗЯЙСТВЕННОЙ БИБЛИОТЕКИ И АГРАРНЫХ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИХ И ОБРАЗОВАТЕЛЬНЫХ УЧРЕЖДЕНИЙ СИБИРСКОГО РЕГИОНА

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Рассмотрены основные направления совместной работы научно-исследовательских учреждений (НИУ) сельскохозяйственного профиля Сибирского региона и Сибирской научной сельскохозяйственной библиотеки (СибНСХБ), функционирующих в структуре Сибирского отделения ВАСХНИЛ (Россельхозакадемии) с момента создания в 1969 г. до реорганизационного периода реформирования науки (2013–2021 гг.). Показана специфика библиотечно-информационной деятельности отраслевой ведомственной библиотеки и многоуровневая модель взаимодействия с институтами по удовлетворению информационных потребностей ученых и специалистов аграрных НИУ в дореформенный период. Представлены результаты мониторинга состояния библиотечно-информационной деятельности в институтах, оказавших влияние на развитие новой концепции взаимодействия с НИУ. На основе анализа реорганизационных процессов представлена новая структура научных организаций сельскохозяйственного профиля Сибири. Она является основой разработки новой парадигмы взаимодействия научных коллективов и Сибирской научной сельскохозяйственной библиотеки, в результате реорганизации получившей статус филиала Государственной публичной научно-технической библиотеки Сибирского отделения Российской академии наук (ГПНТБ СО РАН). Проведенный в условиях реформирования и реорганизационных перемен на основе анкетирования анализ показывает новые тенденции расширения спектра интересов ученых к информационному потенциалу СибНСХБ как крупнейшей отраслевой библиотеки региона. В условиях смены управления и разрушения организационно-функциональных связей аграрных НИУ, вошедших в состав региональных центров СО РАН, отмечена ориентация на развитие и усиление коммуникаций с центральными академическими библиотеками регионов и восстановление на новой основе взаимодействия с библиотеками аграрного образования. Определение структуры аграрных НИУ и учреждений образования региона в новых границах ведомственных отношений Министерства сельского хозяйства, Министерства науки и высшего образования позволяет определять СибНСХБ как системообразующее звено. Это даст возможность развивать основные функциональные направления библиотечно-информационной деятельности в Сибирском регионе.

Ключевые слова: научно-исследовательские институты, отраслевые библиотеки, управление, реорганизация, взаимодействие, коммуникации, моделирование взаимосвязей

PARADIGM OF INTERACTION OF THE SIBERIAN SCIENTIFIC AGRICULTURAL LIBRARY AND AGRARIAN RESEARCH AND EDUCATIONAL INSTITUTIONS OF THE SIBERIAN REGION

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The article covers the main directions of joint work of scientific-research institutions (SRI) of agricultural profile in the Siberian region and Siberian Scientific Agricultural Library (SibSAL) functioning within the structure of the Siberian Branch of VASKHNIL (Russian Agricultural Academy) since its establishment in 1969 up to the reorganization period of science reform (2013-2021). The specificity of library and information activity of departmental library and multilevel model of interaction with institutes to satisfy information needs of scientists and specialists of agrarian research institutes in pre-reform period is presented. The results of monitoring the state of library and information activities in the institutes that have influenced the development of the new concept of interaction with SRI are presented. Based on the analysis of reorganization processes, a new structure of scientific organizations of the agricultural profile of Siberia is presented, which is the basis for the development of a new paradigm of interaction between research teams and the Siberian Scientific Agricultural Library, which received the status of a branch of the State Public Scientific and Technical Library of the Siberian Branch of the Russian Academy of Sciences as a result of the reorganization. The analysis carried out in the conditions of reform and reorganization changes on the basis of a questionnaire shows new trends in expanding the range of interests of scientists to the possibilities of the information potential of the SibSAL as the largest branch library in the region. In the context of the change of management and the destruction of organizational and functional ties of agricultural research institutes that have become part of the regional centers of the SB RAS, the orientation to the development and strengthening of communications with the central academic libraries of the regions and the restoration of interaction with libraries of agricultural education on a new basis is noted. The definition of the system structure of agricultural research institutes and educational institutions of the region within the new boundaries of departmental relations of the Ministry of Agriculture, the Ministry of Science and Higher Education will allow establishing the vector of interaction of the SibSAL as a system-forming link. This will enable the development of the main functional areas of library and information activities in the Siberian region.

Keywords: research institutes, branch libraries, management, reorganization, interaction, communications, modeling of relationships

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The study of the problems of interaction between research institutions in the sphere of information and library activities as the subject of scientific research of Siberian Scientific Agricultural Library (SibSAL) specialists starts from the period of organization in 1969 in Novosibirsk a large scientific centre of agricultural science of Siberia and the Far East - Siberian Branch of the V. I. Lenin All-Union Academy of Agricultural Sciences (Siberian Branch of VASKhNIL). In 1971 thanks to the initiative of the head and organizer of the SB VASKHNIL (Russian Academy of Agricultural Sciences) academician Irakli Ivanovich Sinyagin the departmental scientific library was organized in its structure. According to the decision of the Presidium of the Siberian Branch of the All-Union Academy of Agricultural Sciences of 20.01.1972 the SibSAL became the centre of library and information bibliographic service of the scientists and specialists of agricultural science and production of Siberia and the Far East and the organizing, scientific-methodical and coordinating centre of the libraries of the agricultural research institutions and educational establishments irrespective of their departmental subordination [1]. Established by the experience of the Siberian Branch of the Russian Academy of Sciences and functioning for half a century, the complex of agricultural research institutes with sectoral departmental library has been a benchmark for the organization of agrarian science. It is regarded by specialists as an effective process of scientific communication, ensuring the integrity and interaction of all elements of the system[1]. Further history has shown that the problem of interaction between the participants of this process is not a purely scientific problem, it is closely related to the problem of the relationship between the professional community and all levels of government - from the management of the individual institute to the public authorities[2].

The SibSAL in the structure of SB VASKHNIL (Russian Agricultural Academy) developed under the conditions of the planned economy of the Soviet period in the command-administrative system of management according to the branch and departmental principles. In addition to administrative management by ministries and departments, there was a system of methodological guidance for the country's libraries. Most of the branch scientific departmental libraries, with the exception of the central libraries, had no status of a legal entity, being subordinate to the departmental management within an enterprise or organization. Thanks to one of the advantages of the Soviet period of development of our country, libraries of all branches and departments received professional methodical support and assistance from leading libraries, based on a deep scientific-theoretical basis and generalized practical experience [2].

It was during this period (1965-1979) that Nikolai Semyonovich Kartashov, the prominent scientist of the national library science, the Director of the State Patent Library of the Siberian Branch of the Russian Academy of Science, the author of monographs "The Interaction of Scientific Libraries of the RSFSR" (1975) and "The Formation of Library and Territorial Complexes" (1978), studied the theoretical and practical issues of organizing and functioning of new library systems on the territory of Siberia and the Far East. These theoretical works became the basis for his doctoral thesis "The Interaction of Scientific Libraries (Issues of History and Theory)", defended in 1978 in the Dissertation Council of the V. I. Lenin USSR State Library. N. S. Kartashov substantiated the essence of dialectical contradiction in the activity of libraries in satisfying departmental interests. On one hand, this leads to the maximum coverage of library acquisition boundaries; on the other, due to the permanent funding limitations, to the limited library resources and to the impossibility to satisfy departmental information requests within one library[3,4]. These profound

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generalizations formed the basis for nationwide studies: 'The Place and Use of Library Resources in the Country' (1981-1985) and 'The Development of Regional Interdepartmental Interaction of Libraries' (1985-1992). The studies culminated in the development of scientific foundations for the formation of territorial library associations, as well as in the substantiation of a new scientific trend - regional library science.

The SibSAL, within the framework of development of scientific directions of its department, determined the branch content of the collections, character of activities and development of the information system throughout its history until the reform of the Academy. Within the framework of the unified sectoral system of methodological guidance in coordination with the Central Scientific Agricultural Library (CSAL, Moscow), SibSAL received the status of scientific-methodological and coordinating center within the serviced territory of Siberia and the Far East in order to build a model of information provision for the needs of scientists and specialists with maximum disclosure of regional libraries' resources [3]. This determined a special and unique territorial and structural position of SibSAL in the system of scientific and information activities of the Russian Agricultural Academy. On the one hand, SibSAL was peripheral in relation to the CSAL, on the other hand, it remained central in relation to the agricultural libraries other research institutes in the region and was responsible for their preservation and development. It also performed the functions of information and library provision for scientists and specialists of the Institute in the absence of such libraries. Thus, the CSAL and SibSAL rationally distributed professional authority and influence over the libraries of the vast region [4, 5]. These issues and a brief excursus into the history of relations between the SibSAL and the libraries of agricultural research institutes and organizations are covered in detail in the article [6].

The interaction between the SibSAL and the research institutes also made use of administrative resources. In this connection the most urgent problems of library-information activity were strongly discussed at the meetings of the Presidium, annual report meetings and scientific sessions, where SibSAL reports were periodically heard and decisions were taken as a guide to action for the directors of research institutes. SibSAL proposals on centralization of libraries of the institutes located in Krasnoobsk settlement, introduction of the system of obligatory departmental copying, inclusion in regional research programmes, research and development, coordination of subscription to periodicals, conclusion of agreements on information support of NIU, formation of state tasks for NIU on library services - this is not a complete list of SibSAL initiative projects implemented in practice of research and scientific organizational activities of SRI SB VASKHNIL (Russian Agricultural Academy). It should be noted that during this period the relations between the SibSAL and agrarian higher educational institutions and universities continued to develop on a contractual basis, without including a financial component. The SibSAL has always prioritized students, professors and postgraduates of both Novosibirsk Agrarian University and other regional agrarian higher educational institutions. In return, they provided the library with the works of their scientists.

The principle of constant monitoring of the state of library and information activities in the institutes was the basis for the development of scientific communication between SibSAL and regional SRI, which strengthens the interaction between the parties. In addition to collecting statistical data, generalization and analysis, a questionnaire survey was periodically conducted among libraries, regardless of their place in the structure of the organization, or among specialists responsible for library and information activities in SRI. The survey conducted in 1996, 2006, 2010, 2012, reflecting the dynamics of negative trends, the actual stagnation of activities, further strengthened the specialists of SibSAL to make important decisions on library development and a new concept of interaction with SRI [7, 8]. The concept developed by SibSAL has changed the dogmatic principle, referred to by SRI libraries as "methodological guidance", to "provision of information and advisory assistance" to specialists. It was also aimed at the devel-

opment of new information technologies and complete reorientation of information support to the direct requests and needs of scientists and specialists of the Siberian region's agrarian profile [9].

Before the reform of science in the SB Russian Agricultural Academy, there was a multilevel model of interaction (see Figure 1):

– SibSAL – SB Russian Agricultural Academy Presidium,

– SibSAL – SRI,

– SibSAL – scientist.

Specialists studying the interaction between libraries in the post-Soviet space note a direct link between the changes taking place in all areas of library and information activities in close connection with the reorganization processes taking place in society, culture and science[5].

The reform of state academies 2013 and subordination of all SRI to the Federal Agency of Scientific Organizations (FASO) disrupted the logical sequence of development of the Siberian region's agrarian SRI activities. By introducing the process of basic statutory activities of SRI in violation of the current poorly funded, but systematic process of scientific and production activities, the reform was the beginning of a serious breakdown in the organizational and functional mechanism of the system of SRI of the agrarian sphere in the Siberian region. The process of reforming determined two fundamental directions of SibSAL activities: reorganization of the library itself as a legal entity and reforming of all the research institutes, formerly belonging to the Russian Agricultural Academy, whose researchers and specialists constituted the main contingent of information users. On the threshold of SibSAL transition to a new status, the Concept of development of Siberian Scientific Agricultural Library was worked out for inclusion in the program of creation of the Federal Information Centre "SPSTL SB RAS - SibSAL", which has not been realized in full measure. The functional areas of the SibSAL, which had no departmental boundaries with the libraries of agricultural research institutes and educational institutions of the region, have also undergone changes. This was facilitated by the division of departmental subordination of agricultural research institutes and institutions of higher education between different ministries and departments.

Despite the direct involvement in the process of reorganization, the SibSAL, within the framework of the state assignment, conducted scientific research on "Development of information support system for agricultural science and education in Siberia in view of the changes occurring in the economic, scientific and informational sphere". The study of relationships and search for solutions to problems arising from the destruction of the former systemic links and creation of new ones between the SibSAL and SRI in Siberia in modern conditions has been continued. The results have shown that at the time of the study 27 institutions out of 31 Siberian scientific research institutes have been reorganized and included in the five federal research centers. The status of structural subdivision was given to 21 research organizations, six institutions became separate structural subdivisions (branches), and four institutions retained their legal independence. The number of SRI staff decreased by 45% [10].

All agrarian scientific organizations in Siberia are currently subordinated to the Ministry of Science and Higher Education of the Russian Federation. The scientific and methodological guidance of agrarian research institutes is provided by the Joint Scientific Council for Agricultural Sciences of the Siberian Branch of the Russian Academy of Sciences, which functions as the largest integrator and the main expert of research, scientific-educational, experimental and development work in the eastern part of Russia [11, 12].

In the process of science reform and reorganization changes scientific organizations of agricultural profile, formerly subordinate to the RAAS (Russian Academy of Agricultural Sciences), have been formed into four structural forms:

– federal centers - Siberian Federal Research Centre of AgroBioTechnologies of the

[5] Mazuritski A.M. Interaction of libraries and authorities under transformation of library management system. Culture: theory and practice. Electronic scientific journal. 06.09.2019.

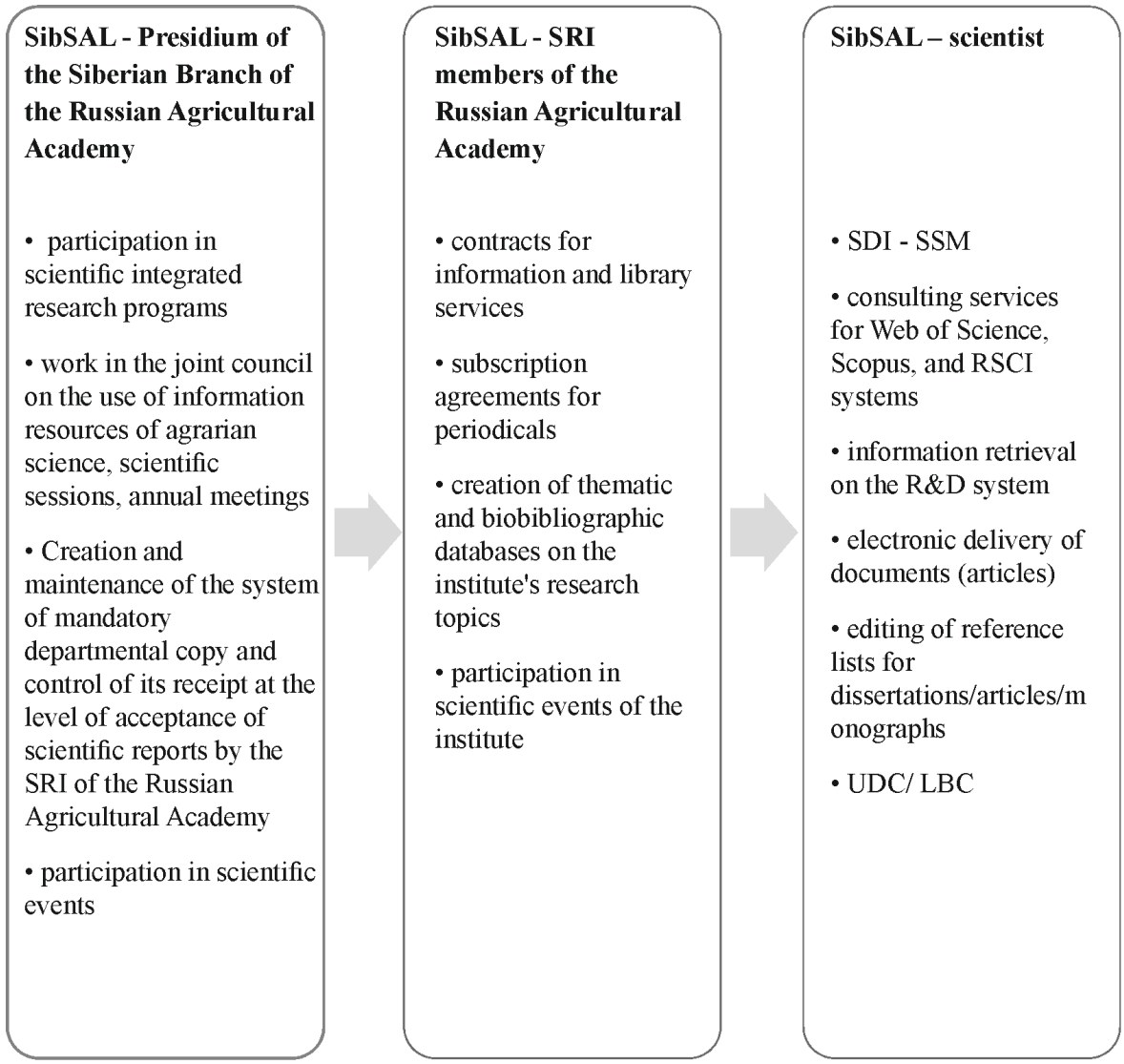

Рис. 1. Модель взаимодействия СибНСХБ в составе СО Россельхозакадемии до реформы:

ИРИ – избирательное распространение информации, ДОР – дифференцированное обслуживание руководителей, РИНЦ – Российский индекс научного цитирования, УДК – универсальная десятичная классификация, ББК – библиотечно-библиографическая классификация

Fig. 1. Model of interaction of the SibSAL as part of the Siberian Branch of the Russian Agricultural Academy before the reform:

ИРИ (SDI) – selective dissemination of information, ДОР (SSM) – selective service for managers, РИНЦ (RSCI) – Russian Science Citation Index, УДК (UDC) – universal decimal classification, LBC – library and bibliographic classification

Russian Academy of Sciences (consolidation of 11 research institutes of the Siberian Branch of the Russian Academy of Agricultural Sciences (SB RAAS) in Krasnoobsk + branches in Tomsk, Kemerovo, Chita);

– regional-branch centers (by regional-branch thematic (agrarian) profile): Federal Altai scientific center of agrobiotechnologies (six research institutes of the Russian Academy of Agricultural Sciences are united in Barnaul), and the Omsk Agrarian Scientific Centre (three in Omsk);

– association of newly established centers on the basis of regional centers of the Siberian Branch of the Russian Academy of Sciences (three institutions became part of the

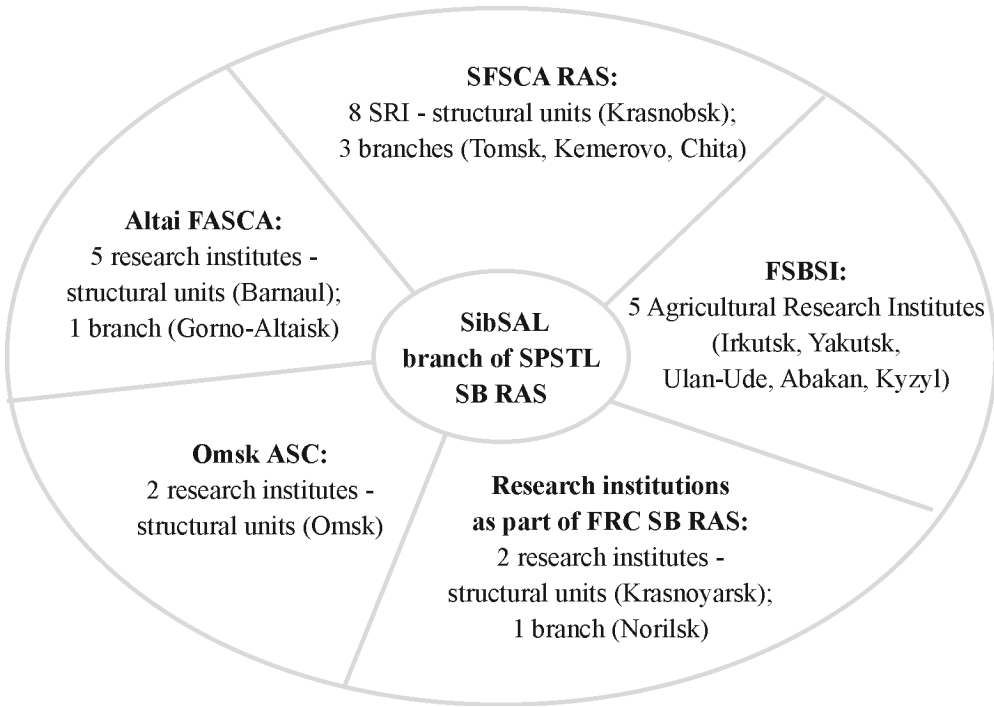

Рис. 2. Научные организации сельскохозяйственного профиля Сибири в зоне информационного обеспечения СибНСХБ

Fig. 2. Scientific organizations of the agricultural profile of Siberia in the information support zone of the SibSAL

Federal Research Centre "Krasnoyarsk Scientific Centre of the Siberian Branch of the Russian Academy of Sciences", two became part of the Tyumen Scientific Centre, one (the Siberian Research Institute of Plant Growing and Selection) became part of the Federal Research Centre of the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences);

– maintenance of the Federal State Budgetary Scientific Institution Agricultural Research Institute status (Buryatia, Yakutia, Tyva, Khakassia, Irkutsk).

The new structure of scientific organizations of agricultural profile requires the SibSAL to develop a new paradigm of interaction between the library and scientific teams of farmers. At the same time, it should be noted that the reorganization process has not been completed, it is becoming permanent, the reforming continues [13, 14]. Integrating scientific organizations of agricultural profile in Siberia into a single information space, SibSAL has begun to work out the first approaches to modeling the system development of scientific-information activity at this stage (see fig. 2). Only interaction with newly established centers and the scientific community allows continuous monitoring of changes [15].

The analysis of the questionnaire survey of scientists and specialists of agricultural research institutes, conducted by SibSAL in the conditions of reforming and organizational changes at the turn of 2019, 2020, has shown the expansion of the range of scientists' interests to the possibilities of information potential of the library. It is justified that most of the information needs of specialists are based on the potential of the SibSAL as the largest branch library in the region. But there is also a need to address to the regional, regional and libraries of agrarian higher education institutions [10].

In the scheme of radical change of management and elimination of organizational-functional ties of agrarian research institutes that have become part of regional centers of SB RAS, their reorientation towards the development and strengthening of links with the cen-

tral academic libraries of the regions, as well as restoration of interaction with the libraries of agrarian education on a new basis is evident.

Defining the systemic structure of agrarian research institutes and educational institutions of the region within the new boundaries of departmental relations between the Ministry of Agriculture, the Ministry of Science and Higher Education will allow to establish the vector of interaction between the SibSAL as a backbone link and on this basis to build library and information activity in the Siberian region.

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КОНСТРУИРОВАНИЕ И ИЗУЧЕНИЕ ИММУНОГЕННОСТИ ВИРУС-ВАКЦИНЫ ПРОТИВ ВИРУСНЫХ ПНЕВМОЭНТЕРИТОВ ТЕЛЯТ

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Изучена на лабораторных животных иммуногенность вирус-вакцины против вирусных пневмоэнтеритов молодняка крупного рогатого скота. Представлены результаты подбора оптимальных вакцинных штаммов по изучению действия различных инактивантов на вирус инфекционного ринотрахеита, вирусной диареи, парагриппа-3, респираторно-синтициального вируса, ротавируса и коронавируса. Накопление авирулентных вакцинных штаммов вирусов проводили с использованием общепринятых вирусологических методов на перевиваемых культурах клеток МДБК (клеток почек теленка) и СПЭВ (клеток почки эмбриона поросенка). Для отработки режимов инактивации вакцинных штаммов – компонентов экспериментальной вакцины – в качестве инактивирующих веществ использовали теотропин и формалин. Изучены антигенная активность аттенуированных штаммов вирусов инфекционного ринотрахеита, вирусной диареи, парагриппа-3, респираторно-синтициального вируса, ротавируса и коронавируса на белых мышах и телятах и уровень специфических антител в сыворотках крови морских свинок, иммунизированных вакциной с использованием разных адъювантов. При конструировании новой вирус-вакцины против вирусных пневмоэнтеритов использованы авирулентные штаммы вирусов: инфекционного ринотрахеита (ИРТ-ВБФ-ВГАВМ № 404); диареи (ВД-ВБФ-ВГАВМ № 406); парагриппа-3 (ПГ-ВБФ-ВГАВМ № 403); респираторно-синцитиального вируса (РСВ-ВБФ-ВГАВМ № 405); ротавируса (РТВ-ВБФ-ВГАВМ № 401) и коронавируса (КВ-ВБФ-ВГАВМ № 407). Выбранные вакцинные штаммы нереактогенные, вызывают активную выработку противовирусных антител в достаточно высоких титрах как у лабораторных животных (белые мыши), так и у сельскохозяйственных (крупный рогатый скот). Наиболее эффективным инактивантивирующим веществом является 0,1%-й теотропин и 0,2%-й формалин. При подборе оптимальных адъювантов для конструирования вирус-вакцины использовали два вида масляных адъювантов – ИЗА 15 и ИЗА 25. Адъювант ИЗА 15 использован в количестве 15% от количества антигенов, ИЗА 25 – 25%. Оптимальным адъювантом при изготовлении экспериментальной вирус-вакцины против вирусных пневмоэнтеритов молодняка крупного рогатого скота является адъювант ИЗА 15 в 15%-й концентрации.

Ключевые слова: вакцина, инактивант, адъювант, культура клеток, пневмоэнтериты, телята

DESIGN AND STUDY OF IMMUNOGENICITY OF VIRUS VACCINE AGAINST VIRAL PNEUMOENTERITIS OF CALVES

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The immunogenicity of a virus vaccine against viral pneumoenteritis in young cattle was studied in laboratory animals. The results of the selection of optimal vaccine strains to study the effects of different inactivants on infectious rhinotracheitis virus, viral diarrhea, parainfluenza-3, respiratory

syncytial virus, rotavirus and coronavirus are presented. The accumulation of avirulent vaccine virus strains was carried out using established virological methods on transplanted cell cultures of MDBC (calf kidney cells) and SPEV (fetal pig kidney cells). Theotropine and formalin were used as inactivating agents to develop inactivation regimes for vaccine strains - components of the experimental vaccine. The antigenic activity of attenuated strains of infectious rhinotracheitis virus, viral diarrhea, parainfluenza-3, respiratory syncytial virus, rotavirus and coronavirus on white mice and calves and the level of specific antibodies in the sera of guinea pigs immunized with vaccines using different adjuvants were studied. Avirulent strains of viruses were used in the design of a new virus vaccine against viral pneumoenteritis: infectious rhinotracheitis (IBR-VBF-VSAVM No. 404); diarrhea (VD-VBF-VSAVM No. 406); parainfluenza-3 (PG-VBF-VSAVM No. 403); respiratory syncytial virus (RSV-VBF-VSAVM No. 405); rotavirus (RTV-VBF-VSAVM No. 401) and coronavirus (CV-VBF-VSAVM No. 407). The selected vaccine strains are non-reactive and induce active production of antiviral antibodies in sufficiently high titres in both laboratory animals (white mice) and farm animals (cattle). The most effective inactivating agents are 0.1% theotropine and 0.2% formalin. Two types of oil-based adjuvants, ISA 15 and ISA 25, were used to select the optimal adjuvants for the design of the virus vaccine. Adjuvant ISA 15 was used at 15% of the antigen quantity, ISA 25 at 25%. The adjuvant IZA 15 at a concentration of 15% is the optimum adjuvant for the preparation of an experimental virus vaccine against viral pneumoenteritis in young cattle.

Keywords: vaccine, inactivant, adjuvant, cell culture, pneumoenteritis, calves

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INTRODUCTION

Currently, pneumoenteritis of young cattle of viral etiology is widespread in livestock complexes and farms [1, 2]. According to N.A. Kovalev et al. and E.V. Sussky et al., the incidence of pneumoenteritis in newborn calves reaches from 214 to 260% of the number of births. Respiratory diseases of viral etiology account for 33 to 60% and gastrointestinal diseases for 55-70% of all cases in calves. Lethality from these diseases is high and varies from 45 to 70%[1] [3–5].

However, these infections most often develop in association form, where two or more infectious pathogens are involved in the infection process, causing a more severe course of the disease with a high mortality rate. The most frequently diagnosed pathogen associations are IBR + VD (infectious rhinotracheitis + viral diarrhoea); IBR + PI-3 (parainfluenza-3); IBR + PI-3 + VD; IBR + VD + RS (respiratory syncytial virus); rota + corona virus + VD [4, 5].

Timely diagnosis to assess the etiological structure of the infectious agents[2] (see footnote 1) plays an important role in anti-epizootic measures. [1].

In industrial livestock farming, the main effective way to prevent further spread of viral infections in calves is specific prevention which is based on the use of virus vaccines and hyperimmune sera or globulins [4-7].

[1]Krasochko P.A., Krasochko I.A. Diagnostics, prevention and therapy of respiratory gastrointestinal diseases of young animals. Problems of pathology, sanitation and infertility in animal husbandry: materials of international scientific and practical conference devoted to the 100th anniversary of H.S. Goregliad and M.K. Yuskovets. Vitebsk, 1998. pp. 15-18.

[2]Gromov I.N., Prudnikov V.S., Krasochko P.A., Motuzko N.S., Zhurov D.O. Sampling for laboratory diagnosis of bacterial and viral diseases of animals: guidance manual. Vitebsk, 2020.

Currently, the biological industry of the Republic of Belarus produces only two associated vaccines - multivalent inactivated viral vaccine against infectious rhinotracheitis, viral diarrhoea, rota-, coronavirus infection of cattle "Tetravak" and viral vaccine live culture against infectious rhinotracheitis, viral diarrhoea, parainfluenza-3. "Kombovak" vaccine (vaccine against infectious rhinotracheitis, parainfluenza-3, viral diarrhoea and respiratory syncytial, rota- and coronavirus infection in cattle) produced by SPU "Vetbiokhim" (Russia) is widely used in the market of biological preparations used in animal husbandry.

Modern agriculture of the republic needs biopreparations with a wider range of pathogens, which also include parainfluenza-3 and respiratory syncytial virus. In this regard, the design of domestic virus-vaccine against infectious rhinotracheitis, viral diarrhea, parainfluenza-3, respiratory syncytial, rota-, coronavirus infection in cattle is an urgent task [1, 8, 9].

The use of highly immunogenic virus strains, the development of optimal means of virus inactivation and the use of adjuvant immunostimulants to improve the efficiency of the immune response are important in vaccine design [3, 5, 7, 8, 10, 11].

In the process of work, we developed polyvalent inactivated viral vaccine against infectious rhinotracheitis, viral diarrhoea, parainfluenza-3, respiratory syncytial, rota and coronavirus infection in cattle "Bolshevak", studied its effect on immunity and metabolic processes in animals[3] (see footnote 2) [2, 5, 9-11].

The aim of the study was to investigate the immunogenicity of the viral vaccine against viral pneumoenteritis in young cattle in laboratory animals.

MATERIAL AND METHODS

Studies were conducted in the conditions of the Department of Epizootology and Infectious Diseases, vivarium, as well as in the branch laboratory of veterinary biotechnology and contagious diseases of animals of VSAVM, Research Institute of Applied Veterinary Medicine and Biotechnology of the Vitebsk State Academy and in livestock farms of Vitebsk region (Republic of Belarus).

A comparative study of the infectious activity of the following avirulent vaccine virus strains was carried out in the design of the viral vaccine against viral pneumoenteritis: infectious rhinotracheitis (IBR-VBF-VSAVM No. 404 and KMIEV-6), diarrhoea (VD-VBF-VSAVM No. 406 and KMIEV-7), parainfluenza-3 (PI-VBF-VSAVM No. 403 and KMIEV-8), respiratory syncytial virus (RSV-VBF-VSAVM No. 405 and RSV), rotavirus (RTV-VBF-VSAVM No. 401 and KMIEV No. 3) coronavirus (CV-VBF-VSAVM No. 407 and KMIEV No. 1)

The accumulation of avirulent vaccine virus strains was carried out using common virological methods on transplanted cell cultures of MDBC (calf kidney cells) and SPEV (fetal pig kidney cells).

Theotropin and formalin were used as inactivating agents to develop modes of inactivation of vaccine strains, the components of the experimental vaccine. For this purpose, inactivating agents in various concentrations (from 0.1 to 0.5%) were added to the pre-titrated virus-containing liquid.

The exposure of vaccine strains to inactivant was 12 and 24 hours. After 6, 12 and 24 hours, samples of virus-containing material were taken and the completeness of inactivation in cell cultures was studied in two to three passages. An indicator of complete inactivation was the presence of CPD (cytopathic action - the occurrence of degenerative changes in cell cultures) after the virus came into contact with the inactivant.

Two types of oil-based adjuvants, ISA 15 and ISA 25 (Montide, Seppic, France), were used to select the optimal adjuvants for the design of the virus vaccine. The adjuvant ISA 15 was used in an amount of 15% of the number of antigens, and ISA 25 in an amount of 25%.

To evaluate the efficacy of the adjuvants, studies were carried out on guinea pigs. For this purpose, three groups of guinea pigs of

[3]Krasochko P.A. Mono- and associative viral respiratory infections in cattle (immunological diagnosis, prevention and therapy): thesis of the Doctor of Science in Veterinary Medicine. Minsk, 1997. 45 p.

five animals each were formed according to the paired-analysis principle. Guinea pigs of experimental group 1 received intramuscularly 0.5 cm^3 of the developed vaccine with ISA 15 adjuvant two times at 21-day intervals into the inner thigh surface, those of experimental group 2 received 0.5 cm^3 of the developed vaccine with ISA 25 adjuvant, and those of control group 3 received a placebo. Blood serum samples were taken from guinea pigs of all groups 21 days after re-injection. The titer of antiviral antibodies in serum samples was determined by RIPR.

RESULTS AND DISCUSSION

The results of the comparative study of the selected vaccine strains infectivity are presented in Table 1.

The following avirulent virus strains should be used in the design of vaccines against viral pneumoenteritis in young cattle: Infectious rhinotracheitis (IBR-VBF-VSAVM No. 404); diarrhoea (VD-VBF-VSAVM No. 406); parainfluenza-3 (PI-VBF-VSAVM No. 403); respiratory syncytial virus (RSV-VBF-VSAVM No. 405); rotavirus (RTV-VBF-VSAVM No. 401); coronavirus (CV-VBF-VSAVM No. 407).

The results of the tests to determine the completeness of virus inactivation are shown in Table 2.

In studies of the effect of inactivating agents on ECD cell culture, it was determined that the use of formalin in concentrations above 0.3% and theotropin above 0.1% caused degeneration of the monolayer.

The use of the studied inactivating agents in low concentrations (0.1% tetropin, 0.2% formalin) was found to inactivate viruses of infectious rhinotracheitis, diarrhoea, parainfluenza-3, respiratory syncytial virus, bovine rotavirus and coronavirus.

The results of the antiviral antibody titres after administration of the developed virus vaccine with different adjuvants to guinea pigs are shown in the figure.

Immunization of guinea pigs with test samples of vaccine with different oil-based adjuvants induces the production of specific antibodies in high titres. The use of the adjuvant ISA 15 promoted an increase in the titre of antibodies in guinea pig sera against the test viruses in the range 3.6 ± 0.3 to 5.8 ± 0.3 $\log^2$, the adjuvant ISA 25 in the range 3.0 ± 0.3 to $5.0 + 0.3$ $\log^2$.

CONCLUSIONS

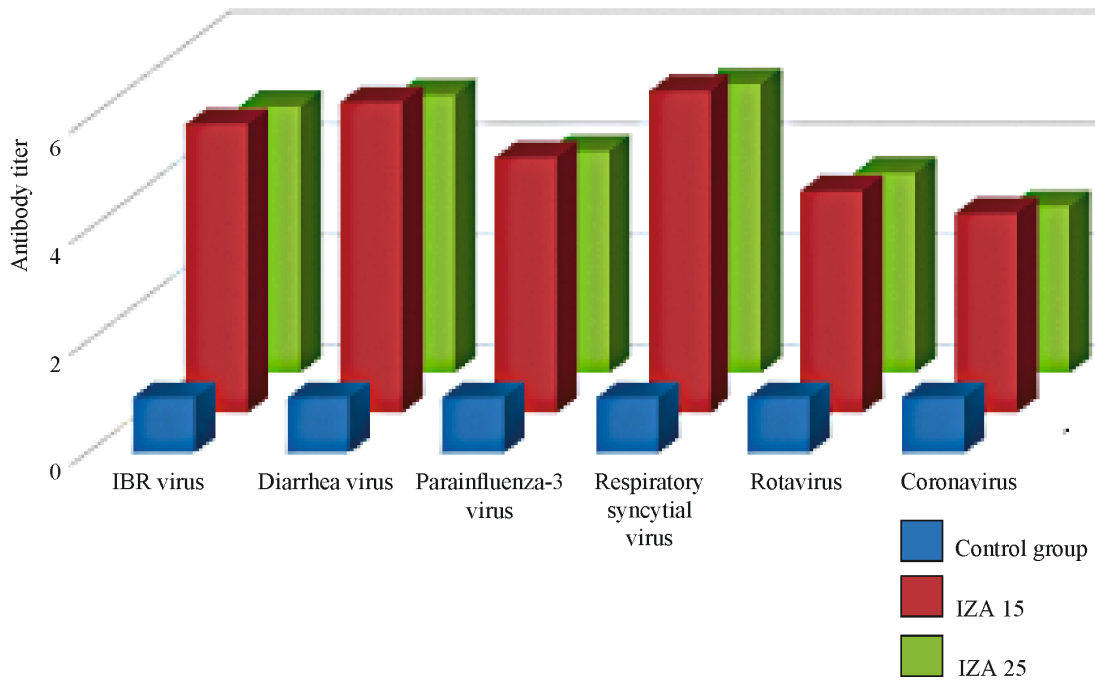
1. When designing an experimental vaccine against viral pneumoenteritis of young cattle, the following avirulent virus strains should be used: Infectious rhinotracheitis (IBR-VBF-VSAVM No 404); diarrhoea (VD-VBF-VSAVM No 406); parainfluenza-3 (PI-VBF-VSAVM No 4 03); respiratory syncytial virus (RSV-VBF-VSAVM No 405); rotavirus (RTV-VBF-VSAVM No 401); coronavirus (CV-VBF-VSAVM No 407).

Табл. 1. Сравнительная инфекционная активность вакцинных штаммов
Table 1. Comparative infectious activity of vaccine strains

Virus	Strain	Virus titer	Strain	Virus titer
IBR	KMIEV – 6	6,5 lg TCD/50	IBR- VBF - VSAVM № 404	7,5 lg TCD /50
Diarrhoea	KMIEV – 7	7,0 lg TCD/50	VD- VBF - VSAVM № 406	7,8 lg TCD /50
Parainfluenza-3	KMIEV – 8	6,3 lg TCD /50	PI- VBF - VSAVM № 403	7,0 lg TCD /50
Rotavirus	KMIEV – 3	7,0 lg TCD /50	RTV- VBF - VSAVM 401	8,0 lg TCD /50
Coronavirus	KMIEV – 1	5,0 lg TCD /50	CV- VBF - VSAVM № 407	6,6 lg TCD /50
Respiratory syncytial virus	RSV	3,5 lg TCD /50	RSV- VBF - VSAVM 405	4,8 lg TCD 50

Табл. 2. Результаты изучения действия различных инактивантов на вакцинные штаммы
Table 2. Results of the study of the effect of various inactivants on vaccine strains

Type and strain of virus	Inactivating agent substance	Inactivation mode	
		Inactivant concentration, %	Exposure, h
IBR virus (IBR- VBF - VSAVM № 404)	Formalin	0,2	24
	Theotropin	0,1	24
Diarrhoea virus (VD- VBF - VSAVM № 406)	Formalin	0,2	12
	Theotropin	0,1	24
Parainfluenza-3 virus (PI- VBF - VSAVM № 403)	Formalin	0,2	12
	Theotropin	0,1	24
Rotavirus (RTV- VBF - VSAVM 401)	Formalin	0,2	12
	Theotropin	0,1	24
Coronavirus (CV- VBF - VSAVM № 407)	Formalin	0,2	24
	Theotropin	0,1	24
Respiratory syncytial virus (RSV- VBF - VSAVM 405)	Formalin	0,2	12
	Theotropin	0,1	24



Уровень специфических антител в сыворотках крови морских свинок, иммунизированных опытной вакциной с различными адъювантами, log^2

The level of specific antibodies in the blood sera of guinea pigs immunized with an experimental vaccine with various adjuvants, log^2

2. The selected vaccine strains are non-reactive and induce active production of antiviral antibodies in sufficiently high titres in both laboratory animals (white mice) and farm animals (cattle).

3. The most effective inactivating agents are 0.1% theotropine and 0.2% formalin.

4. The optimal adjuvant for the preparation of an experimental virus vaccine against viral pneumoenteritis in young cattle is the adjuvant ISA 15 at a concentration of 15%.

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