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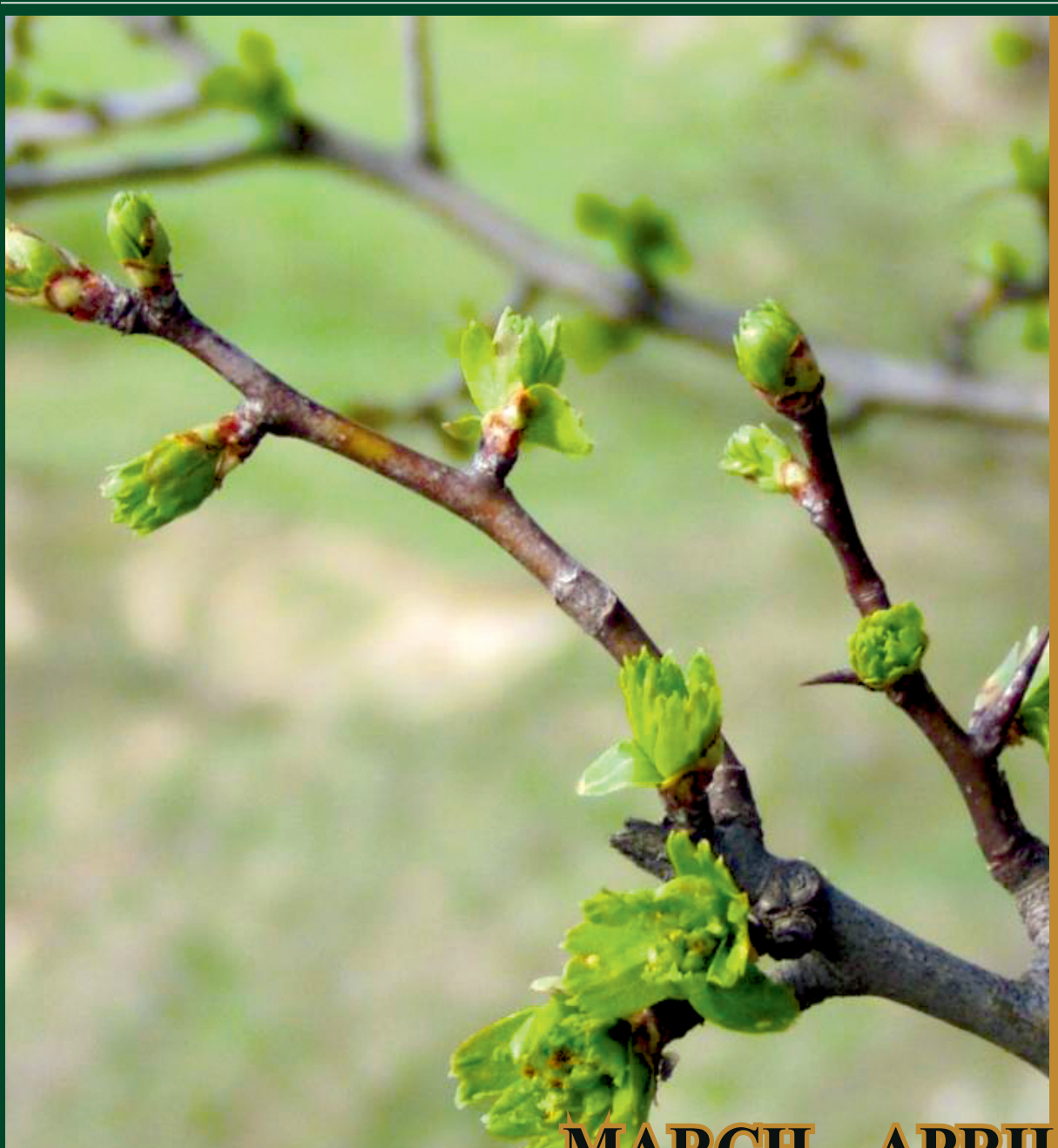

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ПИТАТЕЛЬНЫЙ РЕЖИМ ОРОШАЕМЫХ ЛУГОВО-ЧЕРНОЗЕМНЫХ ПОЧВ ПРИ ДЛИТЕЛЬНОМ ИНТЕНСИВНОМ ИСПОЛЬЗОВАНИИ

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Изучены закономерности фосфорного и калийного режима почв при совершенствовании агротехнологий орошаемого земледелия. Длительные исследования проходили в экспериментальном зернотравяном севообороте на орошаемой лугово-черноземной почве. Опытный участок расположен в южной лесостепи Омской области. Интенсивное использование орошаемой пашни при рациональном сочетании режимов влажности и минерального питания способствует получению максимальных урожаев кормовых и зерновых культур. Создание различных условий минерального питания за счет фонов с повышенной и высокой обеспеченностью подвижным фосфором с наложением на них разных вариантов агротехнологий позволило смоделировать возможные агроэкологические условия, формирующие контрастные показатели продуктивности культур. Сравнительная оценка эффективности различных агроприемов по выращиванию культур на орошаемом фоне свидетельствует, что приемы обработки почвы и предшественники не оказывали существенного влияния на содержание доступного фосфора в почве. Равновесное содержание подвижного фосфора при многолетнем отрицательном балансе изменилось незначительно. Систематическое внесение фосфорсодержащих удобрений заметно повысило фосфатный статус почвы. Однако адекватная оценка фосфатного состояния пахотных почв возможна при использовании нескольких диагностических индексов (методов). Длительное интенсивное использование орошаемой пашни снизило запасы легкообменного калия от 4 до 1–2 мг/100 г почвы в пахотном слое. Содержание обменного калия также снизилось почти в 2 раза, но почва остается в высоком и очень высоком классе обеспеченности им. Однако ряд показателей свидетельствует о нарастающем истощении ее наиболее подвижными фракциями почвенного калия. Более устойчивы запасы необменного калия, которые снизились за 40 лет примерно на 19%, и почва перешла в разряд с неустойчивой обеспеченностью.

Ключевые слова: чернозем, орошение, минеральное питание, фосфор, калий, удобрения

NUTRIENT REGIME OF IRRIGATED MEADOW-CHERNOZEM SOILS UNDER LONG-TERM INTENSIVE USE

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The patterns of phosphorus and potassium status of soils were studied given the improvement of agricultural technologies of irrigated agriculture. Long-term studies were carried out in an experimental grain-grass crop rotation on irrigated meadow-chernozem soil. The experimental plot is located in the southern forest-steppe of Omsk region. Intensive use of irrigated arable land with a

rational combination of moisture and mineral nutrition regimes contributes to obtaining maximum yields of forage and grain crops. The creation of various conditions for mineral nutrition due to an increased and high supply of mobile phosphorus and with the application of different options of agricultural technologies made it possible to simulate possible agro-ecological conditions that form contrasting indices of crop productivity. A comparative assessment of the effectiveness of various agricultural approaches to growing crops under irrigation conditions indicates that soil cultivation techniques and forecrops did not significantly affect the content of available phosphorus in the soil. The equilibrium content of mobile phosphorus given a long-term negative balance changed insignificantly. The systematic application of phosphorus-containing fertilizers significantly increased the phosphate status of the soil. However, an adequate assessment of the phosphate status of arable soils is possible using several diagnostic indices (methods). Long-term intensive use of irrigated arable land has reduced the reserves of easily exchangeable potassium from 4 to 1–2 mg/100 g of soil in the arable layer. The content of exchangeable potassium has also decreased by almost 2 times, but the soil remains in a high and very high class of its availability. However, a number of indicators show its increasing depletion in the most mobile fractions of soil potassium. The reserves of non-exchangeable potassium are more stable, which have decreased by about 19% over 40 years, and the soil has passed into the category with an unstable supply.

Keywords: chernozem, irrigation, mineral nutrition, phosphorus, potassium, fertilizers

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INTRODUCTION

Long-term scientific and practical experience shows that the efficiency of irrigated agriculture increases with the introduction of organic and mineral fertilizers, as well as microelements. Irrigation creates prerequisites for the most effective use of fertilizers for all crops and on all soils. The main condition for obtaining the maximum effect of the application of fertilizers is the correct combination of irrigation regime and fertilizers.

An important sign of fertility is the phosphorus regime in soils. Purposeful regulation of its agrotechnical and reclamation methods affects the reserves of natural phosphorus compounds in soils in order to increase their mobility and accessibilty[1] [1–5].

It is well known that the optimal dose of phosphorus fertilizers is weakly dependent on the type of the soil. The pre-sowing application of $P_{10–15}$ is practically equally effective both on infertile soddy-podzolic soils and on typical and ordinary chernozems. There are practically no soils rich in phosphorus in nature, the level of dynamic equilibrium of phosphate systems of extensively used soils is at the border of low and medium values of phosphorus supply [6, 7].

Potassium as a nutrient is less studied than phosphorus, due to the fact that in arid conditions with low productivity and high potassium supply of the soil, the issue of using potash fertilizers is not as relevant as phosphorus fertilizers. The need for potassium increases due to the more intensive use of arable land with high pro-

[1]Kolbin S.A., Samokhvalova L.M., Prozorov A.S. The influence of the moisture conditions of the growing season on phosphorus removal by spring wheat in the forest-steppe of the Ob region // Soil resources of Siberia: challenges of the XXI century: materials of the All-Russian. scientific. Conf., dedicated to the 110th anniversary of R.V. Kovalev. Novosibirsk, 2017. P. 209–212.

ductivity and saturation of crop rotations with crops with a high removal of potassium from the soil [8–10].

The aim of the work is to study the patterns of the nutritive regime of soils while improving the agricultural technologies of irrigated agriculture.

MATERIALS AND METHODS

The experimental part of the work was carried out in stationary experiments laid down in 1977–1978 in two four-field crop rotations - grain-grass and fodder, combined since 1996 into one eight-field grain-grass crop rotation. The experimental site is located in the southern forest-steppe of the Omsk region.

The climate of the area is typically continental. The sum of the average monthly temperatures for a period> 10 ° C varies within the irrigation zone on average from 1900 to 2200 °. The amount of precipitation during the growing season is about 200 mm.

The soil is meadow-chernozemic, medium-thick, medium-humus, heavy loamy with a humus content in the 0–0.4 m layer of 6.0–6.5%, the thickness of the humus horizon "A" is 0.45 m. The reaction of the soil environment in the arable layer is neutral: pH_{water} - 7.0-7.2.

The soil moisture regime (background) was maintained by irrigation within narrow limits (WRC - 0.9–1.0 HB) in layers of 0.5–1.0 m, depending on the phase of development and biology of crops. The irrigation rate is mainly 300 m3 / ha.

Experiments are two- and three-factor. At the initial stage (from 1978 to 1985), they included four nutritional backgrounds: control (without fertilizers) and with fertilization based on an increase in yield (backgrounds I – III) and 4–5 variants of soil cultivation for fodder and grain crops. Due to the positive balance of phosphorus, backgrounds with increased and high content of phosphorus are created. At the second stage (1986–1995), four backgrounds in terms of the content of mobile phosphorus in the soil were combined with different seeding rates for crops and nitrogen fertilizers (1986–1990). Then (1991–1995), nitrogen fertilizers ($N_{0, 30, 60, 90}$) and micronutrients (Zn, Mo, Cu) were superimposed on these backgrounds. In addition, a spare application of manure of 40 t / ha (and without it) was carried out, as well as compensation for the removal of phosphorus within 10 years by the introduction of 60 kg ai / ha on backgrounds I – III.

From 1996 to 2020, the fundamental difference between the experimental schemes was the refusal to compensate for the removal of phosphorus and its positive balance by the background application of P_{60} with their further detailing by superimposing the variants with the introduction of phosphorus (P_{60}) and without it in combination with nitrogen ($N_{0, 30, 60, 90}$) with fertilizers, depending on the biology of crops.

The crops included in the crop rotation at different periods of the years have been: lucerne, fodder galega, awnless rump in single-species and mixed crops, biennial white and yellow sweet clover, annual legume-bluegrass mixtures for green fodder of the main and intermediate crops, for grain silage - for spring sowing, winter crops (rye, triticale), Sudanese grass of the main and post-cut crops, including mixed with vetch, fodder beans, panic grass of cut-down crops, sugar sorghum, cabbage, cereals and legumes.

Allocation of plots is systematic; their area is 360 m^2 (18 × 20 m). Repetition is three and four times. Watering was carried out by SSR-64 "Volzhanka". In the field experiments we used the appropriate serial tillage, sowing and harvesting equipment.

The organization of field experiments, observations, records and laboratory analyzes was carried out in accordance with the methodological manuals and guidelines generally accepted in agriculture and agrochemistry. These are guidelines for setting up field experiments and conducting field observations[2], methods for chemical analysis of the soils[3].

[2]Dospekhov B.A. Field experiment technique. Moscow: Kolos, 1979.416 p.

[3]Agrochemical methods of soil research: monograph. Moscow: Nauka, 1975.656 p.

The analysis of the content of mobile phosphorus by various methods and forms of potassium was carried out simultaneously in the original (archived) samples and modern soil in 2018 and 2019 respectively.

RESULTS AND DISCUSSION

The experience of conducting intensive agricultural production has shown that obtaining high yields is impossible without a radical improvement in the phosphate regime of soils.

A comparative assessment of the effectiveness of various agricultural practices for growing crops on an irrigated background indicates that soil cultivation techniques and predecessors did not significantly affect the content of available phosphorus in the soil.

The level of phosphorus nutrition was determined by the creation, due to a positive balance of backgrounds, with an increased, high and very high supply of $P_2 O_5$ and compensation of the removal by the introduction of phosphorus-containing fertilizers.

The level of mobile phosphorus in the control variants of experiments on meadow chernozem soil changed insignificantly, despite the long-term alienation of the element from the soil. At the same time, with the systematic application of phosphorus fertilizers, the content of mobile phosphorus increased significantly (see Table 1).

It can be assumed that the value of this indicator as a diagnostic parameter when monitoring the phosphate state of the soils in agrocenoses reflects the mode of accumulation of this element rather well and much worse - the scale of its consumption (removal) by crops. This indicates the advisability of the integrated use of several diagnostic indices for an adequate assessment of the phosphate state of arable soils.

Over the entire research period, taking into account the transformation of the experimental schemes while maintaining control and, to varying degrees, fertilized options, various amounts of mineral fertilizers, including phosphorus-containing ones, were introduced in fodder and grain-grass crop rotations. So, in the fodder crop rotation, taking into account the biology of the crops, over 40 years in the fertilized version, 2739 kg of ai / ha of nitrogen and 3288 kg of ai / ha of phosphorus were introduced, in the grain-grass - 3138 and 2796 kg of ai / ha, respectively. The annual dose of phosphorus in the fodder crop rotation was approximately 82 kg of ai / ha, in the grain-grass - about 70 kg of ai / ha. However, a significant annual removal of phosphorus with two- and three-mowing use of perennial grasses and two harvests of annual forage crops reduced the content of mobile forms of phosphorus in comparison with grain-grass crop rotation.

Табл. 1. Содержание фосфатов в почве при длительных полевых опытах (1978–2019 гг.)
Table 1. The content of phosphates in the soil of long-term field experiments (1978-2019)

Variant	Soil layer, m	Phosphorus content, mg / kg of the soil		
		according to Chirikov	according to Franceson	according to Karpinsky
Raw land (parent)	0–0,2	4,0	60,0	215
	0,2–0,4	2,7	51,9	193
Fodder crop rotation				
Without fertilizers	0–0,2	1,8	32,5	179
	0,2–0,4	0,8	24,2	168
NP	0–0,2	1,2	32,1	174
	0,2–0,4	0,6	25,4	170
Grain crop rotation				
Without fertilizers	0–0,2	1,6	30,3	170
	0,2–0,4	0,7	20,1	165
NP	0–0,2	1,1	30,7	169
	0,2–0,4	0,6	20,4	168
LSD_{05}		0,3	4.4	15

According to A.E. Kochergin[4], the most sensitive assessment of the phosphate state of the West Siberian soils is provided by the Franceson method. The stable content of easily exchangeable phosphorus in the upper layer of the control variants of meadow-chernozem soil in comparison with the initial content and a clear tendency of its corresponding increase in the underlying soil layers are obvious (see Table 1). The reason for this phenomenon can be both a relatively low mobility of phosphorus compounds in this soil, and their certain biogenic accumulation in the upper soil horizons during long-term cultivation of grasses, accompanied, possibly, by a slight increase in the degree of mobility of the available soil phosphate fractions. With the systematic use of phosphorus fertilizers, the level of readily mobile phosphorus in meadow chernozem soil significantly increased, indicating a high supply of available forms of this mineral element to crops.

The high buffering capacity of the meadow chernozem soil and its increased natural fertility contributed to the preservation of a certain level of phosphorus ions in the soil solution even with prolonged agricultural use. However, a significant decrease in the productivity of crops in extensive agrocenoses indicates that the soil possibilities are generally not unlimited.

Potassium is also an important element of plant mineral nutrition. It occupies a leading position among other biophilic elements in the removal of many agricultural crops, especially fodder crops, with the harvest. However, less attention is paid to the optimization of the potassium state of the soils in agrocenoses in comparison with nitrogen and phosphorus. The use of potash fertilizers in modern agriculture in Siberia is at a minimum. This approach is usually justified by the fact that the main arable soils contain rather high reserves of gross potassium and its mobile forms. However, it is often not taken into account that long-term intensive agricultural use of soil can affect soil potassium reserves, influencing the yield and quality of crop production [11].

Optimization of nitrogen-phosphorus nutrition of plants in experiments on meadow-chernozem soil contributed to a significant increase in the yield of forage and grain crops in relation to unfertilized options. At the same time, a significant additional removal of potassium with the crop was noted. The high initial reserves of potassium available to plants did not limit the potassium nutrition of crops, providing an increased removal of an element alienated by plants and the possibility of a long-term negative balance of potassium in agrocenoses.

The potassium fund of the soil is subdivided into four interrelated components (forms), based on the strength of the bond of certain groups of potassium cations with the solid phase of the soil: easily exchangeable potassium (soil solution), exchangeable, non-exchangeable, potassium of the mineral skeleton (structural). The first three forms determine the effective soil fertility with respect to potassium, which necessitates their quantitative and qualitative assessment when monitoring the soil potassium state of the soil [11, 12].

Due to its small absolute values, easily exchangeable potassium is rarely used to characterize the potassium state of arable soils, although the available data indicate a fairly close relationship of this indicator with productivity and its good diagnostic capabilities [12, 13]. The level of easily exchangeable potassium gives an idea of the degree of depletion of the soil, its ability to desorb the ions of this element into the soil solution.

The content of easily exchangeable potassium in the soil is a fairly universal index of the provision of crops with soil potassium. Under similar conditions of potassium nutrition of plants on different soils, the level of easily exchangeable potassium in them is approximately the same regardless of the absolute values of the content of other potassium forms in these soils. The gradations of the supply of potassium in the main arable soils of the Western Siberia according to the content of its easily exchangeable form in them were published earlier [12].

[4]Kochergin A.E. Phosphate soils fund and its availability to plants // Soils of Western Siberia and an increase of their fertility. Omsk: Omsk Agricultural Institute. 1984.P. 12-19.

The content of easily exchangeable potassium in the original soil was very high - 4.0 mg / 100 g in the 0–0.2 m layer and 2.7 mg / 100 g in the 0.2–0.4 m layer (see Table 2).

Long-term agricultural use of the soil in the control variant caused a significant decrease in the reserves of this form of potassium both in the arable layer and especially in the subsoil. The systematic use of mineral fertilizers in the NP variant contributed to an increase in crop productivity and, accordingly, a further decrease in the content of easily exchangeable potassium in the soil. The increased potassium fund of the meadow chernozem soil and the high buffering capacity of its potassium system made it possible for many years to maintain the intensity of the processes of potassium desorption into the soil solution at a sufficiently high level. However, over 40 years of experiments, the supply of the studied soil with easily exchangeable potassium decreased from very high (4 mg / 100 g of soil) to unstable (1–2 mg) in the arable layer of all variants and low (<1 mg per 100 g) in the subsoil. This circumstance testifies to the growing need of grown crops for additional potassium nutrition.

In the arable and subsoil layers, the content of exchangeable potassium has decreased over 40 years by almost 2 times from the initial (from 52-60 to 20-32 mg / 100 g), while remaining, nevertheless, in a high and very high class of availability according to standard gradations (see Table 2). However, the vector of changes in the potassium state of this soil is obvious, which makes it possible to predict its transition in the future to the class of supply with problematic potash nutrition of crops. The options "without fertilizers" and NP did not differ in the scale of the decrease in the content of exchangeable potassium. At the same time, it is possible to note a tendency for the intensification of this process in the grain-grass crop rotation in comparison with the forage one.

In the topsoil, over 40 years of the experiment, the content of non-exchangeable potassium decreased by 36–46 mg / 100 g of soil, which was approximately 19% of the original reserves. In the grain-grass crop rotation, the potassium reserves in the arable and subsoil layers of the soil were used more intensively than in the fodder (see Table 2). According to the proposed gradations [13], the studied heavy loamy soil was initially considered to be optimally provided with a non-exchangeable form of potassium (180–250 mg / 100 g). During the experiments, it passed into the category with an unstable supply (<180 mg).

Табл. 2. Калийное состояние лугово-черноземной почвы в длительном полевом опыте (1978–2018 гг.)
Table 2. Potassium state of meadow-chernozem soil in the long-term field experiment (1978–2018)

Variant	Soil layer, m	The content of forms of potassium, mg / 100 g of soil		
		Easily exchangeable potassium	Exchangeable potassium	Non-exchangeable potassium
Raw land (parent)	0–0,2	4,0	60,0	215
	0,2–0,4	2,7	51,9	193
Fodder crop rotation				
Without fertilizers	0–0,2	1,8	32,5	179
	0,2–0,4	0,8	24,2	168
NP	0–0,2	1,2	32,1	174
	0,2–0,4	0,6	25,4	170
Grain crop rotation				
Without fertilizers	0–0,2	1,6	30,3	170
	0,2–0,4	0,7	20,1	165
NP	0–0,2	1,1	30,7	169
	0,2–0,4	0,6	20,4	168
LSD_{05}		0,3	4.4	15

CONCLUSIONS

1. The content of mobile phosphorus in the control variants changes insignificantly during long-term alienation from the soil. Compensation of phosphorus removal from intensively used meadow chernozem soils and its positive balance reliably maintain the created optimal level of its content, without reducing either crop yields or soil fertility, which is equivalent to the full use of phosphates.

2. Long-term agricultural use of the soil in the control variants significantly reduced the reserves of easily exchangeable potassium. The content of exchangeable potassium has almost halved over 40 years, remaining in a high class of abundance. The meadow-chernozem soil is highly supplied with available potassium and, after 40 years of use, formally belongs to this category. However, a number of additional indicators demonstrate an increasing depletion of its most mobile fractions of soil potassium.

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РЕСУРСОСБЕРЕГАЮЩИЕ ПРИЕМЫ ВОЗДЕЛЫВАНИЯ КОРМОВЫХ КУЛЬТУР В ЗАБАЙКАЛЬСКОМ КРАЕ

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Представлены результаты исследований по сравнительной оценке различных приемов обработки почвы в полевом севообороте с разным уровнем минерального питания ($N_{30}P_{30}$ и $N_{60}P_{30}$ кг д.в./га). Эксперимент проведен на малогумусном малокарбонатном черноземе лесостепной зоны Восточного Забайкалья в 2012–2014 гг. Для посева использованы районированный сорт яровой пшеницы Бурятская-79, сорт овса Метис. Изучены малозатратные приемы обработки почвы, предусматривающие сохранение и повышение плодородия почвы, повышение продуктивности зернофуражных и кормовых культур, снижение материальных и энергетических затрат. Замена основной обработки плугом ПН-4-35 с кольчатым катком в третьем и четвертом полях севооборота поверхностной обработкой культиватором Степняк-7,4 и прямым посевом по стерне сеялкой ППМ Обь-4-ЗТ при внесении минеральных удобрений в норме $N_{60}P_{30}$ кг д.в./га оказывала положительное влияние на состояние почвы. Достигнуты следующие показатели плодородия почвы: коэффициент структурности 1,28–1,38, содержание органического вещества 3,15–3,33%, содержание продуктивной влаги в слое 0–50 см 29,2–31,8 мм, выделение углекислоты 1,810–1,969 кг за 1 ч, содержание P_2O_5 в слое 0–20 см 71–96 мг/кг почвы, K_2O – 57–82 мг/кг почвы. Обеспечена прибавка урожайности зерна овса 0,16–0,21 т/га, зеленой массы однолетних трав – 3,4–4,0 т/га, сбор кормовых единиц – 0,32–0,34 т/га, снижение затрат горюче-смазочных материалов на 31,2–36,4%, повышение рентабельности на 25,0–40,3%.

Ключевые слова: севооборот, отвальная вспашка, поверхностная обработка, прямой посев, плодородие почвы, минеральные удобрения, продуктивность, экономическая эффективность

RESOURCE-SAVING METHODS OF FODDER CROP CULTIVATION IN THE TRANS-BAIKAL TERRITORY

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The results of the study on the comparative assessment of different tillage methods in the field crop rotation with different levels of mineral nutrition ($N_{30}P_{30}$ and $N_{60}P_{30}$ kg of active ingredient/ha) are presented. The experiment was carried out on low-humus low-carbonate chernozem of the forest-steppe zone of Eastern Trans-Baikal Territory in 2012–2014. The zoned variety of Buryatskaya-79 spring wheat, and Metis oat variety were used for sowing. Low-cost methods of soil tillage were studied, providing for the preservation and improvement of soil fertility, an increase in the productivity of grain and fodder crops, and a decrease in material and energy costs. Replacement of the basic tillage with a PN-4-35 plow with a ring roller in the third and fourth crop rotation fields by surface tillage with a Stepnyak-7.4 cultivator and direct sowing on the stubble with a PPM Ob-4-ZT seeder when applying mineral fertilizers at a rate of $N_{60}P_{30}$ kg of active ingredient/ha had a positive effect on the condition of the soil. The following indicators of soil fertility were achieved: structural coefficient 1.28–1.38, organic matter content 3.15–3.33%, productive moisture content in the 0–50 cm layer 29.2–31.8 mm, the release of carbon dioxide 1.810–1.969 kg per 1 hour, the

content of P_2O_5 in the 0–20 cm layer 71–96 mg/kg of soil, the content of K_2O – 57–82 mg/kg of soil. An increase in the yield of oat grain of 0.16–0.21 t/ha, the green mass of annual grasses of 3.4–4.0 t/ha, the collection of feed units of 0.32–0.34 t/ha, a reduction in the cost of fuel and lubricants by 31.2-36.4%, and an increase in profitability by 25.0–40.3% were achieved.

Keywords: crop rotation, moldboard plowing, surface tillage, direct sowing, soil fertility, mineral fertilizers, productivity, economic efficiency

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INTRODUCTION

Different intensity of land use in combination with complex natural and economic factors in the conditions of the Trans-Baikal Territory (violation of the technology of cultivation of agricultural crops, non-observance or absence of scientifically grounded crop rotations, poor quality fallow preparation and tillage) is gradually leading to degradation of the soil and vegetation cover [1-3].

One of the most important tasks of agriculture is to ensure the sustainable development of the production of grain, grain fodder and fodder crops based on the optimization of the structure of sown areas using a biologized and resource-saving farming system.

Tillage in a farming system is an energy-intensive process. In the conditions of Transbaikalia, plowing remains the predominant method of mechanical processing, but its high energy intensity is a limiting technological factor in resource-saving agriculture. Currently, the range of soil cultivation equipment is being replenished by the production of high-performance multi-operational implements, which makes it possible to switch from traditional tillage to minimum.

Usually, to perform pre-sowing soil cultivation, 4-6 passes through the field with tillage and sowing equipment are required. The use of such new units as the PN-4 mounted ripper, the Stepnyak-7,4 cultivator, the Ob-4-ZT tillage and sowing machine allows to reduce the number of passes to a minimum [3, 4].

In recent years, enough experimental material has been accumulated on the development of scientifically grounded biologized crop rotations and resource-saving soil cultivation systems that allow preserving soil fertility, increasing crop yields and product quality, and reducing costs for their cultivation [1, 5-7].

The purpose of the research is to evaluate in comparison energy-saving methods of soil cultivation at different levels of mineral nutrition in field crop rotation on grain fodder and forage crops, to determine the influence of technologies on the main indicators of fertility of low-humus low-carbonate chernozems, crop productivity and their economic efficiency.

MATERIALS AND METHODS

Field agrotechnical experiments were carried out in a stationary four-field field crop rotation of pairs - wheat - oats - annual grasses (oats) in the fields located in the southwestern part of the Ingodinsko-Chita forest-steppe.

The climate of the zone is sharply continental with little snow, cold winters, hot summers and a lack of precipitation. The frost-free period lasts for 90-110 days. The average annual precipitation is 330-380 mm, the main amount (85-90%) falls in the warm period, the maximum -

in July - August, the minimum - in May - June. In general, the regime is characterized by variability of moisture. Years with good moisture supply give way to satisfactory, and more often dry periods. The sum of temperatures above 10 ° C for the summer months is 1500–1800 ° with a high average monthly temperature in July - 19.1 ° C. Hydrothermal coefficients (HC) of the growing seasons during the years of research were 2.7; 2.1; 0.6. According to the State Customs Committee, 2012 and 2013 characterized as sufficiently humid, 2014 - severely arid.

The soil of the experimental plot is chernozem, low-humus, low-carbonate, low-power, light loam. The humus content in the arable layer is 2.78%. The soil supply with mobile forms of phosphorus and exchangeable potassium is average. Lumpiness of the soil is below the threshold of resistance to wind erosion.

The experiment was repeated three times. The sown area of the plot is 1000 m^2. The placement of variants in the first repetition is sequential, in the second and third - randomized. The fields in the crop rotation were located both in space and in time. To cultivate the soil a PN-4-35 mounted plow with rolling ZKKSh-6A, a mounted PN-4 cultivator, KPE-3.8 and Stepnyak-7.4 cultivators, and a PPM Ob-4-ZT seeder for direct sowing were used. The experiment scheme is presented in table 1.

Agrotechnology of cultivation of field crops in crop rotation was carried out according to the scheme of the experiment. Mineral fertilizers were applied simultaneously with sowing at the rate of $N_{30}P_{30}$ kg a.i. / ha in the form of ammonium nitrate and superphosphate for each crop rotation and N_{30} kg a.i. / ha for pre-sowing cultivation in oats and annual grasses in options without basic tillage. In the fight against smut fungi and root rot, the seeds were treated with the fungicide "Bunker" before sowing at a rate of 0.5 l / t of seeds. For sowing, we used the zoned spring wheat variety Buryatskaya-79, the Metis oat variety. Sowing dates: spring wheat in the 1st decade of May, oats in the 3rd decade of May, annual grasses in the 3rd decade of June. For sowing, a PPM Ob-4-ZT seeder was used. The method of sowing is striped with a seeding depth of 6–8 cm. Crop care of agricultural crops was carried out in accordance with the recommendations [1]. In the tillering phase against weeds, wheat and oats were treated with a tank mixture of herbicides Dialen super (0.2 l) + Magnum (0.007 kg) per 1 ha. The harvesting and accounting of the harvest of grain crops was carried out by direct combining with a Yenisei combine (the yield led to 14% moisture and 100% purity), annual grasses for green mass - with a KS-2.1 mower.

The observations and counts were carried out according to the generally accepted methods in agriculture and crop production[1–6].

RESULTS AND DISCUSSION

The research results showed that replacing the traditional moldboard plowing in the third and fourth fields of crop rotation with resource-saving processing systems (cultivation, direct seeding) did not worsen the structural-aggregate state of the arable horizon of 0-30 cm. Against the background of low-cost tillage, the coefficient of structure was 1.28-1 , 37, on the control with moldboard plowing - 1.0-1.1. In the compared variants, the higher indices of the volumetric mass in the arable soil layer in the summer period (1.30 and 1.34 g / cm^3) were obtained without main treatment, lower (1.26 and 1.29 g / cm^3) - in the variants with moldboard plowing. In terms of productive moisture reserves in a half-meter soil layer before harvesting, the traditional technology of cultivation of agricultural crops was inferior to energy-saving

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Табл. 1. Схема опыта в севообороте

Table 1. Scheme of the experiment in crop rotation

Crop rotation fields			
Fallow	Wheat	Oats	Annual grasses (herbage oats)
Tillage type			
Basic tillage PN-4-35 (20–22 cm), during the fallow period 2–3 cultivation KPE-3,8 with BZSS-1 for 8–10, 10–12 cm	Pre- sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH-6A	Basic tillage PN -4-35 (20–22 cm), pre-sowing cultivation KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Basic tillage PN -4-35 (20–22 cm), pre- sowing cultivation KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A
Tillage PN-4 (25–27 cm), during the fallow period 2–3 cultivation KPE -3,8 with BZSS -1 for 8–10, 10–12 cm	Pre- sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Tillage LDT -4 (25–27 cm), pre-sowing cultivation KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Tillage LDT -4 (25–27 cm), pre- sowing cultivation KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A
Tillage PN -4 (25–27 cm), during the fallow period 2–3 cultivation KPE-3,8 with BZSS -1 for 8–10, 10–12 cm	Pre-sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Cultivation Stepnyak-7,4 for 16–18 cm, seeding (fertilizers $N_{30}P_{30}$)	Cultivation Stepnyak-7,4 for 16–18 cm, sowing (fertilizers $N_{30}P_{30}$)
Tillage PN -4 (25–27 cm), during the fallow period 2–3 cultivation KPE -3,8 with BZSS -1 for 8–10, 10–12 cm	Pre-sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Cultivation Stepnyak-7,4 for 16–18 cm, sowing (fertilizers $N_{60}P_{30}$)	Cultivation Stepnyak-7,4 for 16–18 cm, sowing (fertilizers $N_{60}P_{30}$)
Tillage PN -4 (25–27 cm), during the fallow period 2–3 cultivation KPE-3,8 with BZSS -1 for 8–10, 10–12 cm	Pre-sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Sowing on untreated stubble (fertilizers $N_{30}P_{30}$)	Sowing on untreated stubble (fertilizers $N_{30}P_{30}$)
Tillage PN -4 (25–27 cm), during the fallow period 2–3 cultivation KPE -3,8 with BZSS -1 for 8–10, 10–12 cm	Pre-sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Sowing on untreated stubble (fertilizers $N_{60}P_{30}$)	Sowing on untreated stubble (fertilizers $N_{60}P_{30}$)

ones in oats by 2.6–3.1 mm, annual grasses by 6.1–7.7 mm (see Table 2).

The accumulation of plant residues in the upper layer with deep flat-cut loosening, minimal surface treatments and direct sowing on the stubble led to an intensive reproduction of bacteria that enhance the processes of mineralization of organic matter in the soil. In these variants with an increased level of mineral nutrition ($N_{60}P_{30}$), the highest rates of carbon dioxide emission were obtained during the growing season - 1.810–1.969 kg/ha per 1 hour. During moldboard tillage, due to the low input of organic matter and low moisture content, the emission of CO_2 was minimal. - 1.154 kg/ha per 1 hour. Low rates of carbon dioxide emission corresponded to a looser composition of the arable soil layer - 1.26 g/cm^3 (on variants with surface treatments - 1.29-1.30 g/cm^3). The supply of plants with assimilable forms of phosphorus and potassium was higher in crops without basic tillage. The excess to the control in terms of the content of mobile forms of phosphorus and exchangeable potassium in oat crops was 21–46 and 24–40 mg/kg of soil, in crops of annual grasses, respectively - 3–19 and 7–22 mg / kg of soil. The content of organic matter in the variant with deep moldboard plowing was 2.78%, in the variants with low-cost tillage systems - 3.15–3.33% [8–10].

Cultivation of grain fodder crops without basic tillage with the introduction of mineral fertilizers at the rate of $N_{30}P_{30}$ kg a.i./ha provided an equivalent grain yield with the option where the traditional technology was used 1.49-1.60 t / ha (control - 1.59 t/ha). A significant increase in yield to the control variant (0.16–0.21 t/ha) was obtained with surface tillage methods with an increased level of mineral nutrition $N_{60}P_{30}$ kg ai/ha (see Table 3).

The grain yield of oats, depending on the tillage, was formed mainly due to the density of the standing of the plants and the productive stalk. On variants with traditional technology, the plant density before harvesting was 293 plants / m^2, the number of productive stems was 370 plants / m^2, on variants with surface treatments, respectively, 307–327 and 383–454 plants / m^2.

Табл. 2. Влияние предпосевной обработки почвы на ее агрофизические и агрохимические свойства в посевах овса и однолетних трав
Table 2. Effect of pre-sowing tillage on soil agrophysical and agrochemical properties in oat and annual grass crops

Tillage type	Crop rotation culture	Soil criterion					Organic matter content at the end of the crop rotation (0–20 cm), %
		Structure coefficient (0–30 cm)	Weight by volume (0–20 cm), gr/cm^3	Productive moisture reserves before harvesting (0–50 cm), mm	Productive moisture reserves before harvesting (0–50 cm), mm	Productive moisture reserves before harvesting (0–50 cm), mm	
Basic tillage PN -4-35 with star-wheeled roller ZKKSH -6A for 20–22 cm, pre-sowing cultivation for 16–18 cm, compacting ZKKSH -6A, sowing for 6–8 cm, compacting ZKKSH -6A (control)	Oats	1,1	1,26	28,7	1,154	50–42	2,78
	Annual grasses	1,0	1,29	23,1		68–50	
Pre-sowing cultivation for 16–18 cm, sowing for 6–8 cm	Oats	1,37	1,29	31,3	1,714	71–66	3,15
	Annual grasses	1,28	1,32	29,2	1,969	71–72	
Sowing on untreated stubble for 6–8 cm	Oats	1,31	1,30	31,8	1,610	96–82	3,33
	Annual grasses	1,28	1,34	30,8	1,810	87–57	

The same dependence on the methods of soil cultivation and the level of mineral nutrition has developed in the crops of annual grasses.

Variants with traditional technology and the use of low-cost resource-saving methods with the level of mineral nutrition $N_{30}P_{30}$ provided almost equal yield of green mass of annual grasses of 13.2-13.5 t / ha (control - 13.1 t / ha), dry matter collection - 3, 80–4.02 t / ha (control - 3.95 t / ha). The excess to the control for green mass 3.4–4.0 and collection of dry matter 1.0–1.18 t / ha was obtained on variants with surface tillage and direct sowing with an increased level of mineral nutrition ($N_{60}P_{30}$).

Resource-saving technologies for the cultivation of agricultural crops provided savings in material and labor costs. This was achieved through the use of low-cost tillage and the combination of agrotechnical operations using multi-operational tillage and sowing machines. The economic assessment of crops of oats and annual grasses revealed a higher efficiency of the resource-saving soil cultivation system in comparison with the traditional one based on continuous plowing. Depending on the level of mineral nutrition, direct costs decreased by 5.6–15.5%, the cost of fuel - by 31.2–36.4%, the profitability of production increased by 25.0–40.3% (see Table 4).

Resource-saving tillage methods in field crop rotation on low-humus low-carbonate chernozem ensured the highest crop productivity and return on energy costs per hectare of crop rotation area in comparison with traditional technology (see Table 5).

Low-cost tillage compared to moldboard plowing with the same level of mineral nutrition ($N_{30}P_{30}$) increased the collection of fodder units by 0.05–0.05 tons, with an increased level of mineral nutrition ($N_{60}P_{30}$) - by 0.32–0.34 tons. The system data ensured the greatest return on energy costs, where the energy efficiency coefficient, corresponding to the levels, increased by 0.4–0.6 and 1.0–1.2 units. The data obtained agree with the results of other authors [11–16].

CONCLUSIONS

1. Replacement of the main tillage with pre-sowing cultivation and direct sowing on stubble provided the following indicators of soil condition: structural coefficient 1.28-1.38 (in the control with moldboard plowing 1.0-1.1), max-

Табл. 3. Урожайность и элементы структуры урожая овса в зависимости от приемов обработки почвы при разных уровнях минерального питания

Table 3. Yield and structure elements of the oat output depending on the methods of tillage with different levels of mineral nutrition

Experiment option	Crop yield, t/ ha	Number of plants, pcs / m2		Number of productive stems, pcs / m^2	Head length, cm	Number of grains in one head, pcs.	Grain weight from one head, g	Weight of 1000 seeds, g
		by seedlings	before harvesting					
Plowing, pre-sowing cultivation, compacting ZKKSH -6A, sowing, fertilizers $N_{30}P_{30}$, compacting ZKKSH -6A (control)	1,59	309	293	370	13,6	48	1,53	32,2
Pre-sowing cultivation, sowing, fertilizers $N_{30}P_{30}$	1,60	317	314	386	13,3	45	1,34	32,7
Pre-sowing cultivation, sowing, fertilizers $N_{60}P_{30}$	1,80	313	307	445	14,1	46	1,42	32,3
Sowing on untreated stubble, fertilizers $N_{30}P_{30}$	1,49	326	319	383	13,4	45	1,33	32,8
Sowing on untreated stubble, fertilizers $N_{60}P_{30}$	1,79	327	327	454	14,2	46	1,42	32,6
$LSD_{0,5}$	0,15	7	15		$F_ф < F_{0,5}$	$F_ф < F_{0,5}$	$F_ф < F_{0,5}$	

imum content of productive moisture before harvesting in layer 0 –50 cm 29.2–31.8 mm (control 23.1–28.7), release of carbon dioxide 1.810–1.969 kg per hour (control 1.154 kg per hour), content of mobile forms of phosphorus P_2O_5 71– 96 mg / kg soil, exchangeable potassium K_2O 57–82 mg / kg soil (control - P_2O_5 50–68 mg / kg soil, K_2O 42–50 mg / kg soil), organic matter content 3.15–3 , 33% (control 2.78%).

2. Energy-saving methods of soil cultivation in combination with mineral fertilizers ($N_{60}P_{30}$ kg a.i./ ha) provided an increase in the yield of oat grain 0.16-0.21 t / ha (in the control 1.59 t / ha), green mass of annual grasses - 3.4–4.0 t /

Табл. 4. Экономическая эффективность ресурсосберегающих приемов обработки почвы с разными уровнями минерального питания при возделывании овса и однолетних трав в севообороте

Table 4. Economic efficiency of resource-saving methods of tillage with different levels of mineral nutrition in the cultivation of oats and annual grasses in the crop rotation

Element	Traditional technology with a level of mineral nutrition $N_{30}P_{30}$, p.	Resource-saving technology without core tillage with the level of mineral nutrition			
		$N_{30}P_{30}$		$N_{60}P_{30}$	
		p.	% to traditional technology	p.	% to traditional technology
Production cost	7500	7400	–	9000	–
Direct costs – total	5048	4265	84,5	4765	94,4
Including:					
payroll with accruals	800	587	73,4	637	79,6
POL	1156	736	63,6	796	68,8
seeds, fertilizers, pesticides	1896	1996	105,3	2350	123,9
depreciation	530	430	81,1	450	84,9
regular maintenance	666	516	77,5	532	79,8
cost efficiency	48,5	73,5	25,0	88,8	40,3

Табл. 5. Продуктивность и энергетическая эффективность ресурсосберегающих приемов обработки почвы при разных уровнях минерального питания в полевом севообороте

Table 5. Productivity and energy efficiency of resource-saving tillage techniques with different levels of mineral nutrition in the field crop rotation

Process scheme	Output of fodder units from 1 hectare of crop rotation area, t	Energy consumption, MJ, ha	Energy efficiency ratio
Plowing, cultivation, compacting, sowing (fertilizers $N_{30}P_{30}$, herbicides), compacting	1,84	11273	4,5
Cultivation, sowing (fertilizers $N_{30}P_{30}$, herbicides)	1,89	10557	4,9
Cultivation, sowing (fertilizers $N_{60}P_{30}$, herbicides)	2,16	11859	5,5
Direct sowing on stubble (fertilizers $N_{30}P_{30}$, herbicides)	1,89	10295	5,1
Direct sowing on stubble (fertilizers $N_{60}P_{30}$, herbicides)	2,18	11597	5,7

ha (control 13.1 t / ha), collection of feed units - 0.32–0.34 t / ha (control 1.84 t / ha).

3. Resource-saving tillage techniques in field crop rotation provided the greatest return on energy costs per hectare of crop rotation area in comparison with traditional technology. With the level of mineral nutrition $N_{30}P_{30}$, the energy efficiency coefficient increased by 0.4–0.6 units, with $N_{60}P_{30}$ - by 1.0–1.2 units. (on control 4.5 units).

4. Direct costs of growing crops decreased by 5.6–15.5% of fuel and lubricants - by 31.2–36.4%, profitability increased by 25.0–40.3%.

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СЕМЕНОВОДСТВО МНОГОЛЕТНИХ ТРАВ НА КРАЙНЕМ СЕВЕРЕ

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Представлены результаты исследований по улучшению нарушенных земель путем залужения их многолетними травами. Изучены способы производства семян многолетних злаковых трав, генотип которых позволяет в течение короткого теплого периода пройти все фазы развития и возобновить свой рост на следующий год. Исследования проведены в лесотундровой зоне Ямало-Ненецкого автономного округа на старопахотной (30-летнее освоение) поверхностно-подзолистой элювиально-глееватой почве в 2016–2018 гг. Установлено, что посев многолетних трав на семена широкорядным способом эффективнее обычных рядовых посевов. Урожайность семян овсяницы красной в среднем за 2 года при широкорядном способе посева составила 3,6 ц/га, что на 0,8 ц/га, или 28,6%, выше, чем при рядовом. Установлено, что уменьшение нормы высева семян вдвое обеспечивает повышение их урожайности по сравнению с ранее рекомендованными нормами. Урожайность семян овсяницы красной с уменьшенной нормой высева при широкорядном способе посева в среднем за 2 года составила 3,9 ц/га, мятлика альпийского – 6,0 ц/га, что на 0,2–0,6 ц/га соответственно больше, чем в варианте с полными нормами семян. Перспективным получился посев злаковых трав в середине сентября (под зиму). Урожайность семян луговика берингского при подзимнем посеве отмечена более высокой (на 83%), чем при весеннем сроке, овсяницы красной – практически одинаковой на обоих изучаемых вариантах. Максимальную урожайность семян формируют местные виды многолетних трав.

Ключевые слова: многолетние травы, семена, способ, норма, срок посева

SEED PRODUCTION OF PERENNIAL GRASSES IN THE FAR NORTH

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The results of research on improving disturbed lands by sowing them with perennial grasses are presented. The methods of seed production of perennial cereal grasses, the genotype of which allows to go through all development phases during a short warm period and resume their growth the next year, were studied. The study was carried out in the forest-tundra zone of the Yamal-Nenets Autonomous Okrug on an oldarable (30-year development) surface-podzolic eluvial-gleyic soil in 2016-2018. It was established that sowing perennial grasses for seeds using a wide-row method is more effective than conventional row planting. On average in 2 years, the yield of seeds of red fescue grass was 0.36 t/ha, which is 0.08 t/ha or 28.6%, higher with a wide-row sowing method than with the conventional row planting. It was established that a decrease in the seeding rate by half ensures an increase in the yield of seeds compared to the previously recommended rates. The yield of seeds of red fescue grass with a reduced seeding rate and a wide-row sowing method on average

in 2 years was 0.39 t/ha, alpine bluegrass – 0.6 t/ha, which was 0.02–0.06 t/ha higher than with full seeding rates, respectively. Sowing of cereal grasses in the middle of September (before winter) proved to be promising. The seed yield of Bering meadow grass sown in early-winter was noted to be higher (by 83%) than in the spring period; the yield of red fescue grass was practically the same in both studied variants. The maximum seed yield is formed by local species of perennial grasses.

Keywords: perennial grasses, seeds, method, rate, sowing period

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INTRODUCTION

The active industrial development of oil and gas fields in the Yamal-Nenets Autonomous Okrug, the construction of roads and railways increases the number of technologically disturbed lands subject to reclamation [1, 2]. The overgrowth of disturbed areas of the tundra, where the soil and vegetation cover has been completely destroyed, proceeds very slowly. By the end of the second decade, only 20–50% of the area is covered with vegetation [3]. In order to reduce and prevent the consequences of technogenic disturbances, fix sandy surfaces from wind and water erosion, create landscapes around industrial facilities and settlements, it is becoming quite obvious to carry out biological reclamation [4–6]. According to researchers, the main way to improve disturbed lands is to grow perennial grasses (meadow bluegrass, meadow foxtail, red fescue, Beckman's grass, Siberian wheatgrass and other grasses) [7–9]. Tundra lands are most efficiently tilled when using local types of grasses, which are more adapted to natural conditions than introzonal ones [10, 11]. The active restoration of disturbed lands is constrained by the lack of a sufficient amount of grass seeds [12]. Currently, it is important to produce seeds of perennial grasses of local species on the basis of effective cultivation technology. The lowest reproductive activity in the harsh conditions of the North is characteristic of red fescue, in which no more than 17% of individuals enter the generation stage. Common timothy grass and meadow bluegrass occupy an intermediate position. In all types of grasses, the lowest activity of the formation of generative organs is manifested when sowing into a substrate from pure peat, which is associated with the acidic reaction of the environment, which affects the growth and development of plants [13]. The maximum number of generative shoots in common timothy grass per unit area at the end of the growing season is observed with wide-row sowing. The seed production rate was also higher for wide-row sowing compared to solid-sowing, 0.63 and 0.66, respectively[1]. Under the conditions of the Yenisei North, the earing of awnless rump was recorded only in favorable years, Siberian wheatgrass and meadow fescue - annually, grass-root grasses - from the second year of life. Siberian wheatgrass has passed the flowering phase for 3 years of use, in the second and third years of use - meadow bluegrass and in the third year of use - red fescue. Seed formation was noted in grassland grasses in the third year of using herbage [14]. The generative organs of the awnless rump in the tundra of the Polar Yamal were formed only in the third year of the herbage's life. Their bloom began on August 8–10 even

[1]Petrova A.N. Perennial grasses of the flora of Yakutia for the reclamation of disturbed lands in the permafrost zone // Development of the North and the problems of reclamation: reports. III Int. conf. May 27–31, 1996, St. Petersburg. Syktyvkar, 1997. P. 366–372.

in the most favorable year in terms of heat supply. In the subarctic climate of the Zapolyarny Yamal, the seeds of the awnless rump did not ripen [15]. The autumn sowing period is more effective, since the seeds begin to germinate at the very beginning of the growing season of the next year. This allows plants to go through the entire phenological cycle in the short subarctic summer of the first season. By the third growing season, the differences between plots with different sowing dates (autumn and spring) become insignificant[2]. Effective methods, norms and terms of sowing seeds of perennial grasses of local species are currently insufficiently studied.

The purpose of the research is to study the influence of the methods, norms and timing of sowing on the yield of seeds of perennial grasses in the forest-tundra of the Yamal-Nenets Autonomous Okrug.

MATERIALS AND METHODS

Experiments on the cultivation of perennial grasses for seeds were laid on the experimental field of the Yamal Agricultural Experimental Station on an old-arable (30-year development) surface-podzolic eluvial-gley soil. The soil has a light particle size distribution. The sum of fractions less than 0.01 mm in the humus-accumulative horizon (A_{pax}) is 19%, in the humus-eluvial horizon ($A_1 A_2$) - 13%, in the transitional horizon (A_2B) - 20%, in the transitional horizon into the parent material (BC) - 5%. The bulk density in the upper layer (0–21 cm) is 1.38, the solid phase is 2.60 g / cm^3, the lowest moisture content is 25.8%. Old arable soil has a slightly acidic reaction of the environment in the arable layer (pH_{sal} 5.75). Acidity increases sharply down the profile ($A_1 A_2$ - 4.1). It is characterized by high hydrolytic acidity (5.37 meq / 100 g of soil), but it is 1.3 times lower than in the virgin area. The humus content in the arable layer is 3.08%, which is 30% higher than the initial value. With increasing soil depth, the humus content decreases (up to 0.35%). The provision of the soil with mobile forms of phosphorus and potassium increases in the process of cultivation, the indicator in horizon A is 15.0–26.3 mg / 100 g of soil.

The amount of precipitation during the growing season fell below the norm by 16.8–31.3% in 2017, 2018; in 2016 - by 6.8%. The air temperature on average for 3 years of research exceeded the average long-term value by 1.2 ºC. The daily amplitude of air temperature reached 18.1–25.5 ºC.

An experiment to study the influence of sowing methods on the seed productivity of perennial grasses was laid on June 20, 2015 in three replicates. The size of the plots in the experiment was 75 m^2. All sowing methods were studied on one type of perennial grasses (red fescue). The seeding rate of red fescue with all sowing methods was 36 kg / ha. Tundra soil cultivation before sowing perennial grasses consisted of non-moldboard plowing to a depth of 15–18 cm, disking with a heavy disc harrow BDT-2.2 in one track, milling with FBN-1.5 and harrowing with tooth harrows. Before the last harrowing, mineral fertilizers were applied: superphosphate, urea and potassium chloride in doses of $N_{45}P_{45}K_{45}$. Perennial grasses were sown by hand using a marker.

The influence of different seeding rates on the seed productivity of perennial grasses was studied in an experiment laid on June 21 in three replications with a plot size of 75 m^2. Perennial grasses were sown in a bare, wide-row (every 60 cm) method. In this experimental scheme, the seeding rates are taken from the recommendation of the Siberian Research Institute of Fodder Crops for forest-tundra zones. Taking into account the economic suitability, the seeding rates of alpine bluegrass were 36 and 18 kg / ha, respectively; red fescue - 32 and 16 kg/ ha. Tillage technology and sowing are similar to the experience of studying sowing methods.

[2]Popov A.I. Experimental work on biological reclamation in the tundra zone of the Nenets Autonomous Okrug // Actual problems of agricultural. sciences in Russia and abroad: collection of articles. scientific. tr. 2015.S. 9–11.

The study of the influence of different sowing dates on the seed productivity of perennial grasses was carried out in the experiment laid on June 23 (summer period) and September 17 (sub-winter period). The grasses were sown by hand, in a wide-row method (60 cm), using a marker in four replicates. The seeding rate of Bering meadow grass seeds was 12 kg, red fescue - 16 kg / ha. The tillage technology and the dose of mineral fertilizers are similar to the previous experiments. Annual crop care consisted of spring feeding and double inter-row cultivation. In all experiments, the seed yield of perennial grasses was counted using a continuous method.

RESULTS AND DISCUSSION

Studies have shown that in the year of sowing, perennial grasses developed very slowly. The grass stand on the ordinary method of sowing was distinguished by extreme weediness. The number of weeds reached 250 on each square meter. Sowings with row spacing of 30 cm looked better in this respect, and especially - 60 cm. The regrowth of red fescue in 2016 began on June 7. In the following year, the phases of plant development began earlier than usual.

Full ripening of the seeds of red fescue was noted on August 14. By this time, the height of grasses in all sowing methods was 107–108 cm, the number of productive stems was 470–485 pcs / m^2. The weediness of the grass stand in all variants of the experiment was noted to be insignificant - 4–8 pieces / m^2. The least infestation of grasses was observed on wide-row crops.

The seed yield in the experiment corresponded to the general development of the plants. Under the climatic conditions of 2017, the yield of seeds of red fescue was registered higher than in 2016.When sowing by an ordinary method in 2017, the yield of seeds was 3.1 c / ha, which was 0.6 c / ha higher than the yield of 2016 (see Table 1). However, the highest seed yield was observed when sowing grasses in a wide row method with a row spacing of 60 cm.

On average for 2 years the yield of seeds of red fescue with a wide-row sowing method (60 cm) was registered 28.6% higher compared to row sowing. In the relatively favorable growing season of 2017, there were no significant differences in the yield of red fescue seeds in the variants of the experiment with row spacing of 30 and 60 cm. The decrease in the yield of red fescue seeds with an ordinary sowing method compared to wide-row sowing is due to large weeds and thickening, causing lodging and losses of the harvest when harvesting.

The features of plant development given earlier are also characteristic of grasses when studying the effect of seeding rates on seed yield. The grass stand was quite well developed, especially the Alpine bluegrass. Productive bluegrass shoots at low seeding rates (18 kg / ha) were observed significantly more (832 plants / m^2) than on ordinary crops (546 plants / m^2). The plant height was 64–68 cm. The infestation of alpine bluegrass herbage in all variants of the experiment in 2017 was noted to be insignificant (3–5 plants / m^2).

The number of productive shoots in red fescue at the recommended seeding rate (32 kg / ha) was 481 pcs / m^2, with a 2-fold decrease - 433 pcs / m^2. The plants had a great height - 105–110 cm, which is not quite typical of the low grass. The obtained research results provide a basis for the conclusion about the greater intensity of tillering of alpine bluegrass in comparison with red fescue.

Active tillering of alpine bluegrass in 2016 had a significant effect on seed yield (see Table

Табл. 1. Урожайность семян овсяницы красной в зависимости от способов посева

Table 1. The yield of seeds of red fescue grass depending on the methods of sowing

Sowing type	Crop yield, c/ha		On average for 2 years	Increase in yield, c / ha
	2016	2017		
Row, 15 cm	2,5	3,1	2,8	–
Wide-row, 30 cm	3,0	3,8	3,4	0,6
Wide-row, 60 см	3,3	4,0	3,6	0,8
$LSD_{0,5}$	0,2	0,3		

2). Due to the strong lodging of the grass stand and the late harvesting period in 2017, the seed yield decreased by more than 2 times. In this year, on the variants of the experiment with the seeding rates, there were no significant differences in the yield of alpine bluegrass. On average, a high yield of alpine bluegrass was obtained in 2 years. Industrial cultivation of this crop for seeds in the Far North is advisable. Additionally, it is necessary to continue working out the technology of its cultivation, which ensures a fairly stable production of high-quality seeds.

The yield of seeds of red fescue at different seeding rates was registered the same in the years of research. But it is noted lower than the yield of alpine bluegrass. Red fescue showed stable seed yields over the years. The stability of obtaining seeds in the harsh conditions of the Far North when growing red fescue is of very great practical importance, since this cereal plays one of the key functions in the composition of the recultivation grass mixture. The studied seeding rates did not have a significant effect on the seed yield. Production inspection is being carried out to obtain final conclusion. If the field test results are confirmed, then lowering the seeding rate will provide significant savings in seed and money.

Evaluating the state of development of perennial grasses of different sowing terms, better development of autumn sowing grasses should be noted. The grasses in this variant of sowing are better developed and higher than in the variant with the spring sowing period. Productive shoots of red fescue in the autumn sowing period totaled up to 493 pcs / m^2, in the spring - 280 pcs / m^2. The same development was observed on the crops of the Bering meadows (223 and 147 productive shoots / m^2, respectively).

Determination of the yield of seeds of perennial grasses, depending on the timing of sowing, showed the following results. On average over 3 years, the highest yield of red fescue seeds was when sown in spring (3.6 c / ha). The productivity of the Bering meadow is marked by 0.5 c / ha higher in the autumn sowing period. One of the reasons is the high resistance of the meadow to low temperatures in winter and earlier regrowth in the early spring period (see Table 3).

No conclusions have been drawn about the superiority of spring crops, since the observation period is short. Perhaps, in subsequent years the average seed yield for both sowing options will be the same. A similar conclusion applies to the crops of the meadow grass (Bering) with its low yield.

When analyzing the results obtained, the instability of seed yield over the years was noted, due to sharp fluctuations in hydrothermal regimes over the years and during the growing seasons, including summer frosts.

CONCLUSIONS

1. Sowing perennial grasses on seeds in a wide row method is more effective than conventional row crops. The yield of seeds of red

Табл. 2. Урожайность семян многолетних трав в зависимости от норм высева
Table 2. The yield of seeds of perennial grasses depending on the seeding rates

Sample	Seeding rate, kg / ha	Crop yield, c/ha		On average for 2 years	Increase in yield, c / ha
		2016	2017		
Red fescue	32	3,5	4,0	3,7	–
	16	3,7	4,1	3,9	0,2
LSD_{05}		0,31	–		
Alpine bluegrass	36	7,3	3,5	5,4	–
	18	8,4	3,7	6,0	0,6
LSD_{05}		0,76	–		

Табл. 3. Урожайность семян многолетних трав в зависимости от срока посева
Table 3. The yield of seeds of perennial grasses depending on the sowing period

Sample	Sowing time	Crop yield, c/ha			Average yield for 3 years	Increase in yield, c / ha
		2016	2017	2018		
Red fescue	Spring	7,2	0,6	3,1	3,6	0,5
	Autumn	4,3	1,6	3,4	3,1	–
LSD_{05}		0,37	0,42	0,32		
Bering meadow grass	Spring	–	0,6	0,6	0,6	–
	Autumn	–	1,4	0,8	1,1	0,5
LSD_{05}			0,29	0,21		

fescue on average for 2 years with a wide-row sowing method was 3.6 c / ha, which is 0.8 c / ha, or 28.6%, higher than with an ordinary one.

2. Reducing the seeding rate of seeds by half provides an increase in yield compared to the approved rates. The yield of seeds of red fescue with a reduced seeding rate with a wide-row sowing method averaged 3.9 c / ha for 2 years, alpine bluegrass - 6.0 c / ha, which is 0.2-0.6 c / ha, respectively, more. than with full seed rates.

3. Sowing of cereal grasses in the middle of September (i.e. before winter) turned out to be promising. The seed yield of Bering meadow grass under winter sowing was 83% higher than in spring, red fescue was almost the same in all studied variants.

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ВЛИЯНИЕ УСЛОВИЙ ОСЕННЕЙ ВЕГЕТАЦИИ НА ПЕРЕЗИМОВКУ ОЗИМОЙ РЖИ И ПШЕНИЦЫ ПРИ РАЗНЫХ СРОКАХ ПОСЕВА

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Изучено влияние условий осенней вегетации на рост, развитие и перезимовку растений озимой пшеницы и ржи при разных сроках посева. Работа выполнена в 2016–2019 гг. в условиях лесостепи Приобья. Материалом исследований служили сорта тетраплоидной озимой ржи Влада и Тетра короткая и сорта озимой пшеницы Новосибирская 40 и Новосибирская 3. Посев проведен в три срока: 1-й – 23 августа, 2-й –31 августа и 3-й – 7 сентября по чистому пару. Выбор оптимального срока посева создает благоприятные условия для роста и развития озимых культур и подготовки их для дальнейшей перезимовки. Согласно проведенным исследованиям отмечено, что интенсивность осеннего побегообразования и роста растений в большей степени зависит от продолжительности периода осенней вегетации. Снижение темпов роста и образования побегов кущения от 1-го срока посева к 3-му связано со снижением суммы эффективных температур. При посеве в поздние сроки сумма эффективных температур по годам варьировала в диапазоне 90–197°. При этом перезимовка озимой ржи сохранялась на уровне 94–100%, в то время как у озимой пшеницы она снизилась до 40%. Лучшим вариантом, обеспечивающим стабильность зимней устойчивости, является 2-й срок посева (31 августа) при сумме эффективных температур 250–300°, растения формируют 3–4 побега кущения, высота растений достигает 18–25 см. Озимая рожь опережает озимую пшеницу как по темпам осеннего роста и побегообразования, так и по развитию конуса нарастания.

Ключевые слова: озимая рожь, озимая мягкая пшеница, сроки посева, продолжительность осенней вегетации, сумма эффективных температур, перезимовка

EFFECT OF AUTUMN VEGETATION CONDITIONS ON OVERWINTERING OF WINTER RYE AND WHEAT WITH DIFFERENT SOWING DATES

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The research was carried out in order to study the effect of autumn vegetation conditions on the growth, development and overwintering of winter wheat and rye depending on different sowing dates. The work was performed in 2016–2019 in the conditions of the forest-steppe of the Ob region. The research material included the varieties of tetraploid winter rye Vlada and Tetra short and winter wheat varieties Novosibirskaya 40 and Novosibirskaya 3. Sowing was carried out on three dates: 1st – 23 August, 2nd – 31 August and 3rd – 7 September under bare fallow. The choice of the optimal sowing time creates favorable conditions for the growth and development of winter crops and their preparation for further overwintering. According to the studies, it was noted that the intensity of autumn shoot formation and plant growth to a greater extent depends on the duration of the autumn growing season. A decrease in the plant growth rate and formation of tillering shoots from the first sowing date to the third date was associated with a decrease in the sum of effective temperatures. When sowing on a later date, the sum of effective temperatures varied in the range of 90–197° over the years. Under these conditions, overwintering rate of winter rye remained at the level of

94–100%, while in winter wheat it decreased to 40%. The best option, which ensured the stability of winter resistance, was the second sowing date (August 31) with a sum of effective temperatures of 250-300°, whereby the plants formed 3–4 tillering shoots and the plant height reached 18–25 cm. Winter rye outperforms winter wheat in autumn growth rate, shoot formation and in the vegetation cone development.

Keywords: winter rye, soft winter wheat, sowing time, duration of autumn vegetation, sum of effective temperatures, overwintering

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INTRODUCTION

The formation of a trait of winter hardiness of winter crops is greatly influenced by the conditions of autumn vegetation [1, 2]. The period of the initial stages of organogenesis includes the phases of plant development associated with the formation of generative organs, structural and functional rearrangements, changes in the water and carbon balance, which determines the adaptability of plants to overwintering conditions [3].

For a favorable overwintering of winter grain crops, the correct choice of sowing time is necessary, which must correspond to the biological requirements of the crop, take into account the soil and climatic conditions of the autumn vegetation. Against the background of increasing climate instability, expressed in deviations of the temperature regime and the regime of precipitation and in the duration of the autumn growing season from the average long-term values, the variation in the optimal sowing time increases. It is important to study the influence of the duration and temperature conditions of autumn vegetation on the development of plants, which ensure the formation of resistance to the limiting factors of overwintering of winter crops in specific regions of cultivation [4–6].

The limiting factor for the growth processes of winter crops is the temperature regime of the autumn period. A decrease in average daily temperatures at later sowing dates leads to a lag in plant development. Theoretical calculations of the optimal sowing time are related to the sum of positive temperatures in the autumn period from sowing to the end of the growing season. Moreover, the temperature values vary depending on the climatic zone of cultivation [7–11].

Differences in the level of overwintering of varieties and forms of winter crops, along with the temperature conditions of the winter period, are largely due to the intensity of autumn plant growth, the formation of tillering shoots, and the peculiarities of the passage of the stages of organogenesis. For guaranteed overwintering before wintering, winter rye and wheat plants should form, on average, up to 3-4 tillering shoots reaching 2-3 stages of organogenesis

[12].

The connection between the autumn growth processes of plants and their winter hardiness has been repeatedly noted in the works of A.I. Nosatovsky, I.I. Tumanova, F.M. Kuperman, V.A. Moiseichik, Z.A. Morozova and other authors [13–17]. According to A.I. Zadontsev, winter grain plants with optimal sowing times, the height of which is 14–16 cm, are characterized by the maximum frost resistance. Overgrown plants have a height of 23–25 cm and more, the winter hardiness of such plants is reduced[1] [18].

Biological control according to the stages of organogenesis makes it possible, much earlier than with phenological observations, to recognize the unfavorable effect of weather conditions and agrotechnical factors on plants.

Varieties with a high level of winter resistance are needed for sustainable cultivation of winter grain crops in Siberia. Promising varieties of winter wheat and rye have been created through the efforts of Siberian breeders which have high adaptive qualities. The main advantage of Siberian breeding varieties lies in their higher level of ecological stability, since the successful selection of specifically resistant genotypes in the breeding process is possible only under conditions similar to those in which the variety will be cultivated. At the Siberian Research Institute of Plant Growing and Breeding, a branch of the Federal Research Center of the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences the greatest efficiency in the creation of winter wheat varieties with high adaptability and plasticity potential was obtained by the method of recombination selection using interspecific hybridization [19]. Varietal rye populations cultivated in the Siberian region are mainly represented by tetraploid forms, created on the basis of varieties of the Siberian ecotype, combining a high level of winter hardiness with grain size.

The aim of the research is to study the effect of autumn vegetation conditions on the growth, development and overwintering of winter wheat and rye plants at different sowing dates.

MATERIALS AND METHODS

The studies were carried out in the forest-steppe conditions of the Ob region in 2016–2019. The research material was the varieties of tetraploid winter rye Vlada and Tetra short and winter wheat varieties Novosibirskaya 40 and Novosibirskaya 3[2]. Sowing was carried out in three terms: 1st - August 23rd, 2nd - August 31st and 3rd - September 7th for pure fallow in the usual row method with a SSFK-7 seeder with a seeding rate of 5 million seeds / ha for winter rye and 6 million seeds / ha for winter wheat. Plot area 10 m^2, replication five times with a randomized placement of plots.

To conduct counts and observations, we used the methodology of the State Variety Testing of Agricultural Crops[3]. The main mathematical parameters were calculated according to the method of B.A. Dospekhova[4]. During the period of termination of the growing season before the establishment of snow cover, plant samples were taken for laboratory analysis. The linear dimensions of the leaves (the height of the main shoot from the base of the tillering node to the tip of the upper leaf) and the coefficient of tillering (the average number of shoots) were determined. When studying the formation of the growing cone of winter crops, the stages of organogenesis were determined according to F.M. Kuperman[5] using an MBS-9 microscope.

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[3]Methodology for state variety testing of agricultural crops / ed. By M.A. Fedin. M., 1985. 270 pp.

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We selected 10 plants from two repetitions at the end of the autumn growing season. In field conditions, the degree of overwintering of plants was determined as the percentage of the number of overwintered plants (on fixed 6 or 8 plots of 0.25 m^2) to the number of plants that passed away in winter. Meteorological data were obtained by the hydrometeorological station of the village Ogurtsovo (Novosibirsk region).

The weather conditions of the autumn-winter period during the years of scientific research varied significantly. According to long-term data, the end of the autumn growing season in the forest-steppe conditions of the Ob region begins on October 5, when the average daily temperature passes through the 5°C mark towards a decrease. The least favorable conditions for the autumn development of plants developed in 2017, when the end of the growing season was already marked on September 23. The average daily air temperature was 9.2 °C, which is lower than long-term values; the amount of precipitation was close to normal (105%). In 2016, the end of the growing season was marked on September 30, a feature of this year was a significant excess of the average daily September temperatures up to 15-16 °C, relative to the long-term average (10-12 °C) with a total precipitation of 40% of the norm. Autumn 2018 is characterized by a long growing season (until October 14) with an average temperature background (10.8 ° C) and precipitation of 113% to the norm.

In winter, the height of the snow cover varied from 40 to 70 cm from year to year. The maximum height of the snow cover in 2016 was set at 60–65 cm, in 2017 - 65–70 cm, which is 2 times more than the average annual data (30–35 cm). Snow cover in 2018 was 40–50 cm. The minimum temperature at the depth of the tillering node did not drop below minus 5 °C.

Contrasting conditions in 2016–2019 made it possible to evaluate the effect of autumn vegetation on overwintering of plants at different sowing dates in the studied crops.

RESULTS AND DISCUSSION

Over the years of research, the duration of the germination period - the end of the autumn growing season was significantly influenced by two factors: the conditions of the year and the timing of sowing. With the 1st sowing period, carried out at the beginning of the 2nd decade of August, the growth and development of plants continued from 33 days in 2017 to 54 - in 2018.The sum of effective temperatures, respectively, varied in these years from 263 to 351°. In 2016, with a short growth period (up to 38 days), the sum of effective temperatures was 346°, which is explained by high average daily temperatures up to 28 °C during September. The vegetation of plants of the 3rd sowing term lasted from 19 to 36 days, while the sum of effective temperatures varied from 90 to 197 ° over the years (see Table 1).

During the research period, more intensive growth and formation of tillering shoots were noted in winter rye and wheat plants of the 1st sowing period. A decrease in the growing season when sowing in the 2nd and 3rd periods leads to a decrease in the linear growth of plants and a decrease in the number of tillering shoots. These patterns depend on the hydrothermal conditions of the year. In the years with a short growing season (2016, 2017), the height of plants of the 3rd sowing period was recorded 1.5 times less than that of plants sown on August 23 (see Table 2). With an increase in the duration of the autumn growth period, the difference between the plant heights of different sowing dates decreases. In 2018, winter wheat plants of the 1st sowing date had a height of 26.4 cm at the end of the growing season, plants of the 3rd term - 21.6 cm.

The intensity of the process of plant shoot formation in the autumn period is also associated with the duration of the growing season. The largest number of tillering shoots (5.0 and 6.3) was observed in both wheat and rye in 2018 when sown on 23 August, when the growing season was 54 days. When sowing on September 7, 2018, with a reduction in the duration of the growing season associated with the timing of sowing, the number of tillering shoots in rye decreased to 3.9, in wheat - to 3.1. In 2017, plants of the 3rd sowing date in 19

Табл. 1. Сумма эффективных температур и продолжительность вегетационного периода по годам при разных сроках посева озимых культур

Table 1. The sum of effective temperatures and the duration of the growing season by years for different sowing dates of winter crops

Year	Element	Sowing time		
		1-st (23.08)	2-nd (31.08)	3-rd (07.09)
2018	The sum of effective temperatures, degr.	351	250	197
	Number of growing days	54	45	36
2017	The sum of effective temperatures, degr.	263	146	90
	Number of growing days	33	24	19
2016	The sum of effective temperatures, degr.	346	296	167
	Number of growing days	38	31	21

Табл. 2. Высота растений и число побегов кущения в разные сроки посева озимой ржи и пшеницы (2016–2018 гг.)

Table 2. Plant height and number of tillering shoots on different sowing dates for winter rye and wheat (2016–2018)

Sample	Sowing time					
	1-st (23.08)		2-nd (31.08)		3-rd (07.09)	
	Plant height, cm	Shoots number, pcs.	Plant height, cm	Shoots number, pcs.	Plant height, cm	Shoots number, pcs.
			2018			
Rye	29,6 ± 0,9	6,3 ± 0,6	27,1 ± 0,7	5,4 ± 0,4	22,9 ± 0,8	3,9 ± 0,3
Wheat	26,4 ± 1,1	5,0 ± 0,5	21,6 ± 0,6	4,0 ± 0,3	21,6 ± 0,5	3,1 ± 0,2
			2017			
Rye	26,1 ± 0,8	4,9 ± 0,4	18,5 ± 0,5	2,9 ± 0,1	14,8 ± 0,3	1,4 ± 0,2
Wheat	22,3 ± 1,3	4,7 ± 0,6	17,0 ± 0,4	2,7 ± 0,2	13,8 ± 0,3	1,2 ± 0,1
			2016			
Rye	27,5 ± 1,2	5,5 ± 0,5	24,2 ± 1,0	3,7 ± 0,3	18,0 ± 0,5	2,3 ± 0,2
Wheat	33,0 ± 1,3	3,1 ± 0,3	29,6 ± 0,8	2,6 ± 0,2	24,0 ± 0,6	1,3 ± 0,1

days formed an average of 1.4 tillering shoots in rye and 1.2 tillering shoots in wheat.

The processes of linear growth and shoot formation of winter rye and wheat differ in their intensity. Winter rye plants form a more powerful above-ground mass in autumn. So, in 2018, when sowing on 23 August for 54 days of growing season, the height of rye plants was 29.6 cm, in wheat - 26.4 cm, while rye formed 6.3 shoots, and wheat - 5.0. In the third sowing period under low temperature conditions, growth processes and shoot formation slow down significantly both in winter wheat and rye, but the differences between the growth rates of the two crops remain. For 36 days of growing season with a sum of active temperatures of 197°, the linear growth of rye was 22.9 cm, wheat - 21.6 cm, and the number of shoots decreased accordingly (3-4).

In 2017, under conditions of low temperatures

and a short growing season with minimal values of linear growth and shoot formation at all sowing periods, the differences between crops are insignificant. In both rye and wheat, up to 4–5 shoots of tillering were formed during 33 days of growing season in the 1st sowing period, when sowing in the 3rd period, only the beginning of the tillering process was noted.

Under the conditions of an increased temperature background (+3.1 ° C to normal) in 2016, winter wheat in terms of linear growth was significantly ahead of rye. The height of wheat plants at the 1st sowing period averaged 33.0 cm, which is 5.5 cm higher than that of rye. However, the number of tillering shoots in wheat was recorded significantly less and averaged 3.1, while in rye up to 5–6 shoots were formed. The same trend persisted in crops at later dates.

The number of tillering shoots in winter crops is primarily affected by the duration of the autumn growing season. With the sum of effective temperatures of 197 °, an average of 3-4 tillering shoots were formed in 36 days, and only 1-2 shoots were formed during 21 days of vegetation, although the sum of effective temperatures was slightly lower and amounted to 167 °. The processes of linear growth of plants are influenced by the temperature conditions of autumn.

For a more complete study of the development of winter crops in the autumn period, comparative observations of the growth and development of the growing cone were carried out. According to a number of authors, the degree of growth cone development correlates with the level of winter hardiness. The best overwintering was noted in plants where the growing cone reaches the 2nd phase of organogenesis, which coincides with the period of autumn tillering.

A comparative study of two winter crops of wheat and rye revealed significant differences in the rates of autumn development of growing cones. By the end of the autumn growing season, rye was observed to elongate the upper part of the cone and differentiate the base of the cone into segments and leaf ridges, which corresponds to the third stage of organogenesis (see Table 3). The duration of this stage in these studies ranged from 24 (sowing on August 31, 2017) to 54 days (sowing on August 23, 2018) before the end of the growing season. Depending on the temperature conditions of the year, the sizes of the growth cone change, the greatest length (up to 1.11 mm) and enhanced segmentation of the growth cone were noted in

Табл. 3. Размеры конуса нарастания и этапы органогенеза озимой ржи и озимой пшеницы в осенний период вегетации при разных сроках сева (2016–2018 гг.)

Table 3. The sizes of the vegetation cone and the stages of organogenesis of winter rye and winter wheat in the autumn growing season on different sowing dates (2016–2018)

Sample	Sowing time					
	1-st (23.08)		2-nd (31.08)		3-rd (07.09)	
	The vegetation cone size, mm	Organogenesis stage	The vegetation cone size, mm	Organogenesis stage	The vegetation cone size, mm	Organogenesis stage
			2018			
Rye	0,70 ± 0,06	3-rd	0,64 ± 0,04	3-rd	0,46 ± 0,05	3-rd or 2-nd
Wheat	0,31 ± 0,02	2-nd	0,28 ± 0,03	2-nd	0,21 ± 0,01	1-st
			2017			
Rye	0,92 ± 0,12	3-rd	0,68 ± 0,05	3-rd	0,48 ± 0,04	2-nd
Wheat	0,35 ± 0,03	2-nd	0,20 ± 0,02	1-st	0,15 ± 0,02	1-st
			2016			
Rye	1,11 ± 0,15	3-rd	0,86 ± 0,07	3-rd	0,77 ± 0,07	2-nd
Wheat	0,34 ± 0,05	2-nd	0,25 ± 0,02	2-nd	0,22 ± 0,02-й	1-st

2016 at maximum daytime temperatures up to 20 °C. However, the transition to the 4th phase of organogenesis with short daylight hours does not occur until the end of the light stage.

The assessment of winter hardiness of winter rye and wheat plants was carried out in experiments with different sowing dates (see the figure). Overwintering conditions during the years of research were noted to be quite favorable (the soil temperature at the depth of the tillering node did not fall below minus 5 ° C). Thus, the level of winter resistance, along with the hardening conditions, was largely determined by the intensity of autumn growth and development of plants. A great safety of both rye and wheat at all sowing dates was noted in the spring of 2017, when the plants were formed in a short autumn period, but at the same time the sum of effective temperatures reached 167 ° for crops of the 3rd term and 346 ° for crops of the 1st term. The number of tillering shoots varied depending on the sowing time from 2.3 to 5.5 for rye and from 1.3 to 3.1 for winter wheat.

The decrease in the level of overwintering in 2018 can be explained by the less favorable conditions of the winter period and the insufficient duration of the autumn growing season in 2017 (from 19 to 33 days when sowing at different times). In this case, low positive temperatures negatively affected the autumn development of plants, while the number of surviving plants in winter wheat decreased by almost 2 times (to 18%) compared to the previous year. Moreover, late sowing, carried out in the first decade of September, showed greater resistance to overwintering than sowing in early periods. Such results are explained by the higher rates of sugar accumulation in the tillering node of young plants, which allows them to survive more successfully in winter.

The level of overwintering of plants in 2019 was noted to be quite high - up to 83–100% of preserved plants in winter rye and 66–68% in winter wheat. The long period of autumn vegetation (54–45–36 days in terms of sowing) and the sum of effective temperatures (above 197 °) in autumn 2018 contributed to the good development of plants. They formed more than 5 tillering shoots at an early sowing date and 3-4 shoots at sowing on September 7. In rye in crops of the 1st term, the plant height was 29–30 cm, the number of tillering shoots reached 6–7, which led to partial damping off and a decrease in the level of overwintering in comparison with crops of the 2nd and 3rd terms. In all variants of the experiment, the winter hardiness of winter wheat was noted lower than in winter rye by 13-15% in 2017 and by 74-80% in 2018.

CONCLUSIONS

As a result of a comparative study of the initial stages of growth and development of winter crops, it was revealed that the intensity

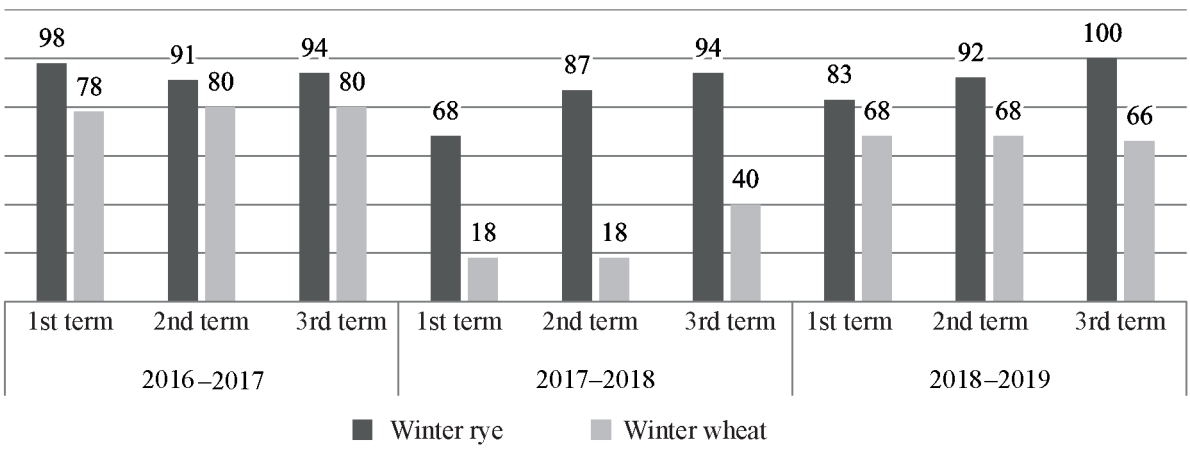

Диаграмма перезимовки озимой ржи и пшеницы при трех сроках посева (2016–2019 гг.), %
Diagram of overwintering of winter rye and wheat on three sowing dates (2016–2019), %

of autumn shoot formation to a greater extent depends on the duration of the growing season. Plants of the 3rd sowing date within 19–21 days of vegetation (2016, 2017) formed only 1–2 shoots of tillering, while during 36 days of vegetation in 2018, 3–4 shoots were formed. The increased temperatures in the autumn of 2016 led to the overgrowth of winter wheat plants by 30–40%, while the process of shoot formation was noted below or at the level compared to 2017.

The sum of effective temperatures in a wide range from 167 to 351 ° C in the autumn of 2016 and 2018 proved to be sufficient for the development of plants of all sowing terms, which ensured a high safety of plants during overwintering in 2017 and 2019. The short period of the autumn growing season from 19 to 33 days (depending on the sowing time) and low temperatures in autumn 2017, along with less favorable winter conditions, led to a significant decrease in the level of overwintering in winter wheat.

No significant differences in the influence of the sowing time on the level of winter rye and wheat overwintering were revealed over the years of research. The conditions of the year had a great influence on overwintering. The best option that ensures the stability of winter resistance is the 2nd sowing date (August 31), when the plants form 3-4 tillering shoots, and their height reaches 18-25 cm.

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ФУНГИЦИДНЫЕ ПРОТРАВИТЕЛИ ДЭЛИТ ПРО И РЕДИГО ПРО ПРОТИВ ГРИБНЫХ ФИТОПАТОГЕНОВ СОИ

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Представлены результаты изучения эффективности фунгицидных протравителей в борьбе с корневыми гнилями и листостебельными болезнями сои. Исследования проведены в Приморском крае в 2019, 2020 гг. в условиях деляночного опыта. Препарат Дэлит Про (д.в. пираклостробин, 200 г/л) применяли в норме расхода 1,0 л/т, Редиго Про (д.в. протиоконазол, 150 г/л + тебуконазол, 20 г/л) – 0,9 л/т. Препараты использовали для протравливания семян полусухим способом перед посевом. Выявлено, что Дэлит Про и Редиго Про не оказывают негативного действия на культуру и положительно влияют на всхожесть семян сои. Отмечена высокая фунгицидная активность опытных протравителей в отношении корневых гнилей, поражающих культуру. Препараты способствовали снижению интенсивности развития инфекций в фазу цветения на 17,0% (Дэлит Про) и 24,9% (Редиго Про). Защитное действие предпосевной обработки семян протравителями проявлялось также в снижении пораженности листостебельными заболеваниями. Установлено, что препараты обладают высокой биологической эффективностью против септориоза (16,7–25,2%), церкоспороза (0–44,6) и пероноспороза (29,5–87,5%). Применение Дэлит Про и Редиго Про способствовало активному росту растений и повышению основных показателей продуктивности: массы семян на 0,1–0,6 г, их числа на 1,4–2,8 шт. с одного растения, а также массы 1000 семян на 8,5–9,3 г. Достоверные прибавки урожая зерна 0,19 т/га (2019 г.) и 0,20 т/га (2020 г.) получены в варианте с использованием протравителя Редиго Про. Применяемые препараты способствовали росту уровня рентабельности на 222 и 564% соответственно.

Ключевые слова: соя, патоген, грибные болезни, протравитель, эффективность, урожайность

FUNGICIDAL PROTECTANTS DELETE PRO AND REDIGO PRO AGAINST FUNGAL PHYTOPATHOGENS OF SOYBEANS

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The results of research into effectiveness of fungicidal protectants against root rot and leaf-stem diseases of soybeans are presented. The study was carried out in the Primorsky Territory in 2019, 2020 in the conditions of plot experiment. Delete Pro (active agent pyraclostrobin, 200 g/l) was used at a consumption rate of 1.0 l/t, Redigo Pro (active agent prothioconazole, 150 g/l + tebuconazole, 20 g/l) – 0.9 l/t. The preparations were used for seed treatment in a semi-dry way before sowing. It was revealed that Delete Pro and Redigo Pro do not have a negative effect on the crop and have a positive effect on the germination of soybean seeds. A high fungicidal activity of the protectants used in the experiment was noted in relation to root rot affecting the crop. The chemicals helped

to reduce the intensity of infections during the flowering phase by 17.0% (Delete Pro) and 24.9% (Redigo Pro). The protective effect of pre-sowing seed treatment with protectants was also revealed in reducing leaf-stem diseases. It was found that the chemicals have high biological effectiveness against septoria (16.7–25.2%), cercosporosis (0–44.6%) and peronosporosis (29.5–87.5%). The use of Delete Pro and Redigo Pro contributed to active growth of plants and an increase in the main productivity indicators: seed weight by 0.1–0.6 g, seed number by 1.4–2.8 pcs from one plant, as well as thousand-seed-weight by 8.5–9.3 g. Significant increase in grain yield of 0.19 t/ha (2019) and 0.20 t/ha (2020) was obtained in the variant with Redigo Pro. The protectants used contributed to the increase in the profitability level by 222 and 564%, respectively.

Keywords: soybean, pathogen, fungal diseases, protectant, efficiency, yield

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The authors declare no conflict of interest.

INTRODUCTION

Soybeans, one of the leading grain legume crops in the world, are of great economic, environmental and social importance in the agricultural sector [1, 2]. The area occupied by soybeans in world production is 123.5 million hectares (the third place after wheat and rice). Such widespread distribution of soybeans is associated with the versatility of its use as food, fodder and industrial crops [3]. In Russia, soybeans are sown in 45 regions. The Far Eastern Federal District accounts for 88% of the sown area and 86% of the gross harvest of soybeans [4, 5]. In 2020, 377.4 thousand tons of soybeans were harvested in the Primorsky Territory from an area of 252.6 thousand hectares with a yield of 1.5 t / ha1.

One of the main problems hindering the increase in soybean yields is the harm caused by pathogens [6]. More than 50 soybean diseases have been identified in the world, about 30 of them have a fungal etiology. They can both negatively affect the state of soybean crops and not cause significant damage to the crop [7, 8]. Fungal diseases of soybeans are widespread in Primorye. Among them, the causative agents of peronosporosis, septoria, cercosporosis, ascochitosis, and fusarial root rot are dominant [9]. Leaf-stem infections (septoria, cercosporosis, peronosporosis) are especially dangerous as the most harmful in the Primorsky Territory, since they sharply reduce the assimilation surface of plants, preventing them from realizing the potential yield of the variety [10, 11].

Most soybean diseases are transmitted through seed, since seeds are a complete nutrient medium for many microorganisms that produce mycotoxins [12]. High contamination of soybean seeds significantly reduces their sowing qualities (energy, germination), leads to damage to the root system by various types of rot, significant shortfalls in grain yield and a decrease in its quality [13].

An operative method of protecting seeds and seedlings from damage by phytopathogenic fungi is their treatment with fungicides [14]. Seed dressing is the most important strategic technique for the formation of the optimal phytosanitary state of crops, which contributes to an increase in yield by 0.2–0.7 t / ha [15].

[1]Information on the progress of agricultural work in the regions of the Primorsky Territory as of December 16, 2020 // Data of the Department of Agriculture and Food of the Primorsky Territory [Electronic resource]. 2020. Access mode: http: // agrodv.ru/f/svodka/16_dekabrya_2020_g_.xlsx.

There are many drugs based on one to three-component active substances of different classes on the modern market. Their use contributes to obtaining healthy seedlings, even with an initially high level of seed infection. However, the effectiveness of individual disinfectants varies greatly depending on the type of disease. With the widespread use of chemicals for plant protection, resistance of pests to pesticides arises. In this regard, there is a need to create new drugs or expand their range at the expense of those registered in other cultures [16].

At present, given the high cost of high-quality dressing machines, there are violations in the processing technology of the seed material. It is important that the technique is correctly calibrated. Often, in practice, the consumption rate of the drug can be very different from the planned one. It is possible for the disinfectant to settle on the walls of the processing machine: the consumption rate will be underestimated and the drug will not show effectiveness. An outdated or inaccurate technique applies liquid preparations unevenly: most of the working solution falls on the seeds that arrive first, the rest, which enter the applicator (auger) later, remain practically untreated. About 20-30% of the seeds receive an excess of the chemical. From this it can be concluded that it is necessary to test drugs in high dosages.

In connection with the need for phytosanitary optimization of soybean cultivation technologies, it is important to form an assortment of dressing agents that are effective against the main pathogens of crop diseases.

The purpose of the work is to obtain experimental data on testing the chemical preparations Delit Pro and Redigo Pro as fungicidal dressing agents for pre-sowing treatment of soybean seeds against the main fungal phytopathogens; to determine the effect of dressing agents on the structure of soybean yield and crop productivity.

MATERIALS AND METHODS

The studies were carried out in 2019, 2020 at the experimental field of the Far Eastern Research Institute of Plant Protection. The soil of the experimental site belongs to the subtype of meadow-brown podzolized, medium loamy in granulometric composition. Humus in the soil is 3.8%, the reaction of the soil solution is weakly acidic (pH 5.3).

Soil preparation was carried out according to the agricultural technology adopted in the Primorsky Territory: autumn plowing to a depth of 18–20 cm, early spring harrowing, and two cultivations. Sowing was carried out in a single-line method with a row spacing of 45 cm. The area of the experimental plot was 10.8 m^2 (1.8 × 6 m), fourfold replication, the placement of variants was randomized. Soybean variety - Asuka, seeding rate - 110 kg / ha. Seeds were treated before sowing in a semi-dry way. Experiment scheme: control (without treatment); Delit Pro, KS (d.v. pyraclostrobin 200 g / l) at a consumption rate of 1.0 l / t; Redigo Pro, KS (a.v. prothioconazole 150 g / l + tebuconazole 20 g / l) - 0.9 l / t.

The work is experimental. Redigo Pro, not registered in the "List of pesticides and agrochemicals permitted for use in the Russian Federation" on soybeans, but having a strong suppressive effect on a wide range of various pathogens of other crops was selected for the study. The drugs were tested in overestimated doses in order to assess not only the biological effectiveness, but also the safety for the culture. In agricultural organizations, drug overdose often occurs due to the use of etching equipment with inaccurate dispensers.

During the growing season of soybeans, manual weeding of experimental plots was carried out. When conducting field experiments, records, observation of growth and development, statistical processing of data was carried out in accordance with generally accepted methodological recommendations [2–6].

The manifestation and intensity of development of soybean diseases are largely determined by weather conditions. Growing seasons 2019 and 2020 were humid and warm, which favorably influenced the spread of pathogens. The amount of precipitation in June 2019 amounted to 144.4 mm, which is 63.7 mm higher than the average annual indicator (80.7 mm). The air temperature varied from 16.7 to 18 °C. The amount of precipitation in June 2020 was

115.4 mm (29.2 mm more than the average annual), the temperature was from 17.2 to 18.4 ° C. July of 2019 was very hot with temperatures reaching 24.5 ° C with 121.4 mm of precipitation per month. In 2020, in the third decade of July, a drought was recorded: the total amount of precipitation for the month did not exceed 69.8 mm at an average air temperature of 21.5 ° C. August in both years of research turned out to be wet: the total precipitation in 2019 was 225 mm, in 2020 - 209.4 mm, which is 59.5 and 54.5 mm, respectively, more than the average annual values. Such weather conditions led to the rapid development and spread of root rot and leaf-stem diseases in soybeans.

RESULTS AND DISCUSSION

Evaluation of the safety of higher doses of preparations for soybeans showed that the dressing agents do not have a negative effect on the crop. On the contrary, the use of drugs has a positive effect on seed germination. On average, over 2 years of testing, the field germination of seeds in the control variant was 79%, when using the disinfectants Delit Pro and Redigo Pro - 80 and 83%, respectively (LSD 05 = 7%).

The use of fungicidal dressing agents Delit Pro and Redigo Pro made it possible to significantly reduce the intensity of root rot development on soybeans. Both drugs had a healing effect on soybean seedlings (see Fig. 1).

The biological efficiency of Redigo Pro in the full germination phase was 73.6%, in the flowering phase - 41.4%. The use of this disinfectant made it possible to significantly (relative to control) reduce the degree of pathogen development: by 3.8 times (full shoots) and 1.7 times (flowering). The effectiveness of Delit Pro against root rot turned out to be low (28.2%) and was recorded only in the soybean flowering phase.

The first signs of leaf-stem diseases in soybeans were noted in the second decade of June in the phase of the appearance of the third trifoliate leaf, the maximum development of the disease - by the end of August. During the study period, such leaf spots as septoria (Septoria glycines Hemmi), cercosporosis (Cercospora

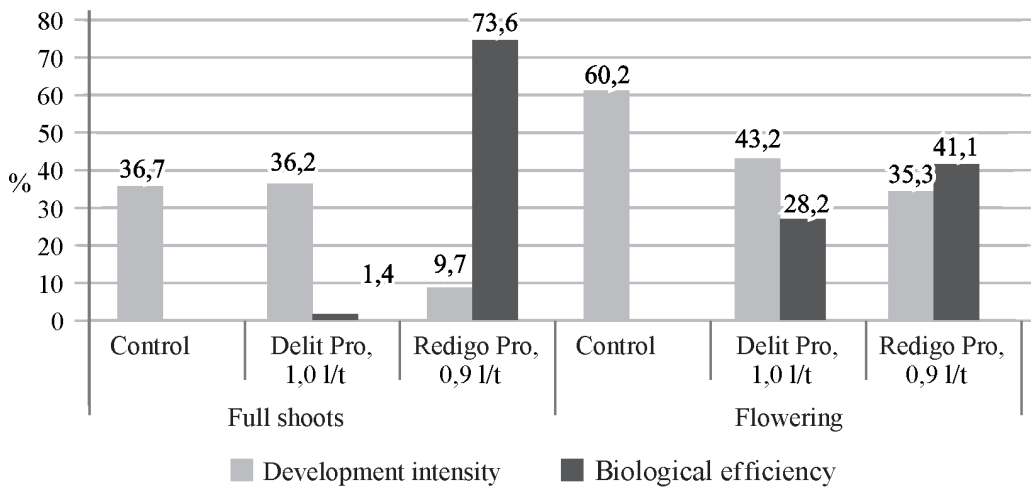

Рис. 1. Интенсивность развития корневых гнилей сои и биологическая эффективность протравителей (среднее за 2019, 2020 гг.)

Fig. 1. Intensity of development of soybean root rot and biological effectiveness of the protectants (average for 2019, 2020)

[2]Dospekhov B.A. Field experiment technique. M.: Agropromizdat, 1985.351 pp.

[3]Korsakov N.I., Ovchinnikova A.N., Mizeva V.I. Study of the resistance of soybeans to fungal diseases: method. directions. L.: VIZR, 1979.46 pp.

[4]Chumakov A.S., Minkevich I.I., Vlasov Yu.I. The main methods of phytopathological research: scientific works. Moscow: Kolos, 1974.190 pp.

[5]James B. Sinclair. Compendium of Soybean Diseases. St.Paul, Min, 1982, 104 p.

[6]Methodical instructions for registration tests of fungicides in agriculture. SPb.: VIZR, 2009.378 p.

sojina Hara), ascochytosis (Ascochyta sojaecola Abramov) and peronosporosis (Peronospora manshurica (Naum.) Syd.) were recorded. Septoriosis manifested itself in the phase of the third trifoliate leaf on primordial leaves. On average, the development of the disease in the control during the growing season was in the range of 6.1–41.0% (see Table 1). The overall assessment of the intensity of the growth of infection and its harmfulness is the relative indicator of AUDPC, which is a graphical display of the area under the curve of the development of the disease during the growing season. The greater its value, the more intensive the growth of the disease occurs in the culture. Judging by the AUDPC indicator (area under disease progress curve, c. u.), the development of the disease in the variant with the use of Delit Pro was 1.3 times less than in the control. The biological effectiveness of the drug was 25.2% (see Fig. 2).

The years of research were favorable for the development of cercosporosis. For the first time, the disease was noted in the phase of three trifoliate leaves. It was found that Delith Pro had no protective effect against the disease. Redigo Pro, on the other hand, significantly reduced the development of cercospora, while the biological efficiency was 44.6% (see Fig. 2).

Ascochitosis was registered in the phase of three trifoliate leaves in the form of single spots. In the control variant, the intensity of development on average for the growing seasons of 2019, 2020. varied from 0.1 to 2.8% (see Table 1). It is impractical to evaluate the bio-

Табл. 1. Влияние протравителей на интенсивность развития листостебельных болезней сои (среднее за 2019, 2020 гг.)

Table 1. Effect of the protectants on the intensity of development of soybean leaf-stem diseases (average for 2019, 2020)

Experiment option	Vegetation phase				AUDPC, c. u.
	Three trifoliate leaves	Flowering	Beans plumpness	Maturation start	
	Disease growth rate, %				
Septoria blight					
Control	6,1	14,4	24,3	41,0	1280,9
Delit Pro, 1,0 l / t	2,2	5,4	22,9	40,9	958,3
Redigo Pro, 0,9 l / t	3,0	12,5	17,1	18,8	1066,7
LSD_{05}	3,4	4,9	1,1	3,0	137,2
Cercospora blight					
Control	0,0	0,2	5,6	12,3	215,7
Delit Pro, 1,0 l / t	1,0	0,8	14,2	33,9	241,2
Redigo Pro, 0,9 l / t	0,0	0,4	2,7	5,1	119,6
LSD_{05}	0,0	0,7	2,1	3,9	64,9
Ascochyta blight					
Control	2,8	0,4	0,1	0,7	34,5
Delit Pro, 1,0 l / t	0,0	0,0	0,0	1,1	13,5
Redigo Pro, 0,9 l / t	0,0	0,2	0,0	0,6	9,5
LSD_{05}	0,0	0,6	0,5	0,5	24,5
False mildew					
Control	0,0	6,3	10,8	33,0	823,2
Delit Pro, 1,0 l / t	0,0	0,0	5,2	10,3	580,5
Redigo Pro, 0,9 l / t	0,0	0,0	1,1	4,2	102,6
LSD_{05}	0,0	2,0	5,4	4,4	68,2

logical effectiveness of drugs at such low rates of disease development, since the behavior of the disinfectants at a high infectious load is unknown.

Weather conditions in late July - early August were favorable for the development of downy mildew. For the spread of the pathogen's conidia, rains, prolonged fogs or abundant dew are necessary, when water droplets remain on the leaves for at least 5 hours.

The damage of adult plants was observed in a local form. For the first time, the disease was recorded in the flowering phase on the leaves of the upper tier in the control variant with a development rate of 6.3%. In the experimental variants, the pathogen manifested itself in the phase of filling the beans, the degree of its development was 5.6% (Delit Pro) and 9.7% (Redigo Pro) less than in the control. By the beginning of the ripening of the beans, peronosporosis in the control variant exceeded the established threshold of harmfulness (25%), but the disinfectants continued to effectively control the disease. The drug Redigo Pro (87.5%) had the highest biological effectiveness against peronosporosis (see Fig. 2) 7.

The analysis of the sheaf material showed the presence of quantitative differences in some structural elements of the crop. The height of soybean plants on average for 2 years was the maximum with the pre-sowing treatment of seeds with Delit Pro, 3.6 cm more than in the control. In the variant with the use of Redigo Pro, no changes in this indicator were noted (see Table 2).

The size of the yield depends on many indicators, among which the characteristic of the structure of its commercial part occupies an important place. The Redigo Pro preparation stimulated an increase in the mass of seeds (by 0.6 g) and their number (by 2.8 pcs.) From one plant in comparison with the unprotected variant. Both preparations significantly increased the thousand-seed-weight (see Table 2).

Correlation analysis of research results showed that the relationship between the yield of soybeans and the intensity of development of the main fungal phytopathogens, such as septoria (r = –0.57), cercosporosis (r = –0.82), ascochitosis (r = –0.89), root rot (r = –0.94) and peronosporosis (r = –1.00), characterized as moderate and strong negative.

In the control variant, on average for 2 years, the lowest yield (1.64 t / ha) was obtained than with the use of dressing agents, which had an effective suppressive effect on crop diseases. In the variant with the use of Redigo Pro, a significant increase in yield was obtained (0.19–

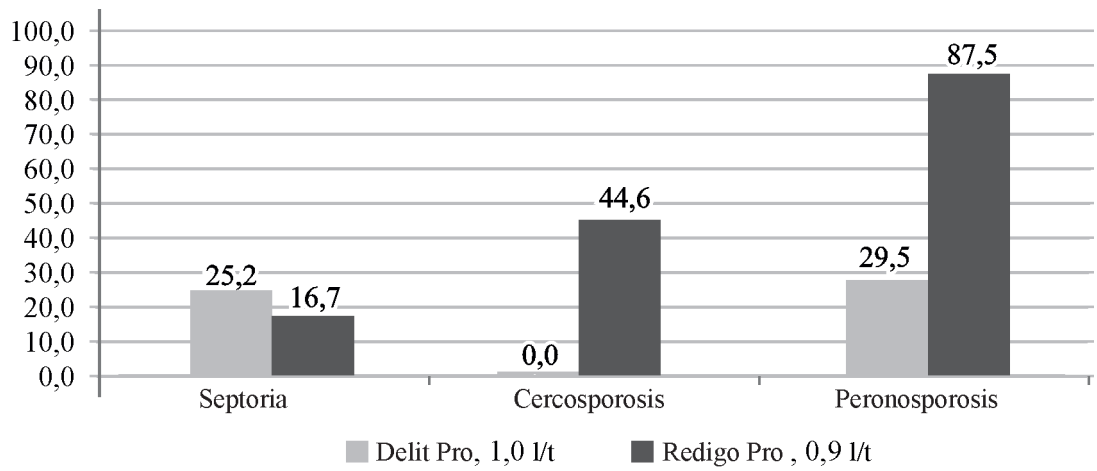

Рис. 2. Биологическая эффективность препаратов против листостебельных болезней сои (среднее за 2019, 2020 гг.)

Fig. 2. Biological efficacy of the chemicals against leaf-stem diseases of soybeans (average for 2019, 2020)

[7]Review of the phytosanitary state of agricultural crops in 2018 and the forecast of the development of harmful objects in 2019 / FSBI "Russian Agricultural Center", Branch of FSBI "Rosselkhoztsentr" in the Primorsky Territory. Vladivostok, 2019.72 p.

Табл. 2. Влияние препаратов на структурные элементы урожая (среднее за 2019, 2020 гг.)
Table 2. Influence of the protectants on the structural elements of the crop yield (average for 2019, 2020)

Experiment option	Preparation consumption rate, l/t	Plant height, cm	Number of seeds per one plant, pcs.	Seed weight from one plant, g	Thousand-seed-weight, g
Control	–	56,4	19,5	3,1	154,4
Delit Pro	1,0	60,0	20,9	3,2	162,9
Redigo Pro	0,9	56,3	22,3	3,7	163,7
LSD_{05}		2,5	2,0	0,4	3,2

0.20 t / ha). When using Delit Pro, there was a tendency to increase the yield relative to the control, but the increase turned out to be insignificant: 0.08 t / ha in 2019 and 0.11 t / ha in 2020 (see Table 3).

High values of net income indicate the cost-effectiveness of experience options. This indicator, taking into account prices for 2020, amounted to 2.3 thousand rubles / ha (Delit Pro) and 5.9 thousand rubles / ha (Redigo Pro). The level of profitability increased relative to control by 222% (Delit Pro) and 564% (Redigo Pro).

CONCLUSION

In the course of the two-year tests of fungicidal dressing agents, it was found that in the agro-climatic conditions of the Primorsky Territory, pre-sowing treatment of soybean seeds is a highly effective way of protecting against root rot and leaf-stem diseases. The use of Delit Pro (1.0 l / t) and Redigo Pro (0.9 l / t) preparations contributed to the active growth of plants and an increase in the main elements of the yield structure: plant height, seed mass and their number per plant, as well as 1000 seeds. In the experimental variants, a tendency to an increase in yield relative to control was noted.

Табл. 3. Влияние препаратов на урожайность сои, т/га
Table 3. Effect of the protectants on the soybean yield, t/ha

Option	2019	2020	Mean
Control	1,52	1,76	1,64
Delit Pro, 1,0 l / t	1,60	1,87	1,74
Redigo Pro, 0,9 l / t	1,71	1,96	1,84
LSD_{05}	0,12	0,15	

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ЭКОЛОГИЧЕСКАЯ ОЦЕНКА ПРИМЕНЕНИЯ ГЕРБИЦИДА ЛЮМАКС

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Изучены чувствительность сельскохозяйственных культур к гербициду Люмакс, состоящего из трех действующих веществ (д.в.): С-метолахлора, тербутилазина и мезотриона, длительность их сохранения в лугово-бурой почве и определено последействие препарата на культуры севооборота. Исследования проведены в Приморском крае в 2019, 2020 гг. в условиях вегетационного домика. На опытных делянках до всходов кукурузы применяли гербицид Люмакс в дозах 4,0 л/га (рекомендованная) и 8,0 л/га (двукратная от рекомендованной). Осенью 2019 г. и весной 2020 г. с опытных участков и с контрольного (без гербицидов) отобраны образцы лугово-бурой почвы с глубины пахотного слоя, содержащего 3,5% гумуса. Образцы использованы для установления длительности сохранения действующего начала и последействия гербицида Люмакс. Предварительно отобраны растения индикаторы остаточных количеств препарата в лугово-бурой почве. Рассчитаны дозы гербицида, снижающие надземную массу тест-растения на 50%, и его предельно-допустимые концентрации в почве. Определено, что к концу вегетационного сезона при норме внесения препарата 4,0 л/га в лугово-бурой почве сохраняется 0,7–3,0% д.в. гербицида Люмакс, при норме 8,0 л/га – 0,6–3,9%. К началу следующего полевого сезона препарат, примененный в рекомендованной норме расхода, полностью разлагается, в двукратной норме от рекомендованной остается 0,8–1,7% гербицида. Через 8 мес после внесения гербицид Люмакс в норме расхода 4,0 л/га безопасен для последующих культур севооборота. В случае передозировки или двойного наложения (8,0 л/га) он способен оказывать последействие на чувствительные культуры. Определены культуры, высокочувствительные к препарату Люмакс: капуста, редис, рапс, свекла, томаты, огурец и рис; чувствительные: пшеница, гречиха и соя; относительно устойчивые: овес и ячмень. Установлена безопасная норма расхода гербицида Люмакс (4,0 л/га) для последующих культур севооборота.

Ключевые слова: гербицид, препарат, Люмакс, норма расхода, доза, культура, почва

ENVIRONMENTAL ASSESSMENT OF THE USE OF THE HERBICIDE LUMAX

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The sensitivity of agricultural crops to the Lumax herbicide, consisting of three active agents C-metolachlor, terbutylazine and mesotrione, the duration of their action in meadow-brown soil, and the aftereffect of the herbicide on the plants of the crop rotation were determined. The study was conducted in the conditions of the greenhouse in the Primorsky Territory in 2019 and 2020. The herbicide Lumax was used on experimental plots before corn germination at doses of 4.0 l/ha (recommended) and 8.0 l/ha (twice the recommended). In the autumn of 2019 and in the spring of 2020, samples of meadow-brown soil were taken from the experimental plots and from the control (without herbicides) from the depth of the arable layer containing 3.5% humus. The samples were used to establish the duration of the action of active agents and the aftereffect of the herbicide Lumax. Prior to this, plants indicating residual amounts of the chemical in meadow-brown soil were preselected. The doses of the herbicide which reduce the above-ground mass of the test plant by 50% were calculated, as well as its maximum permissible concentration in the soil. It was determined that by the end of the growing season, 0.7–3.0% of the active agent of the herbicide Lumax is retained in meadow-brown soil at a rate of application of 4.0 l/ha, and 0.6–3.9% – at a rate of 8.0 l/ha. By

the beginning of the next field season, the preparation applied at the recommended rate completely decomposed, while when it was applied at a double rate of the recommended rate, 0.8–1.7% of the herbicide remained. Eight months after the application at a rate of 4.0 l/ha, the herbicide Lumax is safe for subsequent crops of the crop rotation. In case of overdose or double application (8.0 l/ha), it can have an aftereffect on sensitive crops. The crops that are highly sensitive to the Lumax preparation were identified: cabbage, radish, rapeseed, beetroot, tomatoes, cucumber and rice; sensitive: wheat, buckwheat and soybean; relatively resistant: oats and barley. A safe consumption rate of the Lumax herbicide (4.0 l/ha) for subsequent crops of the crop rotation was established.

Keywords: herbicide, preparation, Lumax, consumption rate, dose, crop, soil

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INTRODUCTION

Weed infestations of crops is one of the factors that hinder getting high and stable corn grain yields. Modern agriculture has a wide range of ways to combat weeds, the most effective of which is the use of herbicides [1]. At present, about half of the world's agricultural crops are obtained from plant protection products, therefore it is practically impossible to provide the growing population of the planet with food and raw materials without the use of pesticides. Under these conditions, there is a high urgency of the problems associated with the control of the behavior of chemicals in the environment. [2–4].

New technologies of agricultural production are used, the safety of plant protection products is studied, environmental standards for their permissible residual content are being developed to solve phytosanitary problems [5, 6].

According to various estimates, 70–90% of pesticides enter the soil at the time of application. Their residual amounts inhibit soil biota, have a negative aftereffect on cultivated plants and pollute surface and ground waters [7].

The problem of contamination of arable soils with modern herbicides is associated with the food security of the country, since it can lead to significant losses in crop yields as a result of uncontrolled use of herbicides [8].

One of the requirements for herbicides during registration tests is environmental safety. It is determined by a number of indicators: decomposition during one growing season, the absence of aftereffect on the next crop rotation, etc. [9, 10]. The absence of negative aftereffect is one of the most important properties of selective herbicides. Most of the drugs used have this property if the regulations for their use are observed. If the technology is violated (overestimation of the consumption rate, uneven distribution over the area, etc.), many drugs become dangerous and can cause damage not only to the processed, but also to subsequent crops of the crop rotation [11].

New generation herbicides have high phytotoxicity and retain herbicidal activity in environmental objects, in particular in soil, for a long time. In connection with the contamination of arable soils with residues of modern persistent herbicides, new ways of solving this problem are required [12–14].

Residual amounts of herbicides or their metabolites affect the subsequent crop. It had no practical significance for field crop rotations, since the share of such herbicides in production was insignificant [15].

The number of chemicals is increasing by about a thousand names every year. However, many of them are insufficiently studied from

the point of view of ecological safety in various soil and climatic conditions [16].

The evaluation of the pesticides detoxification rate is carried out by the following methods: direct determination of the dynamics of the compound of substances in the soil using physicochemical analyzes and indirectly using biotests. The first method, in some cases, is not sensitive enough to detect traces of herbicides, in particular those used in low doses. The phytotest on sensitive plants is recognized as the most accessible and sufficiently informative in this case [17].

The aim of the research is to study the sensitivity of agricultural crops to the Lumax herbicide, which consists of three active substances: C-metolachlor, terbutylazine and mesotrione to establish the duration of their preservation in meadow-brown soil and to determine the aftereffect of the drug on crop rotation crops.

MATERIALS AND METHODS

The studies were carried out in a vegetation house (2019, 2020), as well as on the experimental field of the Far Eastern Research Institute of Plant Protection in 2019. The soil of the site is meadow-brown podzolized medium loamy, containing 3-4% humus in the arable horizon, pH_{sal} 5, 0-5.9. In 2019, in a growing house, the sensitivity of 12 agricultural crops to the Lumax herbicide was determined. A weighed portion of meadow-brown soil, 1.5 kg, was treated with herbicide solutions at doses: 4.0; 3.0; 2.0; 1.0; 0.5; 0.25; 0.125; 0.063 and 0.0315 l / ha. The application of the drug solutions was carried out using an OL-5 laboratory sprayer designed by the All-Russian Research Institute of Phytopathology. One day after thorough mixing, the treated soil was placed in 300 g cups. Seeds of the following test cultures were sown in them: wheat, barley, oats, rice, rapeseed, radish, cucumbers, buckwheat, soybeans, cabbage, beetroot, and tomatoes.

In 2019, the herbicide Lumax was used in the sowing of maize before germination at rates of 4.0 l / ha (recommended) and 8.0 l / ha (two times the recommended). In the fall (after 3 months) and in the spring of 2020 (after 8 months), samples of meadow-brown soil were taken from these plots, as well as from the control variant, from the depth of the arable layer (0–20 cm). The soil was dried, crushed, then the cups were filled with it, after which the seeds of sensitive test cultures were sown in them. At the same time, a weighed portion of pure (without herbicides) meadow-brown soil, 1.5 kg, was treated with Lumax solutions. After the preparation described above, the same selected sensitive cultures were sown. The experiments were repeated five times. The soil moisture in the cups was maintained at the level of 60–70% WFC (water field capacity) by irrigation with tap water. After 30 days, the plants were cut and weighed. The calculation of ED_{10} and ED_{50} (a toxic dose that reduces the green mass of plants by 10 and 50%), as well as residual amounts of active substances in the soil was carried out using a computer. The aftereffect of the Lumax herbicide was determined by the decrease in the aboveground mass of the test plants in comparison with the control.

All studies were carried out in accordance with the approved methodological guidelines[1], and the digital material was processed according to B.A. Dospekhov[2].

RESULTS AND DISCUSSION

Crops reacted differently to the application of the Lumax herbicide to the soil. The complete death of beetroot was observed from the presence in the soil of 0.063 l / ha of the drug, cabbage and cucumber - from 0.25 l / ha, tomatoes, rice, rapeseed and radish - from 0.5 l / ha, buckwheat and wheat - from 2.0 l / ha, and soybeans, oats and barley - from 4.0 l / ha (see table. 1).

The calculation of the toxic dose of the herbicide Lumax, which reduces the green mass of plants by 50%, showed that for beetroot it is equal to 0.004 l / ha, for cabbage, rice, tomatoes, cucumber, rapeseed and radish - 0.045–0.166 l / ha. These crops are identified as highly sen-

[1]Spiridonov Yu.Ya., Larina G.E., Shestakov V.G. Methodical guidelines for the study of herbicides used in crop production. M.: Pechatny gorod, 2009.252 p.

[2]Dospekhov B.A. Field experiment technique. Moscow: Kolos, 1979.416 p.

sitive. Wheat, buckwheat and soybeans turned out to be sensitive crops to this herbicide, while oats and barley were relatively resistant. Plants that indicate residues of the Lumax herbicide in meadow brown soil include highly sensitive and sensitive agricultural crops. According to the ED_{10} indicator of the drug in the soil, the test crops are arranged in descending order as follows: barley → oats → soybean → buckwheat → wheat → radish → rapeseed → cucumbers → tomatoes → rice → cabbage → beetroot.

By the end of the growing season (3 months after treatment) from the application rate of 4.0 l / ha (2.152 kg r.a. / ha), 0.016–0.064 kg r.a. / ha, or 0, remained in the meadow-brown soil. 7-3.0%, herbicide Lumax, from the application rate 8.0 l / ha (4.304 kg r.a. / ha) - 0.024-0.170 kg / ha, or 0.6-3.9%, (see. Table 2).

Almost all of the selected plants showed the presence of the studied preparation in the soil. By the beginning of the next field season (8 months after application), Lumax, applied at the recommended consumption rate, completely decomposed. When the drug was applied in two times the recommended dose, the herbicide remained 0.035–0.072 kg / ha, or 0.8–1.7%. Residual amounts of Lumax in the soil were noted in the crops of cucumbers, soybeans, rice, tomatoes and wheat.

The studies carried out to determine the aftereffect of the herbicide Lumax indicate that, at the recommended consumption rate of 4.0 l / ha, tomatoes slightly (by 1.5%) reduced the aboveground mass (see Table 3).

On the rest of the crops, the green mass of plants was registered by 0.7–7.9% more than on the herbicide-free variant. At a dose of 8.0 l / ha, two times the recommended dose, reliably (LSD 05 = 11.7 and 9.1%, respectively),

Табл. 1. Токсичная доза гербицида Люмакс для сельскохозяйственных культур в лугово-бурой почве, л/га

Table 1. Toxic dose of the Lumax herbicide for agricultural crops in meadow brown soil, l/ha

Crop	Complete death of plants	Reduction of green mass of plants	
		by 50%	by 10%
Barley	4,0	1,193 (1,020 ÷ 1,394)	0,595
Oats	4,0	1,087 (0,994 ÷ 1,188)	0,399
Soy	4,0	0,712 (0,611 ÷ 0,829)	0,201
Buck-wheat	2,0	0,357 (0,308 ÷ 0,413)	0,178
Wheat	2,0	0,336 (0,247 ÷ 0,456)	0,132
Radish	0,5	0,166 (0,126 ÷ 0,219)	0,070
Rapeseed	0,5	0,104 (0,089 ÷ 0,122)	0,042
Cucum-bers	0,25	0,070 (0,057 ÷ 0,085)	0,031
Tomatoes	0,5	0,068 (0,051 ÷ 0,091)	0,020
Rice	0,5	0,067 (0,053 ÷ 0,086)	0,020
Cabbage	0,25	0,045 (0,033 ÷ 0,062)	0,017
Beetroot	0,063	0,004 (0,001 ÷ 0,018)	0

Табл. 2. Динамика содержания действующих веществ гербицида Люмакс в лугово-бурой почве

Table 2. Dynamics of the content of active agents of the herbicide Lumax in meadow-brown soil

Test-crop	Consumption norm, l/ha		Active agents content in the soil layer 0–20 cm			
	acc. to the prep-ara-tion	acc. to a.ag.	in 3 months		in 8 months	
			kg / ha	% of the deposited amount	kg / ha	% of the de-posited amount
Soy	4	2,152	0,060	2,8	0	0
	8	4,304	0,064	1,5	0,040	0,9
Wheat	4	2,152	0,064	3,0	0	0
	8	4,304	0,090	2,1	0,072	1,7
Buck-wheat	4	2,152	0	0	0	0
	8	4,304	0,110	2,6	0	0
Radish	4	2,152	0,016	0,7	0	0
	8	4,304	0,038	1,0	0	0
Rapeseed	4	2,152	0,025	1,2	0	0
	8	4,304	0,056	1,3	0	0
Cabbage	4	2,152	0	0	0	0
	8	4,304	0,026	0,6	0	0
Cucum-bers	4	2,152	0,045	2,1	0	0
	8	4,304	0,050	1,2	0,035	0,8
Tomatoes	4	2,152	0,058	2,7	0	0
	8	4,304	0,062	1,4	0,047	1,1
Rice	4	2,152	0,046	2,1	0	0
	8	4,304	0,064	1,5	0,046	1,1

the smallest increase in green mass was observed on wheat - 12.5% and soybeans - 10%. The aboveground weight of tomatoes, cucumber and rice was also 8.0–9.7% less than in the control.

CONCLUSIONS

1. According to the results of the studies carried out under the conditions of a vegetation house in meadow-brown soil, the sensitivity of agricultural crops to the herbicide Lumax was established. The following highly sensitive crops have been identified: cabbage, radish, rapeseed, beetroot, tomatoes, cucumbers, rice; sensitive: wheat, soy, buckwheat; relatively resistant: barley, oats. Plants that are indicative of Lumax herbicide residues include highly sensitive and sensitive crops.

2. 8 months after the application of the herbicide Lumax in the recommended (4.0 l / ha) consumption rate is safe for subsequent crops of the crop rotation. In case of overdose or double overlapping (8.0 l / ha), it can have an aftereffect. In meadow-brown soil, up to 0.8-1.7% of the active substance of the drug is retained.

Табл. 3. Последействие гербицида Люмакс на культуры севооборота

Table 3. Aftereffect of the herbicide Lumax on the plants of crop rotation

Crop	Green mass of plants in control, g	Reduction of green mass of plants from consumption rates, % to control		LSD_{05}, %
		4,0 l / ha	8,0 l / ha	
Wheat	1,52	+ 0,7	12,5	11,7
Rice	0,86	+ 1,2	9,3	11,6
Soy	2,57	+ 4,7	10	9,1
Buck-wheat	3,64	+ 4,4	0	14,6
Cucum-bers	3,32	+ 6,3	8,7	11
Tomatoes	1,37	1,5	8,0	14
Rapeseed	1,51	+ 7,9	0	12

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ПОКАЗАТЕЛИ ОБЩЕГО ГОМЕОСТАЗА У КОРОВ В РАЗНЫЕ ПЕРИОДЫ ЛАКТАЦИЙ

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Исследованы иммуноморфологические показатели коров крупного рогатого скота, находящегося в разных периодах лактации. В первые 3 мес лактации, исключая 7 дней молозивного периода, в сыворотке крови обнаружено 59,3 ед. циркулирующих иммунных комплексов, в середине лактации (4–7 мес) – 94,2 ($p < 0,05$), в конце (8–10 мес) – 94,1 ед. ($p < 0,05$). Достоверное различие между показателем в первые 3 мес и в последующие периоды лактации, связано с тем, что в начале лактации коровы еще не стельные. В молозивный период высокий показатель циркулирующих иммунных комплексов 116,1 ед. ($p < 0,05$) определен как последствие предродовой иммунной атаки плода на организм коровы, когда система мононуклеарных фагоцитов еще не справилась с элиминацией продуктов нейтрализации. В сухостойный период количество циркулирующих иммунных комплексов составляло 87,6 ед. ($p < 0,05$). Снижение показателя происходило в связи с увеличением активности мононуклеарных фагоцитов и отсутствием лактационной нагрузки на организм. Содержание сегментоядерных, функционально зрелых лейкоцитов в начале лактации составляло 39,4%, в середине лактации этот показатель снижался до 24,8% ($p < 0,05$), в конце ее составил 26,3% ($p < 0,05$). Установлено достоверное различие в относительном количестве сегментоядерных нейтрофилов в контроле и у нелактирующих коров в сухостойном периоде – 29,9% ($p < 0,05$). В молозивный период уровень содержания лимфоцитов в крови животных составил 62,0% ($p < 0,05$) и достоверно отличался от контроля – 43,6%. В середине и в конце лактации также прослеживалось достоверное отличие показателя от контроля до 58,9–59,4% ($p < 0,05$). Установлено достоверное различие с группой глубокостельных сухостойных коров – 53,9% ($p < 0,05$). В первые 1–3 мес лактации коровы или еще не стельные, или между матерью и плодом еще не сформирована тесная связь (плацента), поэтому низкая активность специфического иммунитета в это время вызвана отсутствием в крови коров чужеродных антигенов плода. Полученные данные свидетельствуют о возможности инициации родового процесса иммунной системой.

Ключевые слова: крупный рогатый скот, лактация, резистентность, иммунная система, гомеостаз, лимфоциты, циркулирующие иммунные комплексы, мононуклеарные фагоциты

INDICATORS OF TOTAL HOMEOSTASIS IN COWS IN DIFFERENT PERIODS OF LACTATIONS

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The immunomorphological parameters of cattle in different periods of lactation were studied. In the first 3 months of lactation, excluding 7 days of the colostrum period, 59.3 units of circulating immune complexes were found in the serum, in the middle of lactation (4–7 months) – 94.2 ($p < 0.05$), at the end (8–10 months) – 94.1 units ($p < 0.05$). The significant difference between the indicator in the first 3 months and in the subsequent periods of lactation is due to the fact that at the beginning of lactation the cows were not yet pregnant. In the colostrum period, a high rate of circulating immune complexes of 116.1 units ($p < 0.05$) was determined as a consequence of a fetal prenatal immune attack on the cow's body, when the system of mononuclear phagocytes had not yet coped with the elimination of neutralization products. During the dry period, the number of circulating immune complexes was 87.6 units ($p < 0.05$). The decrease in the indicator occurred due to an increase in the activity of mononuclear phagocytes and the absence of lactation effect on the body. The content of segmental, functionally mature leukocytes at the beginning of lactation was 39.4%, in the middle of lactation this indicator decreased to 24.8% ($p<0.05$), at the end it was 26.3% ($p<0.05$). A significant difference was found in the relative number of segmented neutrophils in the control group and in non-lactating cows in the dry period – 29.9% ($p < 0.05$). During the colostrum period, the level of lymphocytes in the blood of animals was 62.0% ($p < 0.05$) and it significantly differed from the control – 43.6%. In the middle and at the end of lactation, there was also a significant difference between the indicator and the control, up to 58.9–59.4% ($p<0.05$). A significant difference with the group of down-calving dry cows was established – 53.9% ($p < 0.05$). In the first 1–3 months of lactation, cows are either not yet pregnant, or a close bond (placenta) between the mother and the fetus has not yet been formed, therefore a low activity of specific immunity at this time is caused by the absence of foreign fetal antigens in the blood of cows. The findings suggest that the birth process may be initiated by the immune system.

Keywords: cattle, lactation, resistance, immune system, homeostasis, lymphocytes, circulating immune complexes, mononuclear phagocytes

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INTRODUCTION

Milk production technology assumes that within 7 months of lactation cows bear a fetus. The combination of the two such energy-consuming physiological processes as pregnancy and milk production depletes the body systems, causes a violation of compensatory mechanisms, and reduces the duration of operation and life of animals [1, 2]. To ensure the health of the mother and the fetus, the state of the immune system of cows is of particular importance [3, 4].

The aim of the work is to study the most informative homeostatic parameters of blood and blood serum of cattle in different periods of lactation.

MATERIALS AND METHODS

The studies were carried out on the basis of the Novosibirsk State Agrarian University and the Tomsk Agricultural Institute. The object of the study was the cows of Holstein hybrids of the Siberian offspring of the black-and-white breed with different proportions of blood between the first and seventh lactations with a

productivity of 3500–5500 kg. The spread in productivity is dictated by the need to increase the sample of animals. In previous studies, we did not find a significant difference when comparing immunological and hematological parameters in cows with a productivity of 3500 to 5500 kg.

To determine the indicators of general homeostasis in cows, depending on the lactation period, groups were formed with the number of animals from three to 32. Methods of statistical processing were used to compare them, which make it possible to reveal significant differences in groups with different numbers of animals. To assess the dynamics of homeostasis indicators, the obtained data were compared with the control, which was chosen as a group of cows at the beginning of lactation.

In all periods of the experiment, different animals were studied, which made it possible to avoid the possible influence of seasonality, changes in conditions of keeping and feeding on the results of the experiment.

In the blood of lactating cows, the cells were counted, the leukogram was determined according to generally accepted methods using microscopy in the Goryaev chamber and blood smears stained according to Romanovsky - Giemsa. The activity of serum lysozyme was investigated on a photoelectric calorimeter, evaluating the light transmission in control and experimental tubes. Phagocytic activity of neutrophils was determined by the method of opsonophagocytic reaction using a culture of Staphylococcus aureus (strain No. 209). Determination of circulating immune complexes in blood serum was carried out on a photoelectric calorimeter, preliminarily diluting the serum with borate buffer. To assess the blast transformation of lymphocytes, a stimulator phytohemagglutinin was used, the results were taken into account by the morphological method [5].

Statistical processing of the obtained digital data, including the calculation of the mean values and the calculation of the mathematically significant difference in the indicators of the results, was carried out using the statistical software package "Statistica for Windows 6.0".

RESULTS AND DISCUSSION

Analysis of changes in immunological parameters in different periods of lactation shows that the activity of serum lysozyme in the control was 31.6% of light transmission, in the dry period - 35.9% ($p < 0.05$), which indicates an increase in nonspecific immunity before calving (see. Table 1). With lactation lasting more than 12 months, the activity of lysozyme is significantly higher than the control group - 40.7% (p

Табл. 1. Иммунологические показатели крови коров в разные периоды лактации
Table 1. Immunological indicators of cows' blood in different lactation periods

Indicator	Lactation period				
	1–3 months (*n* = 16) control	4–7 months (*n* = 6)	8–10 months (*n* = 32)	Dry (*n* = 28)	Colostric (*n* = 7)
Lysozyme, % light transmission	31,6 ± 1,4	30,3 ± 2,0	32,3 ± 1,5	35,9 ± 1,1*	36,6 ± 3,2
Circulating immune complexes, units	59,3 ± 8,4	94,2 ± 14,5*	94,1 ± 6,4*	87,6 ± 7,0*	116,1 ± 21,0*
Blasts, %	54,8 ± 2,1	51,2 ± 5,1	53,3 ± 1,9	58,5 ± 2,2	53,1 ± 3,2
Average lymphocytes, %	22,6 ± 1,8	20,3 ± 3,2	19,8 ± 1,0	20,5 ± 1,1	23,3 ± 2,0
Small lymphocytes, %	22,7 ± 1,7	28,5 ± 3,3	27,1 ± 1,5	21,2 ± 1,7	23,1 ± 2,0
Active lymphocytes, %	77,3 ± 1,7	71,5 ± 3,3	73,2 ± 1,5	79,0 ± 1,8	76,6 ± 1,9
Spontaneous activity, %	25,4 ± 2,0	26,8 ± 3,7	23,6 ± 1,8	22,0 ± 1,5	24,9 ± 2,5
Active neutrophils, %	39,1 ± 2,0	40,0 ± 2,0	40,8 ± 1,6	37,1 ± 1,6	39,1 ± 3,8

*$p < 0,05$.

<0.05), which may be due to low milk productivity during prolonged lactation [6, 7].

In the first 3 months of lactation, excluding 7 days of the colostrum period, 59.3 units were found in the serum. circulating immune complexes, in the middle of lactation (4-7 months) - 94.2 units (p <0.05), at the end (8-10 months) - 94.1 units (p <0.05). The significant difference between the indicator in the first 3 months and in subsequent periods of lactation is probably due to the fact that at the beginning of lactation the cows are not yet pregnant[1] [8]. Of the 16 animals at the beginning of lactation, 15 were not pregnant, one with an undetermined pregnancy, as she was forced to kill due to an udder injury. The gestation period was determined after the birth of a healthy calf.

In the colostrum period, a high rate of circulating immune complexes is 116.1 units (p <0.05) - indicates a prenatal immune attack of the fetus on the cow's body, the system of mononuclear phagocytes has not yet coped with the elimination of antibodies neutralization products. During the dry period, when the number of circulating immune complexes was 87.6 units (p <0.05), there was a decrease in the indicator, probably due to an increase in the activity of mononuclear phagocytes [9–12].

When assessing the functional activity of lymphocytes, it was found that under the influence of phytohemagglutinin in the control group, 54.8% of lymphocytes were transformed into blasts, at 4–7 months of lactation the number of blasts decreased to 51.2, at 8–10 months the activity of lymphocytes increased to 53.3%.

Thus, the low activity of lymphocytes in the middle of lactation is a consequence of the high productivity and deep pregnancy of animals during this period. During the colostrum period, lymphocytes were transformed into blasts by 53.1%. During the dry period, the activity of lymphocytes increased to 58.5%, which is more than at the end of lactation. With a decrease or cessation of milk production, the specific reactivity and the ability of the animal body to withstand the antigenic load from the fetus increased.

The level of all active lymphocytes, including the average one, was the highest during the dry period - 79.0%, as well as during lactation lasting more than 12 months - 79.7%. The lowest (71.5%) indicator was observed in the middle of lactation, when milk production is highest. This indicates an inverse correlation between the amount of milk produced and the level of specific resistance [13, 14].

Spontaneous activity of lymphocytes was calculated without adding phytohemagglutinin in the control sample. At the beginning of lactation, the indicator was 25.4%, in the middle it increased to 26.8%.

Parameters of phagocytic activity of neutrophils in cows from the colostrum period to 10 months of lactation were stable and varied from 39.1 to 40.8% of active neutrophils.

Hematological blood parameters were studied (see table. 2). At the beginning of lactation, the content of stab neutrophils was 2.9%, in the middle - 2.0, at the end - 1.3%; with lactation lasting more than 12 months - 0.7% (p <0.05). During lactation, a gradual decrease in stab neutrophils was observed in cows, which indicates stabilization of the formation of leukocytes in the hematopoietic organs [15, 16].

The content of segmented, functionally mature leukocytes at the beginning of lactation was 39.4%, in the middle this indicator decreased to 24.8% (p <0.05), at the end of it - 26.3% (p <0.05). At the same time, a significant difference was established in the relative number of segmented neutrophils in the control and in non-lactating cows in the dry period - 29.9% (p <0.05). Thus, leukopoiesis in cows significantly decreased after the first 3 months of lactation; at the same time, the development of the glandular epithelium in the mammary gland of cows and an increase in milk production were established.

Eosinophilic granulocytes at the beginning of lactation were found to be 9.5%, in the middle - 12.0, at the end - 11.0, in the colostrum

[1]Yatsenko Yu.N., Mager S.N. Study of the level of circulating immune complexes in calves with different immune status in the early postnatal period // Actual problems of agro-industrial complex development in the works of young scientists of Siberia: materials of the XI regional scientific-practical conference of young scientists of the Siberian Federal District. Novosibirsk, 2015. P. 155–160.

Табл. 2. Гематологические показатели крови коров в разные периоды лактации
Table 2. Hematological blood counts of cows in different lactation periods

Indicator	Lactation period				
	1–3 months (*n* = 11) control	4–7 months (*n* = 6)	8–10 months (*n* = 25)	Dry (*n* = 26)	Colostric (*n* = 7)
Stab neutrophils, %	2,9 ± 0,9	2,0 ± 1,0	1,3 ± 0,2	1,9 ± 0,4	2,3 ± 1,1
Segmented neutrophils, %	39,4 ± 4,1	24,8 ± 4,6*	26,3 ± 2,2*	29,9 ± 2,6*	26,2 ± 5,2
Acidophiles, %	9,5 ± 2,5	12,0 ± 5,3	11,0 ± 1,3	9,8 ± 1,2	3,7 ± 1,7
Monocytes, %	3,8 ± 0,9	2,0 ± 2,0	2,5 ± 0,4	4,6 ± 0,6	5,8 ± 1,7
Lymphocytes, %	43,6 ± 2,7	59,4 ± 8,1*	58,9 ± 2,6*	53,9 ± 3,1*	62,0 ± 6,8*
Red blood cells, $\times 10^{12}$/l	5,2 ± 0,2	4,9 ± 0,5	5,2 ± 0,2	5,6 ± 0,2	6,1 ± 0,3*
White blood cells, $\times 10^{9}$/l	6,7 ± 0,8	7,7 ± 1,7	7,2 ± 0,5	6,6 ± 0,7	8,2 ± 1,7

*$p < 0,05$.

period - 3.7%. The low content of eosinophils in the colostrum period indicates a decrease in the level of nonspecific protection in favor of specific and the need for the synthesis of immunoglobulins to protect the newborn calf from infections [17].

The content of monocytes in the control group was 3.8%, in the colostrum period - 5.8%, in animals with lactation of 4–7 months - 2.0, in cows lactating for 8–10 months - 2.5%.

The level of lymphocytes in the blood of animals indicates a state of specific resistance [18]. In the colostrum period, this indicator was 62.0% (p <0.05) and significantly differed from the control - 43.6%. During this period, a large number of immunoglobulins appears in the secretion of the mammary gland in cows, which provide protection for the newborn calf. It can be assumed that the percentage of lymphocytes increased not due to a decrease in granulocytes. The increase in the absolute number of leukocytes - 8.2 × 109 / l - was due to the absolute increase in the number of lymphocytes. In the middle and at the end of lactation, there was also a significant difference between the indicator and the control, up to 58.9–59.4% (p <0.05). There was a significant difference with the group of deep-bodied dry cows - 53.9% (p <0.05). In the first 1–3 months of lactation, cows are either not yet pregnant, or the placenta has not yet formed between the mother and the fetus; therefore, the low activity of specific immunity at this time is explained by the absence of fetal antigens in the cows' organism [19–21].

In the first 3 months of lactation, the number of erythrocytes in the blood was 5.2 × 1012 / L, at 4–7 months - 4.9 × 1012 / L, at 8–10 months - 5.2 × 1012 / L. If the number of erythrocytes is considered as an indicator of the level of metabolism, then during lactation it changed insignificantly. A significant difference in the number of erythrocytes was found between the groups of cows at 1–3 months of lactation and the colostrum period - 6.1 × 1012 / l (p <0.05).

Thus, the highest metabolic rate during lactation was noted in the first 7 days after calving. In the dry period, the number of erythrocytes was higher than during lactation, due to the completion of fetal formation, preparation for childbirth and the upcoming lactation.

The dynamics of changes in the leukopoiesis index in lactating cows was revealed: the number of leukocytes at the beginning of lactation was 6.7 × 109 / L, in the middle this indicator

increased to 7.7 × 109, at the end of lactation it decreased to 7.2 × 109 / L. In the colostrum period, this indicator was 8.2 × 109 / l. During lactation lasting more than 12 months, the number of leukocytes decreased - 4.6 × 109 / l ($p < 0.05$), which indicates the stabilization of the immune system in cows with prolonged lactation [22, 23].

Changes in biochemical parameters in the blood serum of cows in different periods of lactation were recorded. Compared with the control (2.38 mmol / l), the calcium content in cows during the colostrum period was significantly different - 3.17 mmol / l ($p < 0.05$), which was due to a small volume of mammary gland secretion and a high level of element metabolism. A significant difference was also found with the group of dry cows - 2.90 mmol / l ($p < 0.05$), which is explained by the absence of calcium elimination with milk and intensive metabolism of the macronutrient associated with the formation of the fetal skeleton.

In the control group, the alkaline reserve was 42.0 vol.% CO^2, in the middle of lactation - 23.4 ($p < 0.05$), at the end - 36.10 vol.% CO^2. In the middle of lactation, there was a significant decrease in the alkaline reserve, which is due to the high productivity of cows during this period. The increase in the alkaline reserve (37.0 vol.% CO^2) at the end of lactation, in our opinion, is caused by a decrease in milk production during the dry period, an insignificant increase occurred after the cessation of feeding the animals with silage (see footnote 1).

At the beginning of lactation, the serum carotene content of cows was 0.92 × 10–2 μmol / L, in the middle it increased to 1.17 × 10–2 μmol / L, by the end of lactation it was 1.36 × 10–2 μmol / l ($p < 0.05$). In colostrum and dry periods, the index of carotene content was 0.89–1.08 × 10–2 μmol / l. During the lactation period, a gradual increase in this indicator was noted, which we associate with the growth, development of the fetus and a decrease in milk production.

The amount of sugar in the blood of animals in the first 1-3 months of lactation was 4.38 mmol / L, at 4-7 months - 2.0 ($p < 0.05$), at 8-10 - 1.91 mmol / L ($p < 0.05$). During lactation, there was a significant decrease in blood sugar. Probably, this process is influenced by an increase in the level of metabolism and an increase in milk production at the beginning of lactation. During the dry period, a significant difference was also found in comparison with the control - 2.16 mmol / l ($p < 0.05$), associated with a decrease in metabolism. A slight increase in glucose levels in dry conditions compared with the end of lactation can be explained by the exclusion of silage containing butyric acid from the diet.

CONCLUSIONS

1. Before calving, the activity of serum lysozyme increases from 31.6% of light transmission in the control to 35.9% ($p < 0.05$) during the dry period.

2. The significant difference between the serum content of circulating immune complexes in the first 3 months and in subsequent periods of lactation is due to the fact that at the beginning of lactation the cows are not yet pregnant.

3. In the colostrum period, a high rate of circulating immune complexes is 116.1 units. ($p < 0.05$) - was defined as a consequence of prenatal immune attack of the fetus on the cow's body, when the system of mononuclear phagocytes has not yet coped with the elimination of neutralization products. During the dry period, the number of circulating immune complexes was 87.6 units. ($p < 0.05$). The decrease in the indicator was probably due to an increase in the activity of mononuclear phagocytes and the absence of a lactational load on the body.

4. In the colostrum period, the level of lymphocytes in the blood of animals is 62.0% ($p < 0.05$) and significantly differs from the control - 43.6%. During this period, a large number of immunoglobulins appears in the secretion of the mammary gland in cows, which provide protection for the newborn calf. There was a significant difference with the group of deep-bodied dry cows - 53.9% ($p < 0.05$). In the first 1-3 months of lactation, cows are either not yet pregnant, or a close bond (placenta) has not yet been formed between the mother and the fetus, therefore, the low activity of specific immunity

at this time is explained by the absence of foreign fetal antigens in the blood of cows.

5. A significant difference in the number of erythrocytes was found between the groups of 1-3 months and the colostrum period - 6.1 × 1012 / l ($p < 0.05$). The highest metabolic rate during lactation was noted in the first 7 days after calving.

6. The immune conflict associated with the stressed state of specific immunity before childbirth and the high content of immune complexes in the blood during the colostrum period contributes to a decrease in the barrier function by the placenta, which, in our opinion, is the main reason for the expulsion of the fetus from the cow's body.

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ИСПОЛЬЗОВАНИЕ ФРАКЦИОНИРОВАННОЙ БЕЛКОВО-ВИТАМИННОЙ МУКИ ИЗ ПШЕНИЧНЫХ ОТРУБЕЙ В РАЦИОНАХ ПЕРЕПЕЛОВ

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Представлены результаты эксперимента по использованию в рационе выращиваемых перепелов белково-витаминной муки из пшеничных отрубей, разделенной на фракции с размером частиц 140, 400 и 800 мкм. Опыт продолжительностью 60 дней проведен по общепринятой методике на перепелах японской породы, сформированных в суточном возрасте в четыре аналогичные группы (одна контрольная и три опытные) по 80 гол. в каждой. Все группы получали комбикорм (основной рацион), приготовленный с учетом возраста и физиологических особенностей перепелов, но в рационе молодняка 1, 2 и 3-й опытных групп часть пшеницы (7%) заменили пшеничной белково-витаминной мукой трех фракций с размером частиц 140, 400 и 800 мкм соответственно. Птицу содержали в клеточной батарее при соблюдении требуемых условий микроклимата. Изучено влияние скармливания фракционированной белково-витаминной муки из пшеничных отрубей на сохранность поголовья, интенсивность роста цыплят, показатели мясной продуктивности и гематологические показатели, изменение видового состава микроорганизмов желудочно-кишечного тракта. Определены оптимальные по эффективности продуктивного и физиологического действия фракции муки из пшеничных отрубей при использовании их в качестве нового кормового средства в рационах перепелов. При введении в комбикорм перепелов белково-витаминной муки из пшеничных отрубей с размером частиц 140 и 400 мкм в количестве 7% от зерновой части рациона повысились сохранность птицы на 3,0%, среднесуточный прирост живой массы на 2,30 и 5,59%, масса потрошеной тушки на 4,5 и 6,16%, содержание белка в мясе на 0,84 и 0,57%. Скармливание перепелам муки различных фракций не оказало положительного влияния на конверсию корма в продукцию. Биохимические показатели крови цыплят оставались в пределах физиологической нормы. Фракционированная белково-витаминная мука с размером частиц 400 и 800 мкм стимулировала рост бифидобактерий, с размером частиц 140 и 800 мкм сдерживала развитие кишечной палочки.

Ключевые слова: перепела, комбикорм, белково-витаминная мука, фракции, сохранность, живая масса, микрофлора

THE USE OF FRACTIONATED PROTEIN-VITAMIN FLOUR FROM WHEAT BRAN IN THE DIETS OF QUAILS

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The results of the experiment on the use of protein-vitamin flour from wheat bran, divided into fractions with particle size of 140, 400 and 800 μm in the diet of domesticated quails are presented. The experiment lasted for 60 days and was carried out according to the generally accepted methods on quails of the Japanese breed, formed in four similar groups (one control and three experimental), 80 heads each, at the age of one-day old. All groups received compound feed (the main diet), prepared taking into account the age and physiological characteristics of quails, but in the bird diet of the 1st, 2nd and 3rd experimental groups, part of the wheat (7%) was replaced with wheat protein-vitamin flour of three fractions with a particle size of 140, 400 and 800 μm, respectively. The poultry was kept in a battery cage under required microclimate conditions. The effect of feeding fractionated protein-vitamin flour from wheat bran was studied on the survival rate of quail chicks,

their growth rate, indicators of meat productivity and hematological parameters, changes in the species composition of microorganisms of the gastrointestinal tract. The optimal fractions of wheat bran flour as the new feed in the diets of quails were determined in terms of efficiency of their productive and physiological action. The introduction of protein-vitamin flour from wheat bran into the compound feed of quails with a particle size of 140 and 400 μm in the amount of 7% of the grain part of the diet increased the survival rate of quail chicks by 3.0%, the average daily gain in live weight by 2.30 and 5.59%, the weight of eviscerated bird carcass by 4.5 and 6.16%, protein content in meat by 0.84 and 0.57%. Feeding the quails with flour of various fractions did not have a positive effect on the conversion of feed into produce. The biochemical parameters of the quail chicks' blood remained within the physiological norm. Fractionated protein-vitamin flour with a particle size of 400 and 800 μm stimulated the growth of bifidobacteria, and with a particle size of 140 and 800 μm inhibited the development of Escherichia coli.

Keywords: quail, compound feed, protein-vitamin flour, fractions, survival rate, live weight, microflora

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INTRODUCTION

One of the most widespread innovations in animal husbandry is the use of feed additives to balance rations in terms of standardized nutrients and make them more complete. A feeding system based on the use of various feed additives is the best way to increase animal productivity, reduce feed consumption per unit of production and improve its quality.

A promising feed additive for poultry should be considered protein-vitamin flour, obtained by grinding wheat or rye bran in a finger-type mill with further fractionation and screen sizing. The resulting flour fractions (140, 400, 800 μm) are characterized by a different granulometric composition. During varietal milling of wheat and rye, biologically valuable morphological parts, such as shells, aleurone layer and germ, are separated from the grain. Cellulose and lignin are practically absent in the aleurone layer, which makes up from 6 to 9% of the mass of wheat kernels, but a higher content of soluble dietary fiber, ferulic acid, and lignans, which have significant antioxidant activity [1–8]. Small fractions of flour are enriched to a greater extent with elements of the aleurone layer and germ, the protein content of which reaches 35%. The protein of the obtained fractions significantly differs in amino acid composition from endosperm proteins and is characterized by better balance in amino acids [9, 10].

To assess the productive and physiological effect of fractionated wheat bran flour, it is advisable to use a model species of poultry - Japanese quails, which are phylogenetically closely related to broiler chickens (they also belong to the order of chickens of the Phasianidae family). The conclusions drawn from the results of experiments carried out on quails can be transferred to other bird species [11, 12].

The purpose of the research is to experimentally substantiate the effectiveness of using a new feed additive in feeding quails grown up to 60 days of age - fractionated protein-vitamin flour from wheat bran. The objectives of the study are to determine the effect of the feed additive on the safety and growth rate, indicators of meat productivity and biochemical parameters of blood, the species composition of the intestinal microflora of quails.

MATERIALS AND METHODS

An experiment lasting 60 days was carried out according to the generally accepted method on the quail farm of the physiological yard of the Siberian Scientific Research and Design Technological Institute of Animal Husbandry (SibNIPTIZh SFSCA RAS) on Japanese quails formed at one day old into four similar groups (one control and three experimental) 80 heads each[1].

The conditions of keeping the birds and the microclimate in the cage battery corresponded to the zootechnical requirements. All experimental quails were fed the same compound feed (main diet), prepared taking into account the age and physiological characteristics of the given bird species.

The intergroup differences were as follows: young animals of the control group consumed only compound feed, for poultry of the 1st, 2nd and 3rd experimental groups, part of the wheat (7%) of the main diet was replaced with protein-vitamin flour from wheat bran, divided into fractions with a particle size of 140, 400 and 800 μm, respectively. Fractionated flour from wheat bran (feed additive) used in the experiment was developed at the experimental stand of Siberian Branch of the Federal Scientific Center for Food Systems named after V.M. Gorbatov RAS (see Table 1).

Fractionated protein-vitamin flour from wheat bran can have various action models: increasing the efficiency of nutrient use in diets, activating animal immunity, stimulating the growth and development of young animals, egg production and reproductive function of poultry, improving and stabilizing the intestinal microflora.

The rations were made in accordance with the standards of the All-Russian Scientific Research Technological Institute of Poultry, Russian Academy of Sciences[2,3]. The compound feed contained a sufficient amount of metabolizable energy and essential nutrients. For the first 5 days, the chickens were fed boiled quail eggs in addition to the compound feed in order

Табл. 1. Характеристика опытных образцов белково-витаминной муки из пшеничных отрубей, разделенной на различные фракции, %

Table 1. Characteristics of control samples of protein-vitamin flour from wheat bran, divided into various fractions, %

Indicator	Fractions of protein-vitamin flour from wheat bran, microns		
	140	400	800
Exchange energy, MJ	13,76	12,98	13,06
Crude fat	2,28	3,52	3,05
Crude protein	17,52	12,36	13,43
Crude ash	3,93	4,43	5,53
Crude fiber	4,91	9,87	8,02
Nitrogen-free extractive substances	58,44	56,83	55,65
Calcium	0,625	0,550	0,649
Phosphorus	0,763	0,887	1,084
The amount of essential amino acids	10,493	8,340	9,786
The amount of nonessential amino acids	10,736	7,402	9,000
Amino acid index	0,977	1,127	1,087

[1]Methodology for conducting scientific and industrial research on feeding poultry / ed. by Fisinin V.I. and Imangulov Sh.A.. Sergiev Posad, 2000. 33 p.

to improve the adaptation of the quail to the external environment. The feed intake was taken into account daily by weighing the given feeds and their residues. Quail behavior and health were monitored daily.

Control weighing of poultry was carried out when setting up for experiment, at the age of 30 days and at 2 months after the end of the growing period. At the age of 60 days, quails were slaughtered (3 heads from each group).

The chemical composition of feed, flour from wheat bran and quail meat was investigated in the biochemical laboratory of SibNIPTIZh SFSCA RAS according to generally accepted methods of zootechnical analysis.

The biochemical composition of the poultry blood was determined in the biotechnology laboratory of the Institute of Experimental Veterinary Medicine of Siberia and the Far East of the Siberian Federal Scientific Center of the Russian Academy of Sciences.

The composition of the microflora isolated from the gastrointestinal tract of quails was determined in the laboratory for the regulation of microbiocinosis of farm animals and plants of SibNIPTIZh SFSCA RAS. When studying the microflora of the digestive tract of birds, we used the Hangate anaerobic technique and nutrient media (we used an extract from quail feces).

The digital material obtained in the experiment was processed by the method of variation statistics on a personal computer using the Microsoft Excel software.

RESULTS AND DISCUSSION

Compound feed for quails was prepared in accordance with the basic requirements for this type of poultry in terms of balance, high calorie content and the required degree of grinding. The composition of the feed consisted of the following components: feed wheat, full-fat soy beans, sunflower meal, fish meal, meat and bone meal, feeding yeast, vegetable fats, Ca / P mineral, feed chalk, premix. The percentage of compound feed ingredients and its nutritional value were different depending on the age of the bird (1–30 and 31–60 days). On average, 100 g of compound feed contained 1.26 MJ of metabolic energy, 26.4 MJ of crude protein, 3.7% crude fiber.

The introduction of fractionated flour from wheat bran into the quail compound feed had a noticeable effect on its palatability. During the growing period (60 days), the poultry of the experimental groups consumed compound feed by 14.55–25.02% more in comparison with the control analogues.

The safety of the livestock of chickens in the experimental groups turned out to be higher compared to the control by 2–3% (see Table 2).

Quails of the 1st and 2nd experimental groups had higher growth vigor and better conversion of feed into meat products. They exceeded the control counterparts in absolute gain in live weight by 2.31 and 5.68%, in average daily gain by 2.30 and 5.59% ($p > 0.05$).

The results of the control slaughter of poultry showed that the weight of the gutted carcass of quails of the 1st and 2nd experimental groups was more than in the control group by 4.50 and 6.16%, the slaughter yield was higher by 1.73 and 3.25% ($p > 0.05$) (see Table 3). The bird of the 3rd experimental group was 3.09% inferior to the control analogues in terms of gutted carcass weight.

The poultry meat of the 1st-3rd experimental groups, in comparison with the control analogues, contained less dry matter (by 2.94, 3.35 and 4.31%), as well as fat (by 1.96; 2.02 and 3, 37 times), but there was more protein (by 0.84, 0.57 and 0.83%) (see Table 4). The poultry meat of the experimental groups had a better balance in amino acids, as evidenced by a higher (1.17–1.50 times) amino acid index.

Biochemical blood parameters reflect the state of the bird's body and are closely related to its productivity. There was an increase in the total protein in the blood serum of quail chick-

[2]Recommendations for feeding poultry / ed. by Fisinin V. I., Imangulov Sh.A., Egorov I.A., Okolelov T.M., Sergiev Posad, 2003.142 p.

[3]Fisinin V.I., Egorov I.A., Okolelova T.M., Imangulov Sh.A. Feeding poultry: a textbook. Sergiev Posad, 2003.375 p.

Табл. 2. Сохранность, прирост живой массы и затраты корма на единицу прироста у цыплят-перепелов за период выращивания

Table 2. Survival rate, live weight gain and feed use per unit of weight gain of quail chicks during the growing period

Indicator	Group			
	control	experimental		
		1-st	2-nd	3-rd
Wheat bran flour fraction, microns	–	140	400	800
Survival rate, %	94	97	97	96
Live weight, g:				
at the beginning of the experiment	8,53 ± 0,08	8,57 ± 0,08	8,61 ± 0,08	8,50 ± 0,07
in 30 days	112,12 ± 2,23	110,74 ± 2,41	114,46 ± 2,10	106,96 ± 2,26
in 60 days	190,71 ± 2,61	194,96 ± 2,45	201,14 ± 2,43	189,47 ± 2,69
Absolute live weight gain, g:				
in 30 days	103,59 ± 2,06	102,17 ± 2,22	105,85 ± 1,94	98,46 ± 3,08
in 60 days	182,18 ± 2,49	186,39 ± 2,34	192,53 ± 2,33	180,97 ± 2,57
Average daily gain in live weight, g:				
in 30 days	3,45 ± 0,07	3,41 ± 0,07	3,53 ± 0,06	3,28 ± 0,07
in 60 days	3,04 ± 0,04	3,11 ± 0,04	3,21 ± 0,04	3,02 ± 0,04
Feed consumed, kg	1,251	1,433	1,564	1,433
Feed costs per 1 g of growth, g	6,87	7,74	8,12	7,97

ens of the 3rd experimental group by 8.71 g / l (21.69%) compared with the control and by 9.36-10.36 g / l (24.87-26, 91%) compared with the 1st and 2nd experimental groups. This trend also applies to the content of globulin, creatinine, AST and phosphorus in the blood. In general, the studied biochemical parameters of the entire experimental bird varied within the physiological norm.

As you know, the main representatives of the normal microflora of the intestines of poultry, including quail, are bifidobacteria and lactobacilli. Their conglomerates are localized on the intestinal mucosa, adjacent to the membranes of enterocytes, and can also be located in the immediate vicinity of the surface of the epithelium in the mucin layer covering the membranes of epithelial cells. Conditionally pathogenic microflora is constantly present in the intestine, the activity of which is restrained by the general resistance of the organism. The prominent representatives of this microflora in the intestines of birds are enterococci, streptococci and Escherichia coli.

Табл. 3. Результаты убоя подопытной птицы

Table 3. Results of slaughter of experimental poultry

Indicator	Group			
	control	experimental		
		1-st	2-nd	3-rd
Wheat bran flour fraction, microns	–	140	400	800
Pre-slaughter live weight, g	185,67 ± 0,67	189,67 ± 0,67	189,00 ± 0,58	177,67 ± 0,67
Gutted carcass weight, g	140,67 ± 0,88	147,00 ± 4,16	149,33 ± 0,88	136,33 ± 1,76
Slaughter yield, %	75,76 ± 0,33	77,49 ± 1,93	79,01 ± 0,23	76,73 ± 0,80

Табл. 4. Химический состав мяса цыплят перепелов, %
Table 4. Chemical composition of quail chick meat, %

Indicator	Group			
	control	control		
		1-st	2-nd	3-rd
Wheat bran flour fraction, microns	–	140	400	800
Dry matter	28,92 ± 0,19	25,98 ± 0,08	25,57 ± 0,30	24,61 ± 0,64
Fat	7,22 ± 0,20	3,69 ± 0,07*	3,57 ± 0,11*	2,14 ± 0,19*
Protein	20,66 ± 0,30	21,50 ± 0,09	21,23 ± 0,25	21,49 ± 0,48
Ash	1,02 ± 0,06	0,93 ± 0,04	0,89 ± 0,03	0,98 ± 0,05
Calcium	0,115 ± 0,003	0,156 ± 0,004	0,155 ± 0,004	0,204 ± 0,006
Phosphorus	0,234 ± 0,006	0,229 ± 0,006	0,209 ± 0,003*	0,199 ± 0,005*
The amount of essential amino acids	8,03	8,36	7,76	7,86
The amount of nonessential amino acids	10,50	9,38	6,99	6,87
Amino acid index	0,76	0,89	1,11	1,14

During the study of quail intestinal microbiosis, material was selected for sowing on special nutrient media in order to determine the main symbionts and pathogenic microorganisms. Obligate intestinal microflora of young monogastric animals and poultry is represented mainly by strict and facultative anaerobes.

Feed additives from fractionated flour, used in the diet of quails of the 2nd and 3rd experimental groups, stimulated the growth of bifidobacteria (increase in lg CFU/ g by 1.68 and 1.63 times). Fractionated flour fed to poultry of the 1st and 3rd experimental groups inhibited the development of E. coli (decrease in lg CFU/ g by 1.6 and 1.88 times) (see Table 5).

CONCLUSIONS

1. The optimum particle size of fractionated protein-vitamin flour from wheat bran, introduced into the diet of quail in the amount of 7% of its grain part, is 140 and 400 μm for chickens raised for 60 days. Feeding poultry with compound feed, consisting of flour with a particle size of 140 and 400 microns, increases the safety of young animals by 3.0%, the average daily gain in live weight by 2.30 and 5.59%, improves the meat productivity of quails (an increase in the weight of gutted chicken carcasses by 4.50 and 6.16%, protein content in meat by 0.84 and 0.57%).

2. The use of fractionated flour from wheat bran in the amount of 7% of the grain portion of the diet does not have a positive effect on the conversion of feed into products.

3. Fractionated bran flour with a particle size of 400 and 800 microns stimulates the growth of bifidobacteria (an increase in lg CFU/ g by 1.68 and 1.63 times), with a particle size of 140

Табл. 5. Видовой состав микрофлоры кишечник перепелов, lg КОЕ/г
Table 5. Species composition of microflora intestines of quails, lg CFU/g

Indicator	Group			
	Control	experimental		
		1-st	2-nd	3-rd
Wheat bran flour fraction, microns	–	140	400	800
Type of microorganism:				
Lactobacillus	9,0	10,1	9,4	10,7
Bifidobacterium	7,3	7,1	12,3	11,9
Enterococcus	6,0	7,3	5,1	7,0
Escherichia coli	3,2	2,0	3,4	1,7

and 800 microns inhibits the development of E. coli (a decrease in lg CFU/ g in 1, 6 and 1.88 times).

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ВЛИЯНИЕ МИКРОБИАЛЬНЫХ ПРЕПАРАТОВ ВЕТОМ 1 И ВЕТОМ 20.76 НА ИНТЕНСИВНОСТЬ РОСТА ГУСЕЙ

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Представлены результаты исследования влияния новых микробиальных препаратов на динамику абсолютной массы и среднесуточного прироста гусей. В научном эксперименте применяли пробиотики Ветом 20.76 на основе хищного гриба *Arthrobotrys oligospora* и Ветом 1 на основе живых спорообразующих бактерий штамма *Bacillus subtilis* DSM 32424, обладающих противогельминтным, противовирусным и противогрибковым действием. По принципу пар-аналогов сформировали одну контрольную и четыре опытных групп по 10 гусят в каждой в возрасте 1 мес. Гусятам опытных групп применяли препарат Ветом 20.76 в различной дозировке: молодняку 1-й опытной группы – 0,5 мкл/кг живой массы тела, 2-й – 1 мкл/кг, 3-й – 2 мкл/кг. Гусятам 4-й опытной группы давали Ветом 1 в дозе 50 мг/кг живой массы тела. Оба препарата применяли в утренние часы с водой ежедневно один раз в сутки в течение 30 сут. Гусям контрольной группы указанные препараты не назначали. Установлено, что препараты Ветом 20.76 в дозах 0,5; 1 и 2 мкл/кг массы тела и Ветом 1 в дозе 50 мг/кг массы тела обладают ростостимулирующим действием при применении его гусятам в течение 30 сут. Интенсивность роста опытной птицы зависела от дозы применяемых препаратов. Оптимальные результаты получены при применении Ветома 20.76 в дозе 2 мкл/кг массы тела и Ветома 1 в дозе 50 мг/кг массы тела один раз в сутки на протяжении 30 сут. Среднесуточный прирост живой массы опытных гусей повышался в 3-й, 4-й опытных группах на 5,24 и 20,60% в первые 15 сут эксперимента и на 24,8 и 44,64% в период последействия препарата.

Ключевые слова: пробиотик, Ветом, гуси, масса тела, среднесуточный прирост

EFFECT OF MICROBIAL PREPARATIONS VETOM 1 AND VETOM 20.76 ON GROWTH INTENSITY OF GEESE

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The results of the study on the effect of new microbial preparations on the dynamics of the absolute weight and average daily gain of geese are presented. In the scientific experiment, probiotics Vetom 20.76 based on the predatory fungus *Arthrobotrys oligospora* and Vetom 1 on the basis of live spore-forming bacteria of the *Bacillus subtilis* DSM 32424 strain, which have anthelmintic, antiviral and antifungal effects, were used. One control and four experimental groups of 10 goslings each at the age of 1 month were formed according to the principle of analog pairs. The goslings of the experimental groups received Vetom 20.76 in various dosages: young birds of the 1st experimental group – 0.5 μl/kg of live body weight, the 2nd – 1 μl/kg, the 3rd – 2 μl/kg. Goslings of the 4th experimental group were given Vetom 1 at a dose of 50 mg/kg of live body weight. Both drugs were given in the morning with water, once a day for 30 days. These drugs were not prescribed to geese of the control group. It was established that Preparations Vetom 20.76 in doses of 0.5; 1 and 2 μl/kg

of body weight and Vetom 1 at a dose of 50 mg/kg of body weight have a growth-stimulating effect when given to goslings for 30 days. The growth rate of the experimental birds depended on the dose of the drugs used. Optimal results were obtained with the use of Vetom 20.76 at a dose of 2 μl/kg of body weight and Vetom 1 at a dose of 50 mg/kg of body weight once a day for 30 days. The average daily gain in live weight of the experimental geese increased in the 3d and 4th experimental groups by 5.24 and 20.60% in the first 15 days of the experiment and by 24.8 and 44.64% during the aftereffect of the drug.

Keywords: probiotic, Vetom, geese, body weight, average daily gain

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The authors declare no conflict of interest.

INTRODUCTION

Poultry farming is one of the most intensive and dynamically developing branches of the agro-industrial complex. Goose breeding is a highly profitable poultry industry. Increasing productivity and producing environmentally friendly products is a priority in goose breeding. This goal can be achieved by reducing the use of antibiotics, reducing their negative impact on the quality of feed, as well as reducing the impact of harmful environmental factors on the body of the bird [1, 2].

One of the ways to bring about positive changes in the body of the bird is the use of probiotics. They are used in poultry farming as feed additives and biological regulators of metabolic processes in the poultry body. Probiotics stabilize the digestive system, destroy pathogenic bacteria and secrete special enzymes that enable the bird to better absorb nutrients, increase its safety and productivity, and reduce feed costs per unit of production [3–8]. The use of probiotics of the Vetom series is very promising for the cultivation of poultry, in particular geese[1–3] [9, 10].

Among probiotics, much attention has recently been paid to new drugs based on predatory apathogenic fungi (Duddingtonia flagrans and Arthrobotrys oligospora), which have anthelmintic, antiviral and antifungal effects. The preparations based on the Duddingtonia flagrans and Arthrobotrys oligospora strains are classified as probiotics [11, 12].

The aim of the study was to study the effect of microbial preparations Vetom 20.76 based on the predatory fungus Arthrobotrys oligospora and Vetom 1 based on Bacillus subtilis on the growth rate of geese.

MATERIALS AND METHODS

The research and production experience was carried out on the basis of the physiological

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yard of the RPC "Research Center" (Koltsovo settlement, Novosibirsk region).

Throughout the experiment, the bird was kept in floor cages on a deep permanent bed under natural conditions and light. When feeding, we used "Delta Feeds" compound feed for poultry from "BioPro". The keeping and feeding of the poultry corresponded to the sanitary and hygienic standards.

The studies were carried out on goslings at the age of 1 month. Four experimental groups and one control group, 10 goslings in each, were formed according to the principle of analogue pairs. Before the start of the experiment, the goslings were quarantined for 2 weeks.

Goslings of the 1-3rd experimental groups were given Vetom 20.76 daily with water once a day for 30 days at a dose of 0.5; 1 and 2 μl / kg of live body weight, respectively. Young animals of the 4th experimental group Vetom 1 were given daily once a day for 30 days at a dose of 50 mg / kg of live body weight. The poultry of the control group were not prescribed these drugs.

The determination of the absolute mass was carried out on an electronic balance before the start of the experiment, on the 15th, 30th and 60th days. The average daily gain was calculated as a quotient of the difference in mass and the period between their measurements.

RESULTS AND DISCUSSION

Before the experiment, the absolute weight of geese in the experimental and control groups had no significant differences (see Table 1).

On the 15th day of the experiment, the median of the increase in the absolute weight of the geese of the 1st to 4th experimental groups was higher in relation to the control by 13.09 ($p < 0.01$); 8.33; 8.96 and 12.94, respectively. On the 30th day of the experiment, the increase in the absolute weight of the geese of the 1st-4th experimental groups was higher than that of the analogs from the control group, by 4.25; 2.87; 4.02; 6.78% respectively. On the 60th day, the median of the absolute weight gain in the geese of the 2nd experimental group was 2.44% lower in relation to the control, in the geese of the 1st, 3rd and 4th experimental groups it was higher by 4.88; 9.76 and 12.2%, respectively.

The growth rate of geese increased with the use of the drug. Mass accumulation was recorded using Vetom 20.76 at a dose of 2 μl / kg of live weight and Vetom 1 at a dose of 50 mg / kg of live weight (see Fig. 1).

According to the results of the study, the average daily gain in live weight of geese in the experimental groups increased (see Table 2).

From the 1st to the 15th day, the median of the average daily gain in the geese of the 1st and 2nd experimental groups was lower in rela-

Табл. 1. Динамика абсолютной массы гусей, г
Table 1. Dynamics of the absolute mass of geese, g

Group	24-hour period		
	15-th	30-th	60-th
Control	2635,00 ± 67,85	3480,00 ± 119,45	4100,00 ± 210,45
Experimental: 1-st	2980,00 ± 69,92**	3628,00 ± 90,01	4300,00 ± 134,78
2-nd	2854,50 ± 90,97	3580,00 ± 107,36	4000,00 ± 203,27
3-rd	2871,00 ± 114,38	3620,00 ± 114,67	4500,00 ± 240,21
4-th	2976,00 ± 117,94	3716,00 ± 124,86	4600,00 ± 275,05

Here and in table. 2:
*$p < 0,05$.
**$p < 0,01$.
***$p < 0,001$.

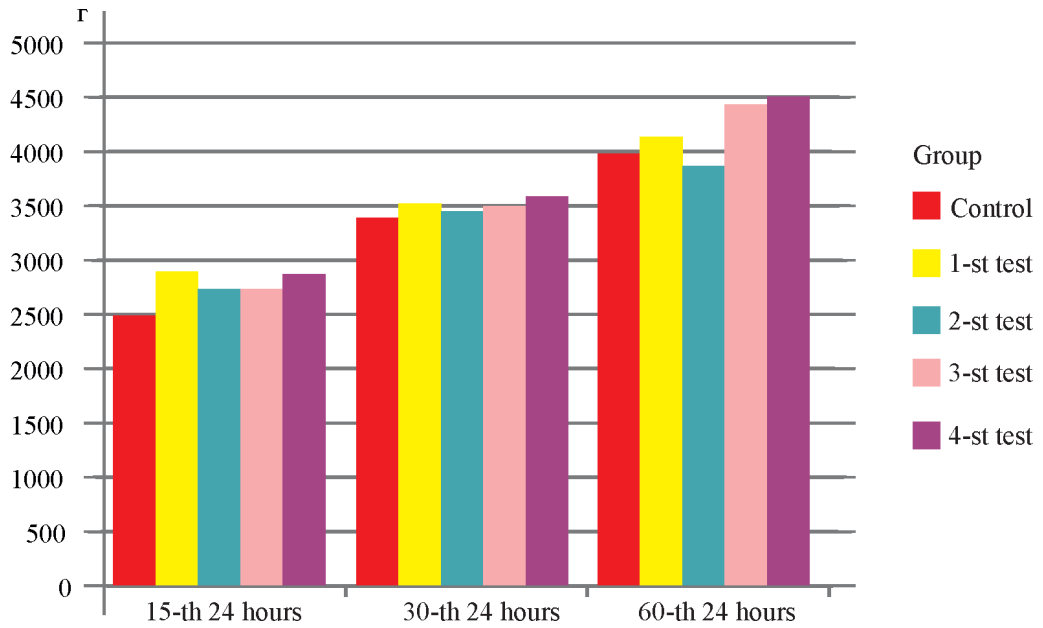

Рис. 1. Динамика абсолютной массы гусей
Fig. 1. Dynamics of the absolute mass of geese

Табл. 2. Среднесуточный прирост живой массы гусей, г
Table 2. Average daily gain in live weight of geese, g

Group	24-hour period			
	1–15-th	15–30-th	30–60-th	1–60-th
Control	99,20 ± 2,36	61,33 ± 2,87	20,83 ± 5,50	50,33 ± 2,93
Experimental: 1-st	98,90 ± 1,87	45,87 ± 2,10***	26,27 ± 2,28	49,20 ± 1,43
2-nd	93,73 ± 2,82	52,83 ± 2,99	14,47 ± 3,60	44,73 ± 2,04
3-rd	104,40 ± 6,85	51,27 ± 4,02 *	26,00 ± 4,75	52,15 ± 3,81
4-th	119,63 ± 4,44**	51,47 ± 2,38*	30,13 ± 4,46	57,25 ± 3,44

tion to the control - 0.3 and 5.51%, respectively, in the geese of the 3rd and 4th experimental groups. groups - higher by 5.24 and 20.60% ($p < 0.01$). From the 15th to the 30th day, the median of the average daily gain in geese from the 1st to 4th experimental groups was lower in relation to the control by 25.22 ($p < 0.001$); 13.86; 16.41 ($p < 0.05$) and 16.09% ($p < 0.05$), respectively. From the 30th to the 60th day, the median of the average daily gain in the geese of the 2nd experimental group was lower in relation to the control by 30.56%, respectively, in the geese of the 1st, 3rd and 4th experimental groups - higher by 26.08; 24.8 and 44.64% respectively.

Over the entire period of the experiment from the 1st to the 60th day, the median of the average daily gain in geese of the 3rd and 4th experimental groups was higher in relation to the control by 3.63 and 13.76%, respectively, in the geese of the 1st and The 2nd experimental group is 2.24 lower; 11.11%.

In the first 15 days of the experiment, an increase in the average daily gain in geese occurred both with the introduction of Vetom 20.76 at a dose of 2 µl / kg of live weight, and

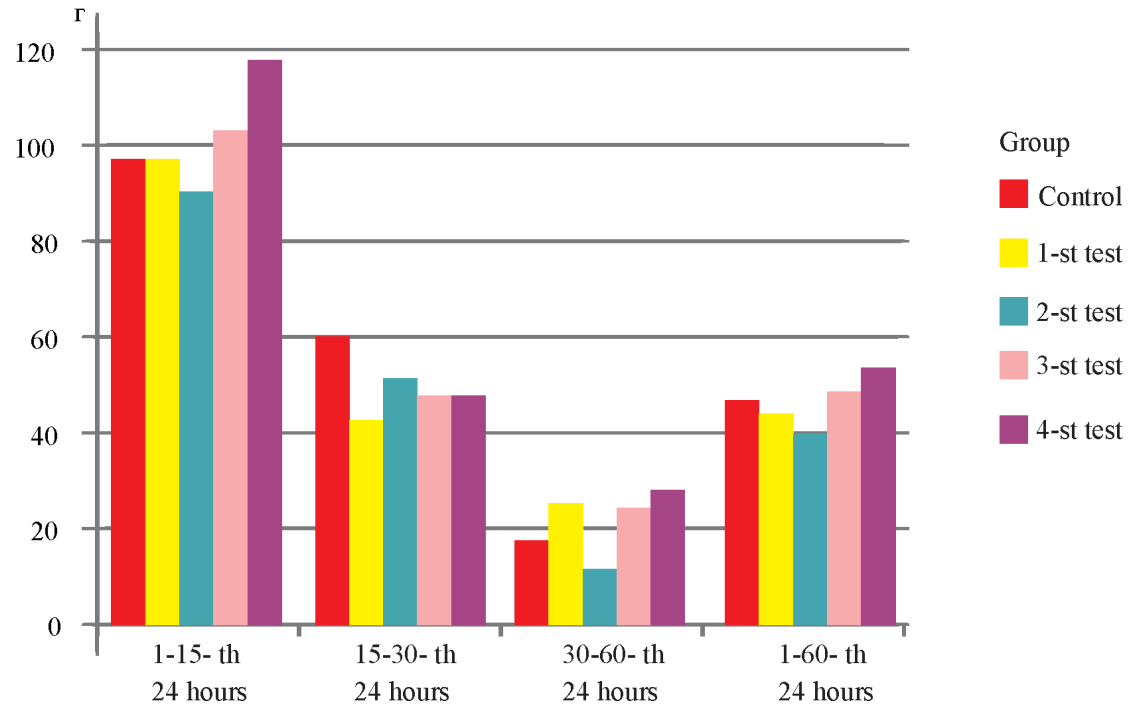

Рис. 2. Динамика среднесуточного прироста гусей, г
Fig. 2. Dynamics of the average daily gain of geese, g

with the use of Vetom 1 at a dose of 50 mg / kg of live weight (see Fig. 2). Throughout the entire experiment and during the aftereffect of the drug (30-60th day), a pronounced average daily increase was noted with the introduction of Vetom 1 at a dose of 50 mg / kg of live body weight.

CONCLUSIONS

1. Preparations Vetom 20.76 in doses of 0.5; 1 and 2 µl / kg of body weight and Vetom 1 at a dose of 50 mg / kg of body weight have a growth-stimulating effect when applied to goslings for 30 days.

2. The growth rate of the experimental bird depended on the dose of the drugs used. Optimal results were obtained when using Vetom 20.76 at a dose of 2 µl / kg of body weight and Vetom 1 at a dose of 50 mg / kg of body weight once a day for 30 days.

3. The average daily gain in live weight of the experimental geese increased in the 3rd and 4th experimental groups by 5.24 and 20.60% in the first 15 days of the experiment and by 24.8 and 44.64% during the aftereffect of the drug.

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КАЛЬЦИЙ КАК ИНГИБИТОР АКТИВНОСТИ ТРИПСИНА В ПАНКРЕАТИЧЕСКОМ СОКЕ КУР

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Представлены результаты изучения взаимодействия кальция и панкреатических ферментов у кур кросса Хайсекс белый 46-недельного возраста. Показано, что одновременно с всасыванием в желудочно-кишечном канале птиц происходит эндогенная экскреция кальция с пищеварительными соками. Определено влияние кальция на активность трипсина в эксперименте *in vitro*. В опыте вводили разные дозы кальция (5,0; 7,5; !0,5; 12,5 и 25,0 мг) в панкреатический сок кур, предварительно разведенный физиологическим раствором в 10 раз. Число повторов в каждом варианте опыта 20 раз. Для опыта применяли кальций хлористый 2-водный (ХИММЕД, РФ). Активность трипсина устанавливали кинетическим методом. Содержание кальция определяли биохимическим анализатором Sinnowa BS-3000P (КНР) и набором для определения кальция в крови животных ДИАКОН-ВЕТ (РФ). Установлено, что в панкреатическом соке кур содержится до 2,9 ± 0,03 ммоль кальция/л, что сопоставимо с уровнем кальция в сыворотке крови 1,99 ± 0,10 – 3,13 ± 0,20 ммоль/л. Определено, что кальций оказывает ингибирующее влияние на активность трипсина. Увеличение кальция в панкреатическом соке кур в 5 раз снижает активность трипсина на 34,7%. По данным дисперсного анализа, концентрация кальция в панкреатическом соке влияет на активность трипсина, сила влияния фактора достоверна и составляет 92%. Установлена устойчивая отрицательная корреляция между содержанием кальция в панкреатическом соке и активностью трипсина $r = –0.78$, что согласуется с корреляцией соответствующих показателей в крови. Это позволяет рассматривать кальций вместе с протеазами как элемент, регулирующий процессы метаболизма в организме кур.

Ключевые слова: панкреатический сок кур, кальций, трипсин, ингибитор

CALCIUM AS AN INHIBITOR OF TRIPSIN ACTIVITY IN PANCREATIC JUICE OF CHICKEN

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The results of studying the interaction of calcium and pancreatic enzymes in 46-week-old Hisex white chickens are presented. It is shown that intestinal absorption of calcium is accompanied by endogenous excretion of calcium with digestive juices. The effect of calcium on tryptic activity in an *in vitro* experiment was determined. In the experiment, different doses of calcium (5.0; 7.5; 0.5; 12.5 and 25.0 mg) were injected into the pancreatic juice of chickens, previously diluted with physiological solution 10 times. The number of repetitions in each variant of the experiment was 20 times. For the experiment, 2-aqueous calcium chloride (Chimmed, RF) was used. Trypsin activity was determined by the kinetic method. The content of calcium was determined with a Sinnowa BS-3000P biochemical analyzer (China) and a set for the determination of calcium in the blood of animals DIAKON-VET (RF). It was found that pancreatic juice of chickens contains up to 2.9 ± 0.03 mmol of calcium/l, which is comparable to the level of calcium in the blood serum of 1.99 ± 0.10 – 3.13 ± 0.20 mmol/l. The inhibiting effect of calcium on the tryptic activity was found. A five-fold increase in calcium in pancreatic juice of chickens reduces the activity of trypsin by 34.7%. According to

the analysis of variance, the concentration of calcium in pancreatic juice affects tryptic activity, the reliability of the effect is confirmed by 92%. A stable negative correlation was established between calcium content in pancreatic juice and activity of trypsin r = –0.78, which is consistent with the correlation of the corresponding parameters in the blood. These findings serve as evidence that calcium together with proteases can be regarded as an element that regulates metabolic processes in chickens.

Keywords: pancreatic juice of chickens, calcium, trypsin, inhibitor

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INTRODUCTION

Calcium in the body of chickens plays an extremely important role in the formation of the skeleton and shell of eggs. In addition, calcium is involved in the contraction of muscle fibers, affects the automation, processes of excitation and contraction of the heart, in blood coagulation, activates a number of enzymes and stabilizes the trypsin of pancreatic juice [1]. Calcium is found in bone tissue, muscles, and biological fluids in the body of animals. Simultaneously with absorption in the gastrointestinal canal of birds, endogenous excretion of calcium with digestive juices occurs. Studies have established that the pancreatic juice of chickens contains up to 2.9 ± 0.03 mmol of calcium / l, which is comparable to the level of calcium in the blood serum - 1.99 ± 0.10 - 3.13 ± 0.20 mmol / l [2]. The norms of calcium in the diet of chickens at different age periods vary depending on the need for a macronutrient. With a high level of calcium, the degree of its assimilation by hens decreases both in absolute and in relative terms [3]. An increase in the diet of layers of calcium above the norm is impractical. Instead of the expected improvement in shell quality, the opposite results are often obtained. Excess calcium inhibits the absorption of trace elements (zinc, manganese, iron, possibly copper) and impairs the absorption of plant (phytate) phosphorus. The introduction of excessive amounts of calcium into compound feed (in Russia, usually in the form of chalk) impairs their taste and eatability by poultry.

The aim of the research is to determine the effect of calcium on the activity of trypsin in the digestive juice of chickens in an in vitro experiment.

Objectives of the study - to study the activity of trypsin against the background of different doses of calcium in the pancreatic juice of Hisex white hens; to carry out an analysis of variance of the influence of the amount of calcium on the activity of trypsin in pancreatic juice, to calculate the correlation between the signs in the pancreatic juice and the blood plasma of chickens.

MATERIALS AND METHODS

The studies were carried out in the conditions of the physiology laboratory of the Federal Scientific Center "All-Russian Research and Technological Institute of Poultry" of the Russian Academy of Sciences in 2020. The object of the study is pancreatic juice obtained in chronic experiments from 46-week-old Hisex white chickens operated on according to the method of Batoev TS. ZH. [4]. Trypsin activity was determined by the kinetic method [5]. The calcium content was determined using a semi-automatic biochemical analyzer Sinnowa BS-3000P (China) and a kit for determining calcium in the blood of animals by the company "DIAKON-VET" (RF). First, the basic activity of trypsin, which was in the pancreatic juice of chickens, was determined. For the experiment, the juice was preliminarily diluted with physiological solution 10 times so that its proteolytic

activity corresponded to the duodenal chyme in chickens. Then, different doses of calcium were injected into the tubes with juice, starting from 5.0 mg, increasing the amount of the mineral by 0.25 mg in each next tube, up to 12.5 and 25.0 mg. For the experiment, we used calcium chloride 2-water (HIMMED, RF). Studies of the activity of trypsin in each of the tubes with calcium were repeated at least 20 times.

For statistical processing of the results, Excel was used to calculate the mean (M), mean square deviation (± m), correlation, and also used the Microsoft Office analysis package to perform the ANOVA. The significance of the differences was established by the Student's t-test; the differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

The results of the study, obtained in vitro, showed that the activity of trypsin in the pancreatic juice of chickens changes with the addition of different doses of calcium (see table. 1). The data in the table indicate that calcium has an inhibitory effect on the activity of trypsin. The sharpest periods of decrease in enzyme activity were noted between the first and second test tubes (by 17.0%, $p < 0.05$), the third and fourth - (by 15.6%, $p < 0.05$). In general, with an increase in calcium in the pancreatic juice of chickens by 5 times, the activity of trypsin decreases by 34.7%.

The conducted analysis of variance showed that there is a relationship between the content of calcium in pancreatic juice and the activity of trypsin (see Tables 2, 3). The strength of the factor's influence (the amount of calcium) is reliable and amounts to 92.0%.

Correlation analysis showed that between the calcium content and the activity of trypsin in the pancreatic juice of chickens, there is a stable inverse relationship, the coefficient of which is minus 0.78.

According to the results of a biochemical study of biochemistry in the blood of laying hens, a stable inverse correlation between calcium and trypsin activity was noted (see figure), $r = –0.51$.

The data obtained are consistent with the results of studies by A.G. Mikhailova et al. [6] on the possibility of regulation with the help of calcium ions of undesirable side hydrolysis when using enteropeptidase. Changes in the content of calcium in the blood of broiler chickens and their progenitors in ontogenesis have been established, which may have an effect on metabolism [7]. Thus, in 1-day-old chickens, the amount of calcium in the blood plasma was markedly low, but already in the first week of postembryonic life, it increased by 38.7% and remained at this level up to 35 days. In the blood plasma of 1-day-old chickens, a high activity of trypsin was observed, which could be associated with the production of a sufficient number of inhibitors that inhibit the activity of the enzyme during embryogenesis. By the age of 7 days, trypsin activity decreased in broiler chickens by 11.8 times. Subsequently, a gradual decrease in this indicator was observed both in absolute terms and in relation to live weight. In general, the relative indicator of trypsin activity per unit of live weight decreased by 501 times over the 35-day study period in broiler

Табл. 1. Активность трипсина на фоне разных доз кальция в панкреатическом соке кур
Table 1. Trypsin activity depending on the doses of calcium in chicken pancreatic juice

The amount of calcium in the test tube, mg / (mmol / l)	Trypsin activity, units / l				
	First test tube	Second test tube	Third test tube	Fourth test tube	Fifth test tube
5,0/3,95	124,8 ± 3,35				
7,5/5,87		103,7 ± 2,82			
10,0/8,07			100,0 ± 0,70		
12,5/10,30				84,4 ± 0,47	
25,0/20,38					81,5 ± 2,21

Табл. 2. Однофакторный дисперсионный анализ взаимосвязи кальция и трипсина
Table 2. One-way ANOVA of the relationship between calcium and trypsin

Group	Count	Sum	Mean	Dispersion
Calcium concentration	5	1,2	0,24	0,02425
Trypsin activity	10	989,689	98,9689	304,5126677

Табл. 3. Дисперсионный анализ влияния количества кальция на активность трипсина панкреатического сока
Table 3. ANOVA of the influence of calcium amount on the activity of trypsin in pancreatic juice

The source of variation	The sum of squared deviations (*SS*)	The degree of freedom (*Df*)	Mean square (*Ms*)	Actual distribution criterion (*F*)	*p* – value*	Theoretical distribution criterion (*F*-critical)
Between groups	32491,32	1	32491,32	154,1159011	1,38935E-08	4.667192732
Within groups	2740,711	13	210,8239			
Total	35232,03	14				
The power of influence 92,0%						

* The probability that the variance reproduced by the equation is equal to the variance of the residuals.

chickens. In addition, calcium ions are markers of the state of the pancreas in its pathology [8, 9]. Pancreatitis is currently a common and severe disease that has no specific therapy and is characterized by an insufficiently studied pathogenesis. Calcium (Ca (2+)) is a universal carrier of signals that regulate many aspects of cellular activity. It controls the secretion of digestive enzymes in the acinar cells of the pancreas. The Ca (2+) reload is a key early event in the pathogenesis of many diseases. In pancreatic acinar cells, abnormal Ca (2+) calcium ions are a key factor in initiating cell damage. Due to the long and constant action of Ca (2+), trypsin is activated, vacuolization and necrosis, which are crucial in the development of pancreatitis. Consequently, in pancreatitis, calcium, on the contrary, is an activator of trypsin, and not its inhibitor, as under normal conditions. Research by O. Gryshchenko et al. [10] also found that Ca (2+) signals in stellate cells provide an amplification loop that promotes the death of acinar cells. The initial release of kallikrein and trypsin proteases from dying acinar cells may, through the generation of bradykinin and protease-activated receptors, induce CA (2+) signals in stellate cells. They can then damage acinar cells and thereby induce additional release of proteases [10]. The authors point to the possible participation of nitric oxide in this process, the connection with which trypsin was established in studies on poultry [11].

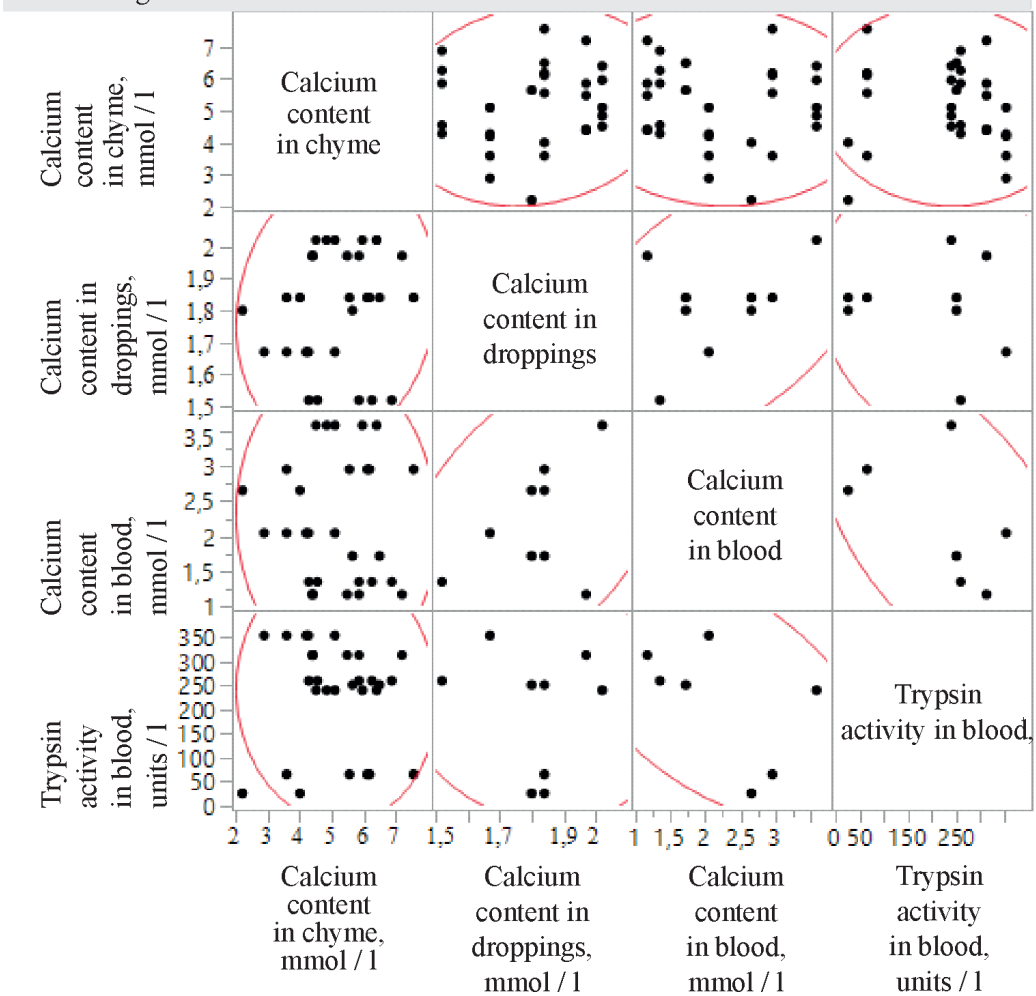
Magnesium is a natural calcium antagonist [12]. An increase in the concentration of calcium in the blood and its introduction into the duodenum enhances the secretion of all pancreatic enzymes, which is not consistent with the results of our study. However, in chronic pancreatitis, the concentration of calcium in pancreatic juice decreases in parallel with the debit of enzymes [12]. Magnesium is also excreted in the pancreatic juice simultaneously with calcium, which indicates its important role in the secretory process of the pancreas. This is confirmed by data on chickens [13].

Thus, calcium in in vitro experiments in chicken pancreatic juice has an inhibitory effect on trypsin activity. The analysis of variance carried out showed that between the content of calcium in pancreatic juice and the activity of trypsin, there is a strong relationship equal to 92.0%. In this case, an inverse correlation is observed, which is characteristic of the indicators of trypsin activity and the calcium content in

Correlation between the activity of trypsin and calcium in biological matrix of chickens

Correlations	Calcium in chyme	Calcium in droppings	Calcium in blood	Trypsin activity in blood
Calcium in chyme	1,0000	0,1267	-0,0420	-0,0413
Calcium in droppings	0,1267	1,0000	0,4718	-0,1496
Calcium in blood	-0,0420	0,4718	1,0000	-0,5143
Trypsin activity in blood	-0,0413	-0,1496	-0,5143	1,0000

Scatter diagram matrix



Корреляция между активностью трипсина и кальцием (Ca) в биологических средах кур (рассчитана в программном обеспечении JMP Trial 14.1.0, производитель SAS Institute, USA Carolina)

Correlation between trypsin activity and calcium (Ca) in biological media of chickens (calculated using JMP Trial 14.1.0 software, manufactured by SAS Institute, USA Carolina)

the blood. The new knowledge gained on the interaction of calcium and trypsin activity allows us to make an assumption about the regulatory function of trypsin and calcium in the metabolism of poultry.

CONCLUSIONS

1. According to the research results, the concentration of calcium in the pancreatic juice of birds affects the activity of trypsin, the strength of the factor's influence is reliable and amounts to 92%.

2. The correlation between the calcium content in pancreatic juice and the activity of trypsin has a stable negative character with a coefficient of minus 0.78, which is consistent with the correlation of the corresponding signs in the blood.

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ПРИЛОЖЕНИЕ ДЛЯ СМАРТФОНА ПО ОБНАРУЖЕНИЮ ГРИБНЫХ БОЛЕЗНЕЙ ЛИСТЬЕВ РАСТЕНИЙ

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Описаны симптомы и биофизические процессы, протекающие в землянике садовой при поражении ее доминирующим видом болезни (до 80%), вызванной грибами-возбудителями. Показана неэффективность визуальной оценки степени поражения болезнями земляники по условной 5-балльной шкале или в процентном отношении по площади, пораженной грибами листовой пластины, с привлечением квалифицированных специалистов. Для создания средств диагностики, позволяющих заранее обнаружить грибные болезни земляники садовой, предложен один из методов компьютерного зрения путем подсчета пикселей изображения в пространстве цветовых каналов красного, зеленого и синего цвета (R, G, B). Данный метод дает возможность определять степень поражения грибными болезнями отдельного листа растения. Алгоритм включает захват изображения с помощью цифровой камеры путем фокусировки на листе растения, размещенном на подложке с равномерным фоном, обеспечивающим контрастное выделение объекта; преобразование цветного изображения в черно-белое; разделение изображения между областями с некротическими пятнами и здоровыми областями листа растения с помощью маскирования и удаления пикселей; подсчет количества пикселей в этих двух областях и расчет их соотношения. Приведены сведения о компьютерной программе определения степени поражения листа земляники садовой грибными болезнями. В качестве языка для разработки логической части информационной системы использован язык программирования Java (операционная система Android Studio 3.4.1). Для построения графического интерфейса использовано обеспечение, облегчающее разработку и объединение разных модулей программного проекта LibGDX. Предлагаемый алгоритм реализован для персонального компьютера и может в виде программного приложения устанавливаться на смартфон, с помощью которого любой сельхозпроизводитель может осуществлять раннюю диагностику грибных болезней растений.

Ключевые слова: земляника садовая, диагностика, болезни, степень поражения, компьютерное зрение, смартфон

APP FOR SMARTPHONE FOR DETECTING FUNGUS DISEASES OF PLANT LEAVES

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The symptoms and biophysical processes occurring in garden strawberry plants when they are affected by the dominant type of disease (up to 80%) caused by pathogenic fungi have been described. The ineffectiveness of the visual assessment of the degree of damage to strawberry diseases by a conventional 5-point scale or as a percentage of the leaf plate area affected by fungi, with the involvement of qualified specialists, has been shown. To create diagnostic tools that allow early detection of fungal diseases of garden strawberries, one of the methods of computer vision was proposed by counting image pixels in the space of color channels of red, green and blue (R, G, B), which makes it possible to determine the degree of fungal diseases affecting an individual plant leaf. The algorithm includes capturing an image with a digital camera by focusing on a plant leaf placed on a substrate with a uniform background providing a contrasting selection of the object; converting a color image to black and white; dividing the image between areas with necrotic spots and healthy areas of the plant leaf by masking and removing pixels; counting the number of pixels in these two areas and calculating their ratio. Information about a computer software for determining the degree of damage to a strawberry leaf by garden fungal diseases has been given. Java programming language (operating system Android Studio 3.4.1) was used as a language for the development of the logical part of the information system. In order to build a graphical interface, the software facilitating the development and integration of various modules of the LibGDX software project was used. The proposed algorithm is implemented for a personal computer and can be installed on a smartphone in the form of a software application, with the help of which any agricultural producer can carry out early diagnosis of fungal plant diseases.

Keywords: garden strawberry, diagnosis, diseases, degree of damage, computer vision, smartphone.

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INTRODUCTION

Products from plant materials not only provide the body with nutrients, but also contain a whole range of useful minerals, vitamins, and also increase the body's resistance to various diseases, i.e. are functional products [1]. Garden strawberry nutritious has an abundant biochemical composition and has high taste, valuable medicinal properties and an attractive appearance.

However, garden strawberries are affected by over 30 fungal, viral and bacterial diseases. Most diseases (about 80%) are caused by fungi [2]. Plant diseases are considered occupational hazards because they are difficult to detect and identify in advance. It is important for growers to detect diseases at an early stage in order to control their spread.

The earliest responses of plant cells to the action of pathogens and the elicitors produced by them (elicitors are exometabolites of the pathogen that bind to the host receptor and trigger a protective reaction) are an increase in the content of calcium ions and protons in the cytosol, a change in the parameters of the transport system of the plasma membrane, including rectifying selective potassium channels, electrogenic hydrogen ATPase pump, calcium-permeable and non-selective cation channels, and depolarization of the plasmalemma and tonoplast [3]. In addition, elicitors “turn on” various signal-

ing systems of plant cells, which leads to the expression of protective genes, the synthesis of the corresponding proteins (antigens), the formation of phytoalexins - secondary metabolites that are never present in a healthy plant, the bulk of which are localized around the site of injury [3] . Phytoalexins lead to a slowdown in the synthesis of enzymes of the fungal phytopathogen, a slowdown in its growth, and sometimes its destruction. The synthesis of phytoalexins is taken over by healthy cells surrounding the necrosis. It is in them that these substances are formed, and then are directed towards danger - into the necrotic cells in which the parasite is located. It is also known that when the causative agents of fungal diseases are damaged, the hosts do not die quickly, but the intensity of photosynthesis of diseased plants is usually much lower than the norm [4]. This is mainly due to a violation of the structure of the photosynthetic apparatus of cells: the number of chloroplasts per unit leaf area, the volume of chloroplasts, the concentration of chlorophyll and the ratio of chlorophylls a and b decrease sharply.

The size of a single leaf of a plant and its area are important parameters on which the efficiency of converting the energy of visible light (photosynthesis) and maintaining the water balance of the whole plant depends [1].

The reaction of plants to the action of causative agents of fungal diseases is also the formation of specific colored necrotic spots on the surface of plant leaves and the configuration of their distribution [5]. Spots arise from disruption of chloroplast activity and a decrease in the content of chlorophyll in the leaves.

When developing a diagnostic tool for a fungal disease of a plant, it is important to determine the degree of damage to a particular leaf of a selected sample of garden strawberry by this disease. In practice, qualified specialists determine the degree of damage by the organoleptic method (according to a conditional 5-point scale or as a percentage of the area affected by fungi of the leaf plate) [6]. Consultation with experts to identify plant diseases is costly and time consuming. Determination of the degree of injury by production workers during the growing season of garden strawberry is subjective, individual and ambiguous, since it is carried out by mentally comparing the colored images of necrotic spots with templates from atlases [7].

Most methods for diagnosing diseases of cultivated plants require the use of expensive bulky equipment. They are invasive and long lasting [1].

The purpose of the research is to substantiate the effectiveness of the application of the express method of computer vision to determine the degree of damage to plant leaves and to create on its basis a portable device for monitoring the phytosanitary state of crops of cultivated plants in their production.

MATERIALS AND METHODS

Portable electronic technology is an essential companion to the life of modern people. This is due to the multifunctionality of such devices. For example, all manufactured smartphones are endowed with the functions of a telephone, a pocket personal computer, a music player and a camera. A smartphone is able to replace a light source, a control panel for various electrical engineering, a building level, a GPS navigator, etc. The evolution of portable electronic equipment is at a high pace and is developing by creating special software applications for the needs of people in various fields of their activity.

A promising direction is the use of smartphones as measuring and diagnostic tools. Currently, smartphones are being developed and are already being used as a "diagnostic center" for individual health by transforming it into a tonometer, thermometer, glucometer, electrocardiograph and other medical devices and devices. For example, thanks to the development of innovative digital technologies and artificial intelligence, smartphones have found wide application in the traditional diagnosis of human diseases [8]. The device in real time, through the application installed on the smartphone of the person caring for the patient, transmits data about his health: heart rate and breathing parameters, stress level and sleep cycles, etc.

Computer vision methods by counting image pixels in the space of red, green, and blue color channels (R, G, B) are promising for the

implementation of plant disease diagnostics in the form of an application to a smartphone [9–14]. A commonly used indicator of plant health is leaf color, which is related to their chlorophyll content.

The development of an algorithm for the program for determining the degree of damage to plant leaves by diseases in the form of applications for a smartphone is based on the following methodological aspects.

Acquiring an image is the first step for any vision system prior to performing an image analysis procedure. The smartphone's digital camera is used to capture images at the required resolution. To improve image quality, it is necessary to maintain an equal angle and illumination. When approaching a leaf, the camera focuses on the leaf, which is positioned on a substrate with a uniform white or black background to obtain a contrasting image of the affected leaf of the plant.

The purpose of image preprocessing is to ensure the following condition: the extraction of informative parameters does not affect the background, size and shape of the leaf, the intensity of the light source, and the characteristics of the camera for diagnosing plant diseases [15]. Image preprocessing is also used to highlight certain features and reveal details in an image. At the same time, various methods are used, such as image filtering, resizing, segmentation, morphological and other operations[1]. In addition, the captured images may contain some noise. Noise removal is performed prior to image analysis using high pass, low pass, median and linear filters, etc. The image can also be enhanced to distinguish between subject and background. Once captured, the image is converted to a spatial representation of a different color if required for further analysis. In some cases, masking and pixel removal is required to detect diseases on plant leaves. Masking is setting the pixel value in an image to some other background value, or to zero. At this stage, it is necessary to identify highly colored pixels. For example, when identifying a disease, green pixels represent a healthy area of a leaf. Therefore, it is preferable to remove green pixels and save pixels from the infected part of the study area. Masking is performed based on the specified threshold. The red, green, and blue component of a pixel is set to zero if the green component of the pixel intensity is less than a pre-calculated threshold. Masking significantly reduces processing time, since disease segmentation is obtained by setting the non-disease portion to zero and 1 for the diseased portion of the leaf.

Image segmentation is the division of an image into an object and an area or background. When identifying a disease, it is used to separate the image between areas with necrotic spots and healthy areas in the leaves [16]. In some cases, the infected part, after it has been removed, is segmented into several spots of the same size.

RESULTS AND DISCUSSION

The algorithm for the implementation of the proposed method of computer vision was initially implemented on a personal computer using previously obtained color images of leaves of garden strawberry (see Fig. 1).

This is due to the need to thoroughly work out the program algorithm, since the computer display has a higher resolution and a larger display area of the program window than a smartphone display. In addition, when analyzing a sufficient number of images using the created program, it will be possible to identify inaccuracies in its operations and to correct or modify the program according to the data obtained using the experimenter's experience. The Java programming language (Android Studio 3.4.1 operating system) was used as a language for the development of the logical part of the information system. To build the graphical interface, we used software that facilitates the development and integration of various modules of the LibGDX software project. The LibGDX project is a cross-platform game development and visualization framework based on the Java programming language with some components written in C and C ++ to improve the performance of certain code. Currently supports Win-

[1]Tichkule S.K., Gawali D.H. Plant diseases detection using image processing techniques // Online International Conference on Green Engineering and Technologies (IC-GET). 2016. DOI: 10.1109/get.2016.7916653.

dows, Linux, Mac OS X, Android, iOS and HTML5 as target platforms[2].

With the help of a camera, a color image of a plant leaf is formed. Next, the resulting image is copied to the Input folder. The selection of an image from the folder is carried out using the vertical sliders of the mouse click (see Fig. 2).

Then the image is converted to the basic format in pixels so that it fits completely on the screen of the LibGDX program.

Next, the process of converting a color image to black and white occurs. The image transformation is segmented by analyzing the black and white color intensity distribution on the histogram to match the requirements of the plant disease dataset. A histogram is a graph with brightness located on the x-axis with a maximum size of 256 pixels. The y-axis is a sequence of pixels from 1 to 200 with the corresponding brightness level.

Once the image is segmented, the extracted area is processed to remove pixel areas that are dominated by green, i. e. the places where the leaf is considered uniquely healthy.

After that, using the slider under the graph, select the pixels of the desired brightness from 0 to 255, where 0 is black, 255 is absolutely white. At this stage, the pixels of the plant leaf area without a background are selected (see Fig. 3).

Then the degree of damage to the plant is determined (see Fig. 4). This procedure is performed by analyzing each pixel by comparing its color signatures, for example, comparing red to green, blue to green.

For a more accurate assessment, two histograms-graphs were created with the x-axis from 1 to 500 pixels and with the y-axis to display the red / green and blue / green pixel ratios vertically on them, which are responsible for

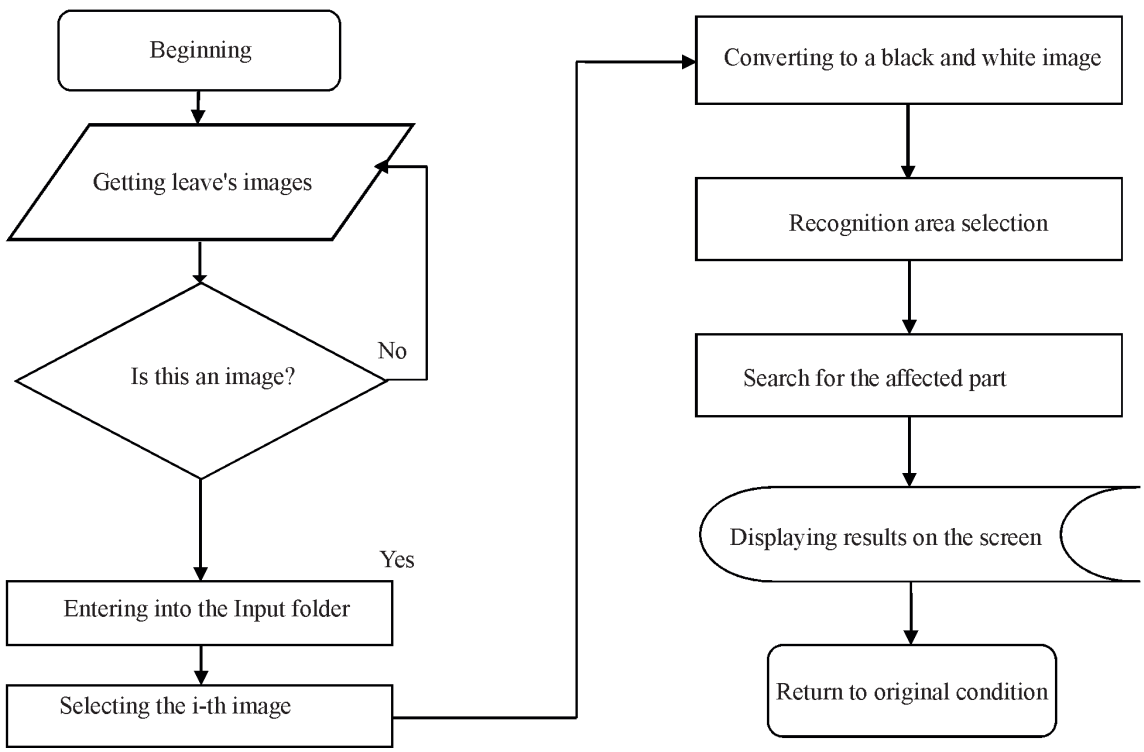

Рис. 1. Алгоритм программы определения степени поражения листа земляники садовой
Fig. 1. Algorithm of the program for determining the degree of damage to the leaf of garden strawberry

[2]libGDX – cross-platform framework for game development and visualization // On-line developer guide URL: http://www.libgdx.ru/p/guide.html (accessed date 10.02.2021).

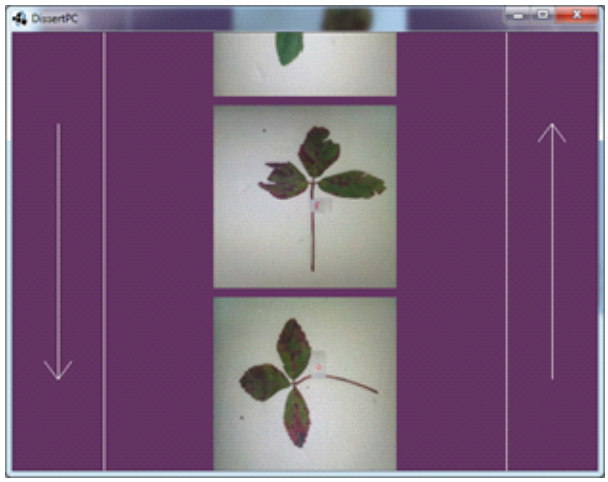

Рис. 2. Выбор изображения для распознавания
Fig. 2. Selecting an image for recognition

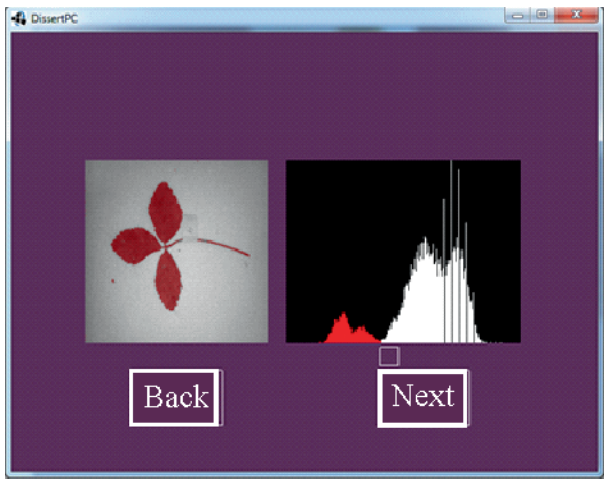

Рис. 3. Пример выбора распознаваемой области
Fig. 3. An example of recognized area selection

Рис. 4. Пример вывода результата обнаружения пораженной болезнями области растения
Fig. 4. An example of the result output of detecting a diseased plant area

removing the pixel areas in which red or blue predominated. (see fig. 4).

As the slider moves to the right along the x-axis, the number of pixels on the screen decreases in proportion to the peak in the histogram (in Fig. 4, the already filtered part is shown on the right).

Here is an example of calculating a peak on a histogram. Take a pixel with the following values: red = 70, green = 50, blue = 60. This pixel will be added to the element of the peak (red / green) array equal to (70/50) × 100 = 140, and the peak with coordinates on the x-axis equal to 140 will be higher by one.

Histograms of pixel array element values have peaks. The higher the peak on the histogram, the more pixels it has with this ratio. Thus, we reduce the number of pixels close to green and therefore find the affected areas. Then remove pixels where the green value is greater than the red and blue value. These questionable pixels with values in the array from 0 to 499 under the histogram are removed with the slider. After removing the questionable pixels, the affected part is calculated and displayed on the screen.

The introduction of the operations described above using two histograms and sliders will allow early diagnosis of diseases when its symptoms are still little noticeable to the observer.

The given algorithm and software are presented in the form of a basic block, which will be improved in the process of further research and experimental work.

When testing the basic block of the program in the field, it will be possible to take into account the observations and wishes of plant protection experts, agronomists, producers and other specialists in the cultivation of specific crops and its further adjustment and transformation. For example, due to the importance of such a plant trait as area, in the photosynthetic process and regulation of water balance, it becomes necessary to determine its size. In the future, it is necessary to solve other more complex problems, for example, the determination

of the dominant fungal plant disease[3], the problem of classification of diseases [17].

CONCLUSION

Based on the variety of the computer vision method, which counts image pixels in the space of color channels of red, green and blue (R, G, B), an algorithm and software product has been developed for the automated determination of the degree of fungal diseases affecting the leaves of garden strawberry, which is more accurate than the widespread one organoleptic visual expert method.

The algorithm and software are presented in the form of a basic block, which can be supplemented and improved in the process of experimental work and to solve related problems to determine economically important plant traits.

The results of the study made it possible to create a software application that can be installed on the personal smartphone of any agricultural specialist. This application will be useful for detecting at an early stage of development of fungal diseases of various crops, as well as for monitoring the phytosanitary state of crops.

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Информация об авторах

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СТРУКТУРА ИНФОРМАЦИОННО-УПРАВЛЯЮЩЕЙ СИСТЕМЫ ВОЗДЕЛЫВАНИЯ ЗЕРНОВЫХ КУЛЬТУР

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Рассмотрены проблемы построения и реализации структуры информационно-управляющей системы (ИУС) возделывания зерновых культур на основе оптимизации выбора агротехнологий с точки зрения методов теории управления, системного и компартментального подходов. В качестве объектов управления рассмотрены почва, возделываемая культура и экология используемого участка агроландшафта. Сделан вывод о том, что ИУС относится к классу систем адаптивного управления с прогнозированием многомерным динамическим стохастическим объектом. Показано новое качество системы управления, существенно определяющее ее структуру, – наличие контура управления поддержания плодородия почвы и экологии в севообороте и контура управления агроценозом культуры. Предложена иерархическая структурная схема системы управления объектом с прогнозированием, реализующая функциональные преобразования информационного потока в ИУС. В качестве критерия выбора альтернативной агротехнологии использована эколого-экономическая эффективность, модифицированная с учетом целей управления и состава машинно-тракторного парка. Аналитическое описание процессов агробиосистемы на современном уровне базируется на компартментальном подходе с описанием явлений в виде дифференциальных уравнений. Содержание компартмента описывает процесс переноса энергии и массы в системе почва – растительный покров – приземный слой воздуха на основе функционального (теоретического) динамического имитационного моделирования. По результатам информационного обзора, реализация подобной системы управления в настоящее время не выявлена. Использование эмпирических имитационных моделей в ИУС неприемлемо, так как смена культуры или природно-климатической зоны потребует разработки новой эмпирической модели. Проанализированы системы имитации биофизических процессов WOFOST, DSSAT, DSSAT Cropping System (CSM), APSIM и AGROTOOL, использующие методы функционального динамического имитационного моделирования в рамках компартментального подхода. Разработанная структура ИУС с использованием модели продуктивности посевов AGROTOOL реализуется при условии создания новых модулей компартментов.

Ключевые слова: адаптивно-ландшафтное земледелие, агротехнологии, математическое моделирование, информационно-управляющие системы, компартментальный подход

STRUCTURE OF THE INFORMATION MANAGEMENT SYSTEM OF CEREAL CROPS CULTIVATION

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The problems of constructing and implementing the structure of the information management system (IMS) for the cultivation of grain crops based on the optimization of the choice of agricultural technologies in view of the methods of the management theory, system and compartmental approaches are considered. The objects of management are soil, a cultivated crop and ecology of the agricultural landscape area used. It is concluded that the IMS belongs to the class of adaptive control systems with prediction by a multidimensional dynamic stochastic object. A new quality of the management system, which significantly determines its structure, is shown, namely the presence of a control loop for maintaining soil fertility and ecology in crop rotation and a control loop for the agrocenosis of the crop. A hierarchical block diagram of the object management system with forecasting is proposed, which implements functional transformations of the information flow in the IMS. As a criterion for choosing an alternative agricultural technology, environmental and economic efficiency was used, modified in view of the management goals and the composition of the machine and tractor fleet. The analytical description of the processes of the agrobiosystem at the modern level is based on the compartmental approach with the description of phenomena in the form of differential equations. The content of the compartment describes the process of energy and mass transfer in the system: soil – vegetation cover – ground layer of the air based on functional (theoretical) dynamic simulation. Based on the results of the information review, the possibility of implementation of such a management system has not been currently identified. The use of empirical simulation models in the IMS is unacceptable, since a change in a crop or natural-climatic zone will require the development of a new empirical model. The systems for simulating biophysical processes WOFOST, DSSAT, DSSAT Cropping System (CSM), APSIM and AGROTOOL, using methods of functional dynamic simulation within the framework of the compartmental approach, have been analyzed. The developed IMS structure using the AGROTOOL crop productivity model is implemented on condition that new modules of compartments are created.

Keywords: adaptive landscape agriculture, agricultural technologies, mathematical modeling, information management systems, compartmental approach

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The automation of the management of the cultivation of grain crops is aimed at introducing digital technologies. In particular, information management systems (IMS) are used to calculate the parameters of agricultural technologies that determine the performance of technological operations in the field. At the same time, the problem of creating an IMS system at the level of agricultural enterprises has not been solved at present, since many processes in the control object (soil, culture, ecology) are not described in an analytical form sufficient for the synthesis of the implemented IMS structure.

Let us consider the ways of solving the problem posed, limiting the analysis of the management of the cultivation of grain crops to a plot of the agricultural landscape (field) with a given system of crop rotation and a seasonal nature of control actions. Such a control method relates to predictive control[1] based on the creation of new information in the course of forecasting during generation and the choice of alternatives.

To do this, we synthesize the structure of the IMS system in accordance with its classification in terms of general control theory, the control properties of the control object (OC), and a functional set of descriptions of informa-

[1]Kasperovich S.A. Forecasting and planning of the economy: a course of lectures for students. Minsk: BSTU, 2007.172 p.

tion flow transformation processes for control purposes. At the same time, we will evaluate the possibility of its implementation within the framework of known solutions.

The purpose of the functioning of the adaptive landscape farming system is the production of products of an economically and ecologically determined quantity and quality in accordance with social (market) needs, natural and production resources while ensuring the sustainability of the agricultural landscape and reproduction of soil fertility [1].

Achieving this goal requires the management of a complex of interrelated agrotechnical, reclamation and organizational measures that make up the essence of agro-technologies.

Note that the parameters of soil, culture and ecology are stochastic in nature and are mainly determined by climatic conditions and the intensity of solar radiation. In addition, the properties of OC depend on the agroclimatic zone of the agricultural landscape, which determines the adaptive mechanisms of the IMS functioning.

Therefore, in general, the control system can be attributed to the class of adaptive control systems with prediction by a multidimensional dynamic stochastic object [2] with the ability to change the parameters or structure of the controller depending on the parameters of the control unit or external disturbances[2].

The IMS structure is based on analytical models describing the physical processes in the OC, and a mathematical model for calculating control actions on the OC to achieve the control goal.

In the mathematical modeling of agroecosystem processes, the main directions in the class of simulation models can be distinguished [3, 4]:

– an empirical approach with extensive use of a heuristic description of the determining processes (regression relations, allometry equations, numerous stress functions, etc. are used);

– functional or theoretical (mechanistic or ecophysiological) approach considering the essence of processes and cause-and-effect relationships in the agroecosystem with a description of their dynamics based on physically interpreted dependencies.

The analytical description of the processes of the agrobiosystem at the modern level is based on the compartmental approach[3]. In this case, it is assumed that within the volume of the compartment, the processes are not a function of the spatial variable, therefore, description in the form of ordinary differential equations is allowed. This approach is used to study the processes of transfer of matter and energy within a living system and their exchange with the environment, in particular, in the system soil - vegetation cover - surface air layer. The structure of the analytical description of biophysical processes is based on functional (theoretical) dynamic simulation and is presented in the form of interconnected compartments. The use of empirical simulation models is unacceptable, since a change in culture or natural climatic zone will require the development of a new empirical model. In the case of the compartmental approach, the physical essence of the OC processes remains unchanged when changing the OC parameters, which determines the variability of the simulation model.

Let us define the structure of the IMS of adaptive control with forecasting the cultivation of grain crops from the standpoint of functional transformations of the information flow. Let us note the properties of the OC regulation process determined by the decomposition of the main goal:

– management has two management objectives: managing sustainability, maintaining soil fertility and ecology in crop rotation (management objective 1) and managing the agrocenosis of a crop, including changing soil con-

[2]Adaptive management. URL: https://ru.wikipedia.org/

[3]Novoseltsev V.N. Control theory and biosystems. Analysis of preservation properties. M .: main edition of physical and mathematical literature of the publishing house "Nauka", 1978. 320 p.

ditions, crop ecology (management objective 2) and, accordingly, two management loops with management periods equal to the period of full rotation of the crop rotation and the season of crop cultivation;

– management prediction is carried out by choosing an alternative from $k1 = 0, ..., N1$, $k2 = 0, ..., N2$ numbers of agro-technology alternatives and from $k3 = 0, ..., N3$, $k4 = 0, ..., N4$ numbers of alternatives for the composition of the machine and tractor fleet (MTF), respectively, control loops 1, 2 in accordance with the criterion function and their adaptation to the zonal conditions of use.

The efficiency of management for practical purposes can be assessed by the indicator of ecological and economic efficiency Eee_{gen}, reflecting the amount of net income (or profit), taking into account the prevented environmental damage [1] according to the formula

$$Ee_{e_{gen}} = \frac{В_п – З_п – (У – К \cdot З_у)}{З_{ээ}}, \quad (1)$$

where $В_п$ is the cost of gross output; $З_п$ - operational costs; У is the amount of environmental and economic damage to agricultural production; К - coefficient of efficiency of environmental protection measures; $З_у$ - costs aimed at preventing and eliminating damage in agriculture; $З_{ээ}$ - costs that provide an ecological and economic effect, including environmental protection measures.

Taking into account the array of alternatives, the criterial control function will have the form

$$F = \max_{\substack{0 \le k1 \le N1 \\ 0 \le k2 \le N2}} \left\{ \frac{В_{п_{k1,\,k2}} - \min_{0 \le k3 \le N3} \left(З_{nyps_{k1,\,k3}}\right) - \min_{0 \le k4 \le N4} \left(З_{nypk_{k2,\,k4}} + З_{nyak_{k2,\,k4}}\right)}{\left(\min_{0 \le k3 \le N3} \left(З_{ээps_{k1,\,k3}} / N_{ps}\right) + \min_{0 \le k4 \le N4} \left(З_{ээpk_{k2,\,k4}} + З_{ээak_{k2,\,k4}}\right)\right)} \right\}, \quad (2)$$

where $З_{nypsk1,\,k3}$, $З_{nypkk2,\,k4}$, $З_{nyakk2,\,k4}$ - ecological and economic costs of alternative agricultural technology, including the cost of performing agricultural technology operations with units from alternative sets of MTF; $З_{epsk1,\,k3}$, $З_{ee}$, $З_{eakk2,\,k4}$ are the costs that ensured the ecological and economic effect, including environmental protection measures when the soil condition changes in the crop rotation cycle (indices *ps*, *k*1, *k*3), respectively, when the soil condition changes when managing the agrocenosis of the crop (indices *pk*, *k*2, *k*4) and when the state of the culture changes (indices *ak*, *k*2, *k*4); N_{ps} is the number of crop rotation periods.

We will consider functional transformations of the information flow in a predictive control system from the standpoint of the elements of set theory. The information flow is represented by a set of parameters of the form $v = \{v1\ (t), ..., vn\ (t)\}$, where *vn (t)* is an element of the set (parameter) describing the state of the system at time t and having functional relations f with the set *w: w = f {v}*. In the general case, *f* is a functional (any mapping from an arbitrary set to an arbitrary one), an operator is a mapping that associate a function with another function. Then the information flow transformations can be described as follows:

a) $a, b, c, d, a_p, b_p, cp, dp, at, bt, ct, dt$, where *a, b* are the sets of soil parameters that ensure stability, fertility and ecology in the crop rotation cycle and season, respectively, *c* is the state of the agrocenosis of the crop, *d* are climatic conditions, while the * *p,* * *t* index determines the predicted and current sets of parameters;

b) the set of parameters of agricultural technology for maintaining soil fertility alternatives *k*1 and agrocenosis of the culture *k*2 are determined, respectively, by the functionals, taking into account the set of MTP mtp_{k1}, mtp_{k2}: $AT_{ps,\,k1} = f_{atps}\{a, b, c, d, mtp_{k1}\}$, $AT_{ak,\,k2} = f_{atak}\{a, b, c, d, mtp_{k2}\}$, the sets of unit parameters for technological operations are determined by the functionals $mtp_{pk1} = f_{umtps}\{AT_{ps,\,k1}\}$ and $mtp_{pk2} = f_{umtak}\{AT_{ak,\,k2}\}$. The predicted sets of parameters of the state of the object, yield and the parameter of stability and preservation of soil fertility are calculated by operators:

$$a_p = A_{Ta_{k1,\,k2}}(a,\,b),$$
$$b_p = A_{Tb_{k1,\,k2}}(a,\,b),$$
$$c_p = A_{TC_{k1,\,k2}}(a,\,b,\,c),$$
$$c_p = A_{TC_{k1,\,k2}}(a_p,\,b_p,\,c_p),$$
$$W_a = A_{Tow}\{AT_{ps,\,k1},\,AT_{ps,\,k2}\},$$

functionally interconnected with the parameters of agricultural technologies:

$$A_{Ta_{k1,\,k2}} = f_{oa}\{AT_{ps,\,k1}, AT_{ak,\,k2}\},$$
$$A_{Tb_{k1,\,k2}} = f_{ob}\{AT_{ps,\,k1}, AT_{ak,\,k2}\},$$
$$A_{TC_{k1,\,k2}} = f_{oc}\{AT_{ps,\,k1}, AT_{ak,\,k2}\},$$
$$A_{TC_{k1,\,k2}} = f_{oC}\{AT_{ps,\,k1}, AT_{ak,\,k2}\},$$
$$A_{Tow} = f_{ow}\{AT_{ps,\,k1}, AT_{ak,\,k2}\}.$$

The values of the sets of parameters of impacts on the soil and soil ecology in the cycle of crop rotation, season, agrocenosis and culture ecology are determined, respectively, by the functionals:

$$U_{Ps} = f_{ups}\{AT_{ps,\,k1}\},$$
$$U_{es} = f_{ues}\{AT_{ps,\,k1}\},$$
$$U_{p_k} = f_{upk}\{AT_{ak,\,k2}\},$$
$$U_{ak} = f_{uak}\{AT_{ak,\,k2}\},$$
$$U_{ek} = f_{uek}\{AT_{ak,\,k2}\},$$

and the set of parameters of the units for the implementation of technological operations in the rotation cycle of crop rotation and season is determined by the functionals:

$$mtp_{p_{k1}} = f_{umtps}\{AT_{ps,\,k1}\} \text{ и } mtp_{p_{k2}} = f_{umtak}\{AT_{ak,\,k2}\}.$$

The listed set of functions and operators, using the systematic approach [5], can be represented as a hierarchical structure of the object management system shown in the figure. Management is carried out by the following actions:

– for a given area-specific zone of an agrarian landscape plot (agro-technological type and type of land), type of crop rotation, sowing culture, predicted climatic conditions and a basic set of MTF, a set of *k*1, *k*2 predicted functions is synthesized. You can choose from the known values corresponding to the functionals f_{atps}, f_{oa}, f_{ups}, f_{ues}, f_{umtps}, f_{atak}, f_{ob}, f_{uak}, f_{uek}, f_{umtpk}, f_{oc}, which are also determined by the type of agricultural technology (extensive, normal, intensive, high-intensity), taking into account the state a control object determined by the set of parameters *a, b, c,* d_p, MTF. At the same time, the necessary set of functions is generated that connect the output and input sets of parameters of this functional;

– many parameters of predicted agricultural technologies for maintaining soil fertility in the cycle of crop rotation AT_{ps}, agrocenosis of the AT_{ak} crop are calculated;

– transformation operators of a set of parameters are synthesized or selected from the known $A_{Tak1,\ k2}$, $A_{Tbk1,\ k2}$, $A_{Tck1,\ k2,}$ a set of parameters of the basic set of MTF $mtpp_{,\ k1}$, $mtpp_{,\ k2}$, predicted to carry out the necessary operations on the field;

– the predicted sets of parameters of soil fertility and agrocenosis of the culture of the controlled object *a, b, c* are calculated by transformation operators;

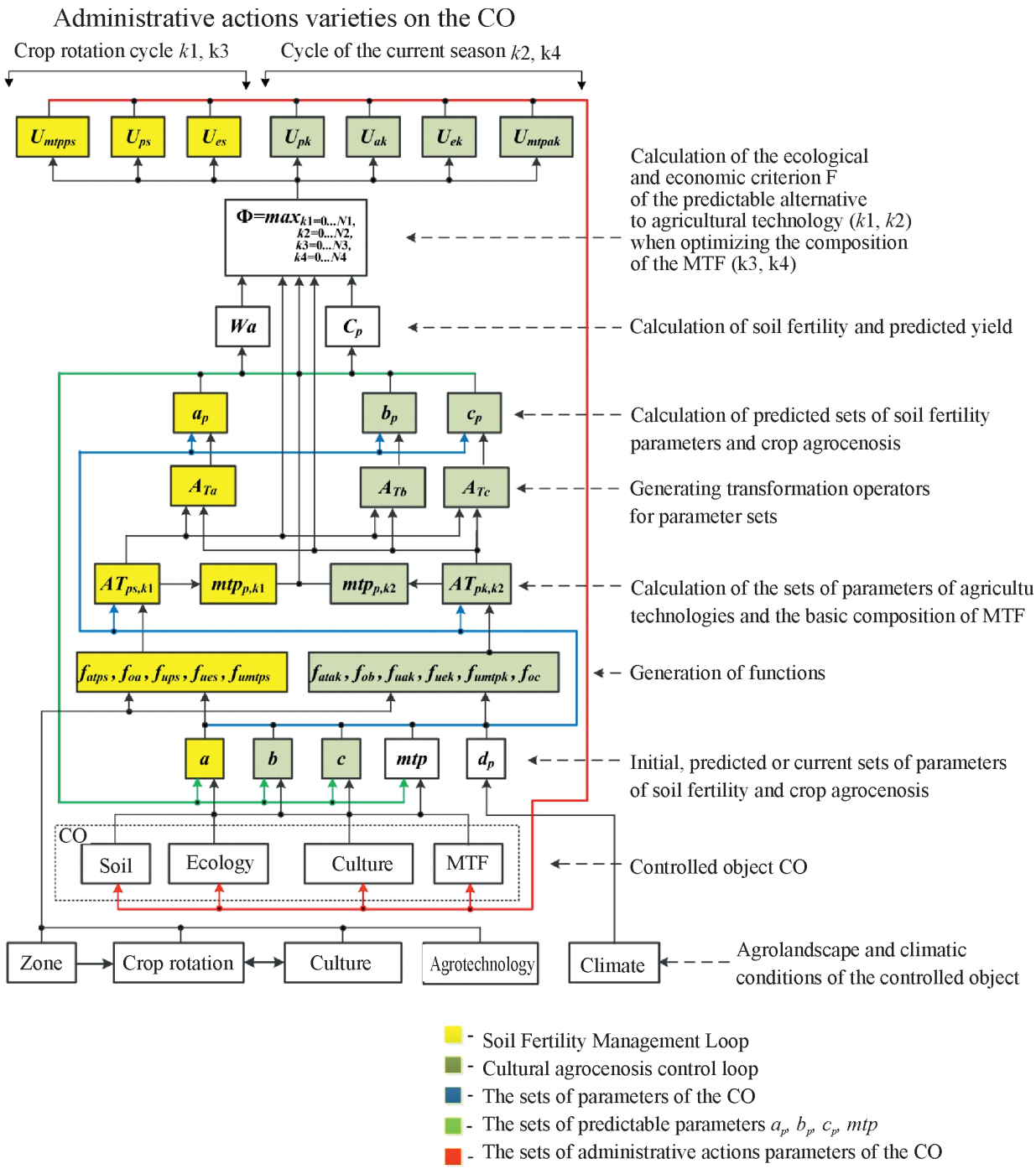
– the conditions of soil fertility *Wa* and the predicted yield C_p are calculated;

– when the condition of the soil fertility $Wa \geq 0$ is fulfilled, the ecological and economic costs, the set of parameters of the units for the implementation of technological operations $U_{mtpps\ k1,\ k3}$, $U_{mtpak\ k2,\ k4}$ and the value of the ecological and economic criterion F according to expression (2) are calculated;

– an alternative option *k*1, *k*2, *k*3, *k*4 of agricultural technologies is searched for, corresponding to the maximum value of the ecological and economic criterion F;

– the values of the set of parameters of impacts on the soil and soil ecology in the cycle of crop rotation, season and agrocenosis and the ecology of culture are determined, respectively, by the functional *Umtpps, Ups, Ues, Upk, Uak, Uek, Umtpak*;

– the deviation of the predicted state of the control object from the actual one is determined in accordance with the control cycle. At the same time, the actual value of the ecological and economic criterion F is calculated and the procedure for generating functions in the control system is adjusted to minimize deviations in the next management cycle.



Иерархическая структура системы управления объектом с прогнозированием
Hierarchical structure of the object management system with forecasting

Let us evaluate the possibility of implementing the synthesized structure of the IMS with forecasting (hereinafter IMS) by the known solutions in the field of information technology and mathematical modeling of agroecological problems (see the figure). A review of information sources[4] was carried out [6].

The management system based on heuristic models includes, for example, a multilevel model of intelligent control of an agro-technological process in a bio-production system [7]. It is based on heuristic correction of mathematical models of agroecosystems with heuristic knowledge of farmers. The system "Eidos-X ++" is based on the system-cognitive statistical relationship of the required parameters for the known set of implementations of the agrotechnological process. The application of this system is limited by knowledge of the real statistics of the history of the application of agricultural technologies over a long period of time [8]. In most cases, such information is not available on farms.

Other well-known methods or mathematical models describe individual processes of an agrobiosystem without describing their relationship. Such systems are the models for determining the optimal doses of fertilizers[5] and the dynamics of humus [9], the automated bank of fertility models "PLOMOD" [6], in which the relationship of crop rotation parameters with the state of fertility and soil ecology is determined mainly at the level of methodologies and belongs to the category of knowledge [10]. These methods cannot be applied in the IMS without finalizing the analytical description of the interconnection processes within the framework of the compartment approach.

Mathematical models of processes that are not related to the agrocenosis of a culture or models for assessing results deserve attention. These are the agrometeorological information and forecasting system of the IPS of the All-Russian Scientific Research Institute of Agricultural Meteorology (ARRIAM) based on the synoptic-statistical method[7], mathematical models and algorithms for predicting the yield of grain crops using satellite data (EPIC model)[8], the assessment of the stability of soil organic matter based on mathematical theory of catastrophes [11, 12], optimization of the composition of MTF[9] [13, 14]. Such models can be applied in the structure of the IMS system when they are being finalized.

There are known systems for simulating biophysical processes based on functional (theoretical) dynamic simulation of agrobiosystem processes within the framework of the compartment approach. These are WOFOST[10] (Netherlands), DSSAT - The Decision Support System for Agrotechnology Transfer[11], DSSAT Cropping System (CSM)[12], IBSNAT project (USA), APSIM modeling system - Agricultural Production Systems SIMulator[13], (Australia) and the AGROTOOL crop productivity model (Russia) [15]. These models are semi-empirical, have a similar structure and differ mainly in the nomenclature and details of the description of individual blocks. These systems are not control systems, since they simulate the processes soil - surface air layer - plant without taking into

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[11]Jones J.W. Hoogenboom G., Porter C.H., Boote K.J., Batchelor W.D., Hunt L.A., Wilkens P.W., Singh U., Gijsman A.J., Ritchie J.T. The DSSAT cropping system model // European Journal of Agronomy. 2003. № 18 (3–4). C. 235–265.

account the processes of adaptive management with forecasting.

Let us consider the implementation of the IMS structure, taking into account the model of crop productivity AGROTOOL, which includes a description of the following processes taking place in the system soil - vegetation cover - surface air layer:

– soil compartment - dynamics of soil moisture, dynamics of nitrogen compounds in the soil, growth and development of the root system;

– compartment of the surface layer of air - modes of sowing, photosynthesis and photorespiration, transpiration of plants and evaporation of moisture from the soil surface, the choice of norms and terms of irrigation in irrigated agriculture;

– plant compartment - moisture transfer to the plant, plant growth and development (aboveground organs), yield prediction (starting from the earing phase).

Let us represent the IMS structure as a set of compartments that analytically describe the functional transformations of the information flow: soil stability and fertility *fatps, foa, ATak1, k2,* agrocenosis of the culture *fatak, fob, foc, foC, ATbk1, k2, ATck1, k2, ATCk1, k2*, formation of predicted parameters *ap, bp, cp*.

At the same time, the processes of agrocenosis of a culture and the predicted parameters of soil, crops can be represented by similar compartments soil - vegetation cover - surface air layer of the AGROTOOL system. The rest of the processes of functional transformations of the information flow in the IMS and the conditions for the implementation of control have no analogues in the compartment structure of the AGROTOOL system. Therefore, the IMS compartments should additionally contain an analytical description of the following processes and conditions for the implementation of management: - soil compartment - soil stability and fertility, the formation of a predictable set of soil parameters, the relationship of soil parameters with the crop rotation cycle; - additional compartment soil and plant ecology - the relationship between the parameters of the intensity of the planned agricultural technology with the parameters of the soil. - conditions for the implementation of management - the formation of an alternative version of agricultural technology, containing the planned operations in the field and the composition of the MTF, can be carried out in accordance with the federal (regional) register of agricultural technologies. The timing of the operation in the field, the amount of fertilizers is determined by the results of running the mathematical models of the IMS. Adaptation of management by the types of crop rotation and the soil-climatic zone of the agricultural landscape can be carried out by adjusting the analytical content of the compartments by the OM parameters.

CONCLUSION

As a result of the analysis of information materials, it was found that the analytical description of the processes of the agrobiosystem at the modern level is based on a compartment approach using the methods of functional (theoretical) dynamic simulation. The use of empirical models is unacceptable, since a change in culture or natural-climatic zone requires the development of a new model with the inclusion of research and verification stages.

The synthesis of the structure of the information management system was carried out with the limitation of the area of management of a plot of the agricultural landscape (field) with a given system of crop rotation and the seasonal nature of control actions. The seasonal nature of the control actions and the change in the natural and climatic zone determine the class of the information and control system as an adaptive control system with forecasting.

The information and control system has two control loops: the first is the maintenance of soil fertility and ecology in crop rotation, the second is the agrocenosis of the culture, includ-

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ing changes in the state of the soil, the ecology of crops.

Based on the functional transformation of the information flow, a hierarchical structure of the information management system has been synthesized, the functional of which in terms of describing the processes in the control object can be represented in the form of compartments. Based on the results of the information review, the implementation of such an information management system has not been identified. The possibility of implementing the developed structure of the information management system, taking into account the systems for simulating biophysical processes WOFOST, DSSAT, DSSAT Cropping System (CSM), APSIM and AGROTOOL, using the methods of functional (theoretical) dynamic simulation within the framework of the compartment approach is considered.

A comparative analysis of the composition of the compartments necessary for the analytical description of the functionals of the processes in the control object of the structure of the information management system and the AGROTOOL system is carried out. It has been established that the processes of agrocenosis of a crop and the predicted parameters of soil, crops can be represented by similar compartments soil - vegetation cover - surface air layer of the AGROTOOL system. In this case, the structure of the IMS system must additionally contain, at least, an analytical description of the following processes and conditions for the implementation of management:

– compartment soil - soil stability and fertility, the formation of a predictable set of soil parameters, the relationship of soil parameters with the crop rotation cycle;

– additional compartment soil and plant ecology - the relationship of the parameters of the intensity of the planned agricultural technology with the parameters of the soil;

– the conditions for the implementation of control are determined by the algorithm for the formation of an alternative version of agricultural technology, containing the planned operations in the field, the amount of fertilizers and the composition of the machine-tractor fleet, and the algorithm for adapting the analytical content of the compartments to the types of crop rotation and the soil-climatic zone of the agricultural landscape.

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ОЦЕНКА СТЕПЕНИ ПОРАЖЕНИЯ РАСТЕНИЙ БОЛЕЗНЯМИ МЕТОДАМИ КОМПЬЮТЕРНОГО ЗРЕНИЯ

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Представлены результаты первого этапа исследования в рамках диссертационной работы «Исследование методов и алгоритмов компьютерного зрения в области выявления болезней растений». Проведен анализ работ, связанных с автоматической оценкой степени поражения растений болезнями. Установлено, что для решения задач в данной области перспективными методами являются сверточные нейронные сети, которые в настоящее время по точности превосходят классические методы компьютерного зрения. Для оценки степени поражения используются классификационные и сегментационные архитектуры сверточных нейронных сетей. При этом, классификационные архитектуры способны учитывать визуальные особенности признаков болезней на разных стадиях заболевания, но с их помощью нельзя получить информацию о фактической площади поражения. Решения, основанные на сегментационных архитектурах, позволяют получить информацию о площади поражения, но не проводят градацию степени поражения по видимым признакам болезни. На основании проведенного анализа существующих работ, основанных на применении сверточных нейронных сетей и вариантов их использования, определена цель настоящего исследования: разработать автоматическую систему, способную определять площадь поражения, а также учитывать визуальные особенности признаков заболевания и тип иммунологической реакции растения на разных стадиях развития. Планируется построить систему на основе сегментационной архитектуры сверточной нейронной сети, которая будет производить мультиклассовую сегментацию изображений. Такая сеть способна разделять пиксели изображения на несколько классов: фон, здоровая область листа, пораженная область листа. В свою очередь класс «пораженная область» будет включать в себя несколько подклассов, соответствующих визуальным особенностям заболевания на разных стадиях развития.

Ключевые слова: болезни растений, степень поражения растений, компьютерное зрение, сверточные нейронные сети, классификация, сегментация, разметка датасета

PLANT DISEASE SEVERITY ESTIMATION BY COMPUTER VISION METHODS

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The first stage results within the framework of the thesis “Investigation of computer vision methods and algorithms in the field of plant diseases detection” are presented. The analysis of the work

related to the automatic assessment of plant disease severity was carried out. It was established that for solving problems in this field, convolution neural networks are promising methods, which are currently superior to classical methods of computer vision in terms of accuracy. To assess the severity degree, classification and segmentation architectures of convolutional neural networks are used. Classification architectures are able to take into account disease visual features at different stages of the disease development, but information about the actual affected area is unavailable. On the other hand, solutions based on segmentation architectures provide actual data on the lesion area, but do not grade severity levels according to disease visual features. Based on the result of the research into the application of convolutional neural networks and options for their use, the goal of this study was determined, which is to develop an automatic system capable of determining the lesion area, as well as to take into account disease visual features and the type of immunological reaction of the plant at different stages of disease progress. It is planned to build a system based on the segmentation architecture of a convolutional neural network, which will produce multi-class image segmentation. Such a network is able to divide image pixels into several classes: background, healthy leaf area, affected leaf area. In turn, the class "affected leaf area" will include several subclasses corresponding to the disease visual features at different stages of disease progress.

Keywords: plants diseases, plant disease severity, computer vision, convolutional neural networks, classification, segmentation, dataset markup

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During 1980–2020 annual losses of the world harvest due to diseases and pests ranged from 20 to 40% [1]. With the current growth of the world's population, due to the lack of quality food, such trends can lead not only to a deterioration in human health, but also become a threat to the existence of mankind. Carrying out timely control of the state of agricultural crops and selection of plant varieties resistant to various diseases will prevent these negative consequences. In this regard, visual monitoring of plants is required [2, 3]. Currently, such monitoring is performed manually, its quality is subjective and not always qualified by experts. With the development of machine learning and robotics technologies, the implementation of these tasks is possible in the agricultural industry using methods and algorithms of computer vision, including convolutional neural networks (CNN) as artificial neural networks for effective pattern recognition.

Convolutional neural networks are capable of detecting diseases at various stages, as visible signs of disease change over time. It is urgent to create a system capable of detecting a disease throughout the entire cycle of its development and classifying plant damage according to its severity. The solution to this problem is necessary for the early prevention of the development of diseases, to determine the resistance of the variety to pathogens, to maintain crop yields.

The aim of the study is to develop an automatic system for classifying the degree of plant disease damage using convolutional neural networks, to assess the efficiency of the system.

Within the framework of the dissertation research, it is planned to solve the following tasks:

1) to analyze the existing algorithms of convolutional neural networks and options for their use to solve the problems of classifying the degree of damage to plants by diseases;

2) to develop an algorithm for marking up a dataset on images of diseased and healthy plant leaves;

3) to develop a system based on convolutional neural networks for segmentation of diseased plant areas and their classification according to the degree of damage;

4) evaluate the effectiveness of the developed system according to the selected metrics on various data sets.

At the first stage of the research, an analysis of literature sources was carried out with a description of systems for classifying plants according to the degree of disease damage using neural networks.

Computer vision is a set of methods and algorithms that allow the detection, observation and classification of objects, obtaining information from images. There are two main directions in the field of computer vision:

1) classical methods;

2) deep learning[1].

They differ in that classical methods involve the selection of image features manually, by an operator, while deep learning (neural networks) does this automatically. There is a significant difference in the accuracy of these approaches. The best methods of classical computer vision provide an accuracy of up to 80%, while deep learning in some cases - 99% [4]. To ensure high accuracy of the neural network operation, it is necessary to train it (teach to select and generalize features) on a sufficient amount of data. This is important to solve problems of identifying plant diseases [4, 5].

Most of the research that is carried out in this area is related to the identification of plants and diseases. However, the disease in the process of its development has various manifestations and symptoms, which is not always taken into account when developing systems based on the CNN [6, 7]. To determine the degree of damage to plants, two types of CNN architectures are used: classification and segmentation [8]. Classification CNN establish the belonging of the whole image to a certain class. To train them, it is enough to annotate the images with signatures, for example, with a certain degree of defeat. In turn, the segmentation networks classify each pixel in the image, they need masks of the affected areas for training.

The following are some of the existing approaches to assessing plant diseases by degree of damage and methods of data preparation that were used for training.

CNN classification architectures are used in the works [9–12]. Annotation of the data was carried out manually by specialists; a caption was added to each image: a healthy organ, a diseased organ at different stages of the severity (initial, medium and severe) [9–11]. The authors of other works proposed to annotate images of leaves of various plants automatically [12]. The background, leaf and affected areas were highlighted using classical computer vision methods. The degree of severity was determined by counting the number of pixels of the affected area relative to the number of pixels of the entire leaf. As a result, as in the case of manual marking, each sheet image was annotated with a caption. Then, CNN were trained on these data and the accuracy with which they carried out the classification was assessed.

There are also studies based on segmentation architectures of neural networks. A system for automatic assessment of the resistance of wheat varieties to Fusarium head blight has been developed and the efficiency of its work has been evaluated [13]. The input data were photographs of ears of wheat taken in the field. The marking was done manually. In each image of the ears, the affected area was highlighted. The resulting masks and images were used to train the CNN. As a result of the training, the neural network generated masks, according to which the degree of severity was determined by calculating the area of the affected zone relative to the area of the entire wheat ear. It was proposed to segment the affected areas of cucumber leaves with powdery mildew using CNN in [14]. Preliminary processing (marking) of images was carried out using classical methods of computer vision, as a result of which masks of the affected areas were obtained. The efficiency of the CNN was assessed.

[1]O'Mahony N., Campbell S., Carvalho A., Harapanahalli S., Hernandez G. V., Krpalkova L., Riordan D., Walsh J. Deep Learning vs. Traditional Computer Vision // Proceedings of the 2019 Computer Vision Conference (CVC), 2019, vol. 1, pp. 128–144. DOI: 10.1007/978-3-030-17795-9_10.

Classification architectures can take into account the visual features of signs of diseases at different stages of the course of the disease, but information on the actual area of the severity is not available [9–14]. Segmentation architectures allow us to solve the problem of determining the area of the severity, but do not take into account the visual features of the signs of diseases and the type of immunological reaction (assessment of the degree of resistance) at different stages of development.

Within the framework of this study, the author plans to develop a system based on the CNN segmentation architecture, which, in addition to the affected area, will take into account the visual signs of damage to wheat leaves. Multiclass segmentation of the leaves affected by leaf rust images taken from a publicly available dataset[2] will be performed. There is a known scale for assessing the reaction and the degree of leaf rust infestation of wheat varieties, divided into five gradations[3]:

1) healthy leaf;
2) resistance;
3) average resistance;
4) average susceptibility;
5) susceptibility.

Moreover, on each of them, except for the first, the disease has the corresponding symptoms and the percentage of leaf damage. One more class is added to these classes - the background. As a result, three classes were defined for training CNN: background, healthy leaves and leaves of four degrees of infestation. CNN will allow you to distinguish both objects of different classes (background, diseased leaf, healthy leaf) and objects belonging to a specific class. This will determine the degree of leaf rust infestation on the leaves. This task is called Instance Segmentation [15]. To provide the neural network with training samples, software for automated marking of dataset images will be developed.

The analysis of the literature shows that the issue of automatic classification of the degree of damage to plants, taking into account their visual characteristics and the type of immunological reaction (assessment of the degree of resistance) is a promising area of research. In this regard, a goal was determined and tasks were set to be performed within the framework of the author's dissertation work. Research results and software products developed on their basis can be used in environmental monitoring of crops and in the development of optimal plant protection measures that reduce pesticide consumption, improve product quality, and automate the work of breeders to create resistant varieties of plants.

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