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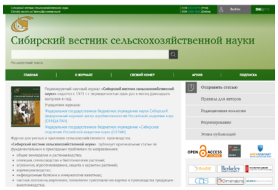

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СОДЕРЖАНИЕ

ЗЕМЛЕДЕЛИЕ И ХИМИЗАЦИЯ

Инишева Л.И., Порохина Е.В., Головченко А.В. Биохимическая активность торфов различного генезиса **5**

РАСТЕНИЕВОДСТВО И СЕЛЕКЦИЯ

Разгонова М.П., Демидова Е.Н., Кириленко Н.С., Конькова Н.Г., Голохваст К.С. Вторичные метаболиты периллы (*Perilla frutescens* (L.) Britton) дальневосточного происхождения, идентифицированные методом тандемной масс-спектрометрии **17**

Андреева О.Т. Продуктивность малораспространенных сельскохозяйственных культур в зависимости от сроков посева в условиях Забайкалья **37**

CONTENTS

AGRICULTURE AND CHEMICALIZATION

Inisheva L.I., Porokhina E.V., Golovchenko A.V. Biochemical activity of peats of different genesis **5**

PLANT GROWING AND BREEDING

Razgonova M.P., Demidova E.N., Kirilenko N.S., Kon'kova N.G., Golokhvast K.S. Secondary metabolites of perilla (*Perilla frutescens* (L.) Britton) of Far Eastern origin identified by tandem mass spectrometry **17**

Andreeva O.T. Productivity of less common agricultural crops depending on the sowing dates in the conditions of Transbaikalia **37**

ЗАЩИТА РАСТЕНИЙ

Федина Л.А., Маркова Т.О., Маслов М.В. Оценка видового состава сорных растений семейства Капустные (Brassicaceae) рудеральных и сегетальных местообитаний Уссурийского городского округа Приморского края

Смук В.В. Повреждаемость клубней картофеля подгрызающими совками в зернотравяно-пропашном севообороте на северо-западе Российской Федерации

PLANT PROTECTION

49 **Fedina L.A., Markova T.O., Maslov M.V.** Assessment of weed species composition of Cabbage family plants (Brassicaceae) of ruderal and segetal habitats of the Ussuriisk urban district of the Primorsky Territory

56 **Smuk V.V.** Damage to potato tubers by cut worms in grain-grass root-crop rotation in the north-west of the Russian Federation

ЗООТЕХНИЯ И ВЕТЕРИНАРИЯ

Петров П.Л., Смолянинов Ю.И., Протодьяконова Г.П., Степанюк М.А., Терновой В.А. Эпизоотическая ситуация и молекулярно-генетическая характеристика вируса бешенства, изолированного из мозга домашнего северного оленя в Якутии

Терещенко В.А., Иванов Е.А., Любимова Ю.Г., Иванова О.В. Повышение продуктивности коров за счет использования в кормлении премиксов на основе лесных и минеральных ресурсов

Манакова О.О., Янченко Т.А., Власенко В.С. Особенности кислород-независимого метаболизма нейтрофилов у животных, сенсибилизированных неагглютиногенным штаммом бруцелл

ZOOTECHNICS AND VETERINARY MEDICINE

64 **Petrov P.L., Smolyaninov Yu.I., Protodiakonova G.P., Stepanyuk M.A., Ternovoy V.A.** Epizootic situation and molecular genetic characteristics of the rabies virus isolated from the brain of domestic reindeer in Yakutia

72 **Tereshchenko V.A., Ivanov E.A., Lyubimova Yu.G., Ivanova O.V.** Increasing the productivity of cows through the use of premixes based on forest and mineral resources in feeding

81 **Manakova O.O., Yanchenko T.A., Vlasenko V.S.** Features of oxygen-independent metabolism of neutrophils in the animals sensitized with non-agglutinogenic Brucella strain

Дурсенев М.С., Баюнова Н.А., Овсянников Ю.С. Эффективность использования покрытия кормового стола «Луг Здоровья» **89**

Попов А.А., Неустроев М.П., Васильева С.А. История изучения ринопневмонии лошадей **98**

МЕХАНИЗАЦИЯ, АВТОМАТИЗАЦИЯ, МОДЕЛИРОВАНИЕ И ИНФОРМАЦИОННОЕ ОБЕСПЕЧЕНИЕ

Иванов Н.М., Левин А.М., Федоренко И.Я. Динамические особенности виброщекового измельчителя кормового зерна **105**

НАШИ ЮБИЛЯРЫ

Александр Семенович Донченко **113**

К юбилею Галины Моисеевны Гончаренко **116**

К 70-летию Виктора Александровича Рогачева **118**

Dursenev M.S., Bayunova N.A., Ovsyannikov Yu.S. Efficiency of using the "Meadow of Health" feed table cover **89**

Popov A.A., Neustroev M.P., Vasil'eva S.A. History of equine rhinopneumonia research **98**

MECHANISATION, AUTOMATION, MODELLING AND DATAWARE

Ivanov N.M., Levin A.M., Fedorenko I.Ya. Dynamic features of vibrating jaw crusher of feed grain **105**

OUR JUBILJARS

Alexandr Semyonovich Donchenko **113**

To the anniversary of Galina Moiseevna Goncharenko **116**

To the 70th anniversary of Viktor Aleksandrovich Rogachev **118**

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Биохимическая активность торфов различного генезиса

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Представлены результаты исследования ферментативной активности торфов трех болот верхового и низинного типов – Саим, Большое и Тунгусовское (Томская область). Приведены особенности формирования органического вещества торфов разного вида. Показано, что свойства торфов, насчитывающих в своем составе до восьми разных растений, являются следствием неодинакового строения полимеров исходных растений. Определены показатели активности ферментов инвертазы, протеазы, каталазы, полифенолоксидазы, нитрат- и нитритредуктазы в торфах различного генезиса. Так, на типовом уровне экстремальные значения активности нитрат- и нитритредуктазы в торфах верхового болота равны соответственно 3,60–4,94 мг восстановленного NO_3^-/24 ч/г и 3,52–7,01 мг восстановленного NO_2^-/24 ч/г, низинного болота – 4,66–19,33 мг восстановленного NO_3^-/24 ч/г и 0,9–13,0 мг восстановленного NO_2^-/24 ч/г, пойменного болота – 8,77–22,29 мг восстановленного NO_3^-/24 ч/г и 0,2–13,6 мг восстановленного NO_2^-/24 ч/г. Проведено сравнение активности фермента в торфах и в минеральных почвах с оценкой активности по шкале Д.Г. Звягинцева. Установлено, что в торфах отмечается более широкий интервал значений инвертазы, чем это показано по шкале. Выявлена необходимость разработки градации оценки ферментативной активности для торфов. Вероятно, при изменении внешних условий в сторону потепления активность ферментов по трансформации органического вещества торфов может возрасти. В перспективе предлагаем разработать оценочный кадастр торфов по ферментативной активности, который позволит путем сбалансированного подбора торфов для производства сельскохозяйственной продукции обеспечить требуемое качество продукции, ее экологическую безопасность и экономическую эффективность.

Ключевые слова: торф, торфяной профиль, ферменты, трансформация органического вещества, кадастр

Biochemical activity of peats of different genesis

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The results of the study of enzymatic activity of peats of the three bogs of upper and lowland types – Saim, Bolshoye and Tungusovskoye (Tomsk region) are presented. The peculiarities of organic matter formation of peats of different types are given. It is shown that the properties of peats with up to eight different plants in their composition are a consequence of the different structure of polymers of the original plants. The activity indices of enzymes invertase, protease, catalase, polyphenol oxidase, nitrate and nitrite reductase in the peats of different genesis are determined. Thus, at

the type level, the extreme values of nitrate and nitrite reductase activity in the peats of the upland bog are equal to 3.60–4.94 mg of reduced NO_3^-/24 h/g and 3.52–7.01 mg of reduced NO_2^-/24 h/g, respectively, lowland bog – 4.66–19.33 mg of reduced NO_3^-/24 h/g and 0.9–13.0 mg of reduced NO_2^-/24 h/g, fluvial bog – 8.77–22.29 mg of reduced NO_3^-/24 h/g and 0.2–13.6 mg of reduced NO_2^-/24 h/g. The activity of the enzyme in peats and in mineral soils is compared with the activity estimation according to the D.G. Zvyagintsev scale. Peats are found to show a wider range of invertase values than indicated by the scale. The need to develop a gradation of enzymatic activity assessment for peats is identified. Probably, the activity of enzymes on peat OM transformation may increase when external conditions change towards warming. In the future, it is suggested to develop an evaluation cadastre of peats by enzymatic activity, which will allow, through a balanced selection of peats for agricultural production, to ensure the required quality of products, their environmental safety and economic efficiency.

Keywords: peat, peat profile, enzymes, transformation of organic matter, cadastre

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INTRODUCTION

Soil is a system rich in enzyme composition and pool due to the complex source of enzyme supply (microorganisms, plants, soil biota). In this regard, enzymatic activity along with other criteria is a reliable diagnostic indicator of the rate of transformation of organic matter (OM) in soil. Such studies are widely presented for mineral soils [1–6]. As for peat soils, little attention is paid to their enzymatic activity[1] [7–9].

At the same time, the organogenic profile of bogs is composed of peats of different species composition. The basis of peat consists of plant residues of solid polymers of cellulose nature and their decomposition products, which are in equilibrium with aqueous solution of low- and high-molecular substances. Such a complex system needs a thorough study of its biological component, which catalyzes the biochemical processes of peat OM transformation. Occupying significant areas in Russia, peat bogs are the largest reservoirs of OM containing carbon (100.93 billion tons)[2]. It is also important to emphasize that peat applied to the fields as an organic fertilizer and ameliorant is not only a source of nutrients for agricultural crops, but also an enzymatic activator, which plays a significant role in improving soil fertility.

Therefore, the purpose of our study was to investigate the enzymatic activity of peats.

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[2] *Vompersky S.E.* Role of bogs in the carbon cycle // Biogeocenotic particularities of bogs and their rational use: XI Readings in memory of Academician V.N. Sukachev. Moscow: Nauka, 1994, pp. 5–37.

MATERIAL AND METHODS

The study was conducted in the Tomsk region on three bogs of different genesis. The Saim bog, located in the Alexandrovsky district and categorized as a bog of the upper type, has an area of 3611.2 ha, formed on the second supra-floodplain terrace of the Ob in the conditions of atmospheric feeding on sandy loam soils. This bog began to develop from the mesotrophic stage of peat formation: in the process of development, the wood-scheuchzeria peat changed to scheuchzeria and scheuchzeria -sphagnum peat and further at the surface to sphagnum depression peat. The whole profile is represented by oligotrophic peats (1.1–3.4%). The low degree of decomposition (5%), observed near the surface, increases to the bedrock to 31% simultaneously with a slight increase in the sum of absorbed bases at a constant medium reaction of 3.0–3.5 and high hydrolytic acidity (104.0–130.8 mg-eq/100 g).

The Bolshoye bog, classified as a lowland type bog, is located in the Bakcharsky District, on the terrace of the Andarma river. Its water supply is realized due to the inflow of surface water run-offs from the catchment area and confined ground-water. The underlying soils are clays. The area of the bog is 1391 ha. It was formed under the conditions of rich mineral nutrition with deposits of peats of woody and woody-sedge types with ash content of 8.3–11.4%. The degree of decomposition in the peat profile increases from 15% starting from the surface to 40% to the underlying rocks. In the same direction the acidity of peats changes (from slightly acidic to neutral reaction) and the sum of absorbed bases increases (143.5 – 242.2 mg-eq/100 g).

The Tungusovskoye floodplain bog, with an area of 82 ha, is located in the Molchanovsky District, in the floodplain of the Bolshoi Tatosh river. The underlying rocks are loams and clays. The presence of confined ground-water feeding with hydrocarbonate-calcium waters in the floodplain bog caused the peat profile to be divided into two parts: upper part with normal-ash peats (8.2–15.5%), low values of hydrolytic acidity (2.7–16.1 mg-eq/100 g) and pH_{salt} close to neutral (6.6–6.9), and lower part with high-ash peats (24.0–31.6%) and weakly alkaline reaction of the medium (7.4–7.5).

Botanical composition and degree of decomposition, ash content, exchangeable acidity and sum of absorbed bases[3] were determined in the peats, and enzymes of oxidoreductase and hydrolase classes were studied. The fractional composition of OM was determined by V.V. Ponomareva and T.A. Nikolaeva[4], the total activity of catalase was determined using the gasometric method[5], and non-enzymatic catalase was determined according to F.H. Khaziev[6]. Polyphenol oxidase activity was determined according to the method of L.A. Karyagina and N.A. Mikhailovskaya[7], invertase activity according to the method of T.A. Scherbakova[8], nitrite and nitrate reductase activity according to L.A. Murdam[9]. In order to reveal the dependences between the enzyme activity and chemical composition of peats, correlation analysis was carried out separately for peats of high and lowland types. The calculated correlation coefficients are significant at a confidence level of 95%.

[3]*Bazin E.T., Kopenkin V.D., Kosov V.I., Korchunov S.S., Petrovich V.M.* Technical analysis of peat. Moscow: Nedra, 1992, 358 p.

[4]*Ponomareva V.V., Nikolaeva T.A.* Methods of studying organic matter in peat-bog soils // Eurasian Soil Science, 1961, N 5, pp. 88–95.

[5]*Kruglov Yu.V., Paromenskaya L.N.* Modification of the gasometric method for determination of catalase activity // Eurasian Soil Science, 1966, N 1, pp. 93–95.

[6]*Khaziev F.H.* Methods of soil enzymology. Moscow, 1990, 189 p.

[7]*Karyagina L.A., Mihailovskaya N.A.* Determination of polyphenol oxidase and oxidase activity in soil // Proceedings of the Academy of Sciences of BSSR. Series of Agricultural Sciences, 1986, N 2, pp. 40–41.

[8]*Shcherbakova T.A.* Enzymatic activity of soils and transformation of organic matter. Minsk, 1983, 222 p.

[9]*Murdam L.A.* Dynamics of microbiological processes and enzymatic activity in connection with the transformation of nitrogen in soil: Candidate's thesis in Biology, Tallinn, 1982, 168 p.

RESULTS AND DISCUSSION

A certain enzyme pool is created in peat soil, which composition and activity corresponds to the biocenotic composition of the biogeocenosis and the properties of peat as a catalytic matrix. In turn, the peculiarities of formation of the bogs of different genesis determine the enzymatic activity of peats in the peat profile.

To understand the peculiarities of enzymatic activity of peats in the bogs of different genesis, the composition of OM was considered. The indices of hydrolysates, sums of humic acids (HA) and fulvic acids (FA), C/N and S_{HA}/S_{FA} ratios are the most informative for assessing enzymatic activity (see Table 1).

It has been established on the basis of the study of the Saim bog that the non-hydrolyzable residue (47.4–59.7%) predominates in the composition of the OM in the peats of the upper bog. Easily hydrolyzable and hard-to-hydrolyze substances together constitute only a small share (2.9–14.4%), their high values are noted in the upper layers composed of sphagnum depression and scheuchzeria-sphagnum peat. Humic acids are the main substances determining the enzymatic properties of peats. The amount of HA increases with increasing depth from 15.0–19.7 to 29.7–37.8%, which is explained by the change of peat species composition. The presence of sphagnum mosses in peat composition inhibits the process of decomposition of hydrolyzable compounds and formation of humus substances. The sum of FA also increases down the profile, but insignificantly, with a simultaneous increase in the S_{HA}/S_{FA} ratio from 3.6 to 5.7.

In the Bolshoye bog, peats classified as the lowland type compared to the peats of the upland bog with low carbon content, the fraction of non-hydrolyzable residue, hydrolysates, especially hard-to-hydrolyze substances, and FA

Табл. 1. Фракционный состав органического вещества торфов, % от $C_{общ}$
Table 1. Fractional composition of organic matter peats, % from C_{tot}

Peat type	Depth, cm	C_{tot}, %	HA	FA	C_{HA}/C_{FA}	Hydrolysates			N/h	C/N
						e/h	h/h	sum		
Saim										
Sphagnum depression	25–75	47,5	15,0	4,2	3,6	7,7	6,7	14,4	59,7	–
Scheuchzeria-sphagnum	75–125	44,1	19,7	5,9	3,3	4,5	7,4	11,9	54,8	–
Scheuchzeria	125–150	44,9	29,7	6,6	4,6	2,4	4,1	6,5	47,4	–
»	175–200	52,1	37,8	6,6	5,7	1,1	1,9	2,9	42,7	–
Woody-scheuchzeria	200–225	55,8	33,6	6,4	5,3	0,9	2,3	3,2	47,9	–
Bolshoye										
Woody	0–25	29,6	25,6	17,6	1,5	6,0	6,8	12,8	40,5	20,5
»	75–100	30,3	17,8	12,1	1,5	6,1	7,7	13,8	52,8	20,1
Woody-sedge	125–150	30,9	19,6	13,1	1,5	5,2	7,0	12,2	51,1	17,2
»	175–200	31,3	21,3	12,0	1,7	4,4	6,3	10,7	54,1	16,4
»	200–225	30,4	22,5	11,5	1,9	3,3	7,0	10,4	52,7	19,1
Tungusovskoye										
Sedge	0–25	45,6	16,9	30,8	0,5	6,1	5,6	11,7	33,8	25,2
»	25–75	49,1	20,8	24,0	0,9	5,4	4,8	10,2	38,4	–
Sedge-hypnum	100–125	49,1	21,1	24,0	0,9	4,3	4,7	9,0	38,9	24,9
»	175–200	50,4	21,7	21,3	1,0	4,2	4,7	8,9	40,4	25,7
Sedge	225–250	50,6	22,7	22,1	1,0	3,7	4,8	8,5	40,2	24,6
Grass	325–350	38,3	30,8	25,5	1,2	3,8	4,1	7,9	27,3	21,1

Note. C_{tot} – total carbon content; C_{HA}/C_{FA} – the ratio of the amount of carbon in humic acids to the amount of carbon in fulvic acids; e/h – easily hydrolyzable substances; h/h – hard-to-hydrolize substances; n/h – non-hydrolyzable residue; «–» – did not identify.

prevails. Humic acids in the lowland bog peats were found less than in the upland bog peats and only in the woody type peat in the 0–25 cm layer their content increases by 1.7 times. It should be noted that lowland woody peat, which makes up most of the lowland bog profile, contains less HA than, for example, lowland grass peat. This is due to the initial composition of woody residues, which are almost 80% carbohydrate[10], and during transformation the carbohydrate complex is actively degraded by the microflora with the help of enzymes, not contributing to the formation of HA. C/N ratio varies in the range of 16.4–20.5, S_{HA}/S_{FA} – 1.5–1.9.

The profile of the lowland floodplain bog Tungusovskoye is composed with the predominance of sedge and sedge-hypnum species of peat. Based on the analysis of plant composition, it is known that sedges and green mosses decompose at a slower rate, and proline predominates among amino acids. This acid is subject to decomposition in the first place. Also, in these types of peat low nitrogen content is noted. As a result, the OM composition of peats in the floodplain bog profile is characterized by the lowest content of non-hydrolyzable residue and high content of FA. According to the content of hydrolysates, they occupy an intermediate position between the peats of upland and lowland bogs, while the fractions of easily hydrolyzable and hard-to-hydrolyze substances in this case are approximately equal. The C/N ratio in the peats of the floodplain bog is higher than in the peats of the lowland bog, S_{HA}/S_{FA} is the lowest (from 0.6 to 1.2).

Thus, in the peat profile of different genesis there is a variation of OM composition in accordance with the species diversity of peat-forming plants. As a rule, peats may include from three to seven peat-forming plants. According to the works of V.E. Rakovsky and L.V. Pigulevskaya (see footnote 10), botanically "pure" types of peat, composed entirely or 85–95% by one plant species, have a clear degree of decomposition and constant chemical composition. For example, a significant difference in the composition of fuskum and magellanicum peat samples was found. If the content of FA in magellanicum is 19%, in fuskum it is only 4%. Accordingly, their ratio in the botanical composition of peat influences the composition of OM. Or, for example, hypnum peat of lowland bogs synthesizes OM with sharply different composition depending on the ecological factors and peculiarities of mineral nutrition, which is observed in the composition of OM of a floodplain bog.

The process of peat OM transformation is controlled by the activity of the enzymes as catalytic activators of biochemical processes. Taking this fact into account, let us consider the activity of individual enzymes (see Tables 2–4).

As already noted, about 80-90% of peat OM are carbohydrates, subjected to the action of a complex of enzymes of the hydrolase class, among which the most studied is invertase. This enzyme splits carbohydrates into glucose and fructose molecules, which are further included in the biosynthesis of high-molecular compounds. The activity of invertase in the peat profile of the upland bog varies from 17.24 to 65.92 mg glucose/4 h/g (hereinafter referred to as "units"), lowland bog – from zero to 74.45 units, floodplain bog – from zero to 133.07 units. High enzyme activity is characteristic of the upper part of the peat profile (see Table 2). In the upper meter layer, invertase activity values in peats of the upland bog are 44.32–65.92 units (see Table 2), in peats of the lowland bog – 42.77–74.45 units (see Table 3), and in floodplain peats – 56.04–133.07 units (see Table 4).

Below the peat profile of the upland bog, the activity of invertase decreases, which is also characteristic of floodplain bog peats. This is partly explained by the decrease in the content of easily hydrolyzable substances to the underlying rocks. A wider range of invertase values can be traced across the peat profile of the lowland bog (33.75–49.15 units). It is also important to note that at a depth of 200–225 cm in the lowland bog (woody-sedge type of peat) and

[10]*Rakovsky V.E., Pigulevskaya L.V.* Chemistry and genesis of peat. Moscow: Nedra, 1978, 231 p.

Табл. 2. Ферментативная активность торфов в болоте Саим
Table 2. Enzymatic activity of peats in the Saim bog

Peat type	Depth, cm	Invertase, mg of glucose/4 h/g	Catalase			Polyphenol oxidase, mg 1,4-p-benzo-quinone/ 30 min/g	Nitrate reductase, mg of reduced NO_3^-/24 h/g	Nitrite reductase, mg of reduced NO_2^-/ 24 h/g
			total	enzymatic				
			ml O_2 / 2 min/g		% of the total			
Tirr	0–25	–	–	–	–	–	–	–
Sphagnum depression	25–75	65,92	0,64	0,35	56	0,00	4,94	3,52
Scheuchzeria-sphagnum	75–125	44,32	0,42	0,12	52	0,62	4,91	5,26
Scheuchzeria	125–150	24,41	0,71	0,54	76	0,93	3,61	4,37
»	150–175	22,37	0,22	0,13	59	0,49	3,73	7,01
»	175–200	17,24	0,56	0,40	71	1,81	3,63	5,89
Woody-scheuchzeria	200–225	27,50	0,44	0,30	68	3,41	4,80	4,70

Табл. 3. Ферментативная активность торфов в болоте Большое
Table 3. Enzymatic activity of peats in the Bolshoye bog

Peat type	Depth, cm	Invertase, mg of glucose/4 h/g	Protease, mg of tyrosine/ 18 h/g	Catalase			Polyphenol oxidase, mg 1,4-p-benzo-quinone/ 30 min/g	Nitrate reductase, mg of reduced NO_3^-/24 h/g	Nitrite reductase, mg of reduced NO_2^-/ 24 h/g
				total	enzymatic				
				ml O_2 / 2 min/g		% of the total			
Woody	0–25	74,45	1,06	3,30	2,39	72	1,33	19,33	4,69
Woody-sedge	25–50	42,77	2,12	1,15	0,38	34	0,76	8,60	1,89
Woody	50–75	53,95	0,03	5,72	4,65	81	0,37	6,36	3,37
»	75–100	37,56	0,34	0,90	0,19	22	0,67	8,09	3,85
Woody-sedge	100–125	54,94	0,04	0,88	0,15	17	0,91	5,41	2,24
»	150–175	49,15	0,08	0,78	0,28	36	0,61	5,41	2,03
»	175–200	34,45	0,25	0,80	0,35	44	1,03	4,74	2,43
»	200–225	0,00	0,01	0,94	0,40	43	0,92	5,47	0,93
Sedge	225–250	33,75	0,00	0,87	0,23	26	0,99	7,88	13,03
»	250–275	36,43	0,00	1,10	0,29	26	1,09	8,89	12,03

Табл. 4. Ферментативная активность торфов в болоте Тунгусовское
Table 4. Enzymatic activity of peats in the Tungusovskoe bog

Peat type	Depth, cm	Invertase, mg of glucose/4 h/g	Protease, mg of tyrosine/ 18 h/g	Catalase			Polyphenol oxidase, mg 1,4-p-benzoquinone/ 30 min/g	Nitrate reductase, mg of reduced NO_3^- /24 h/g	Nitrite reductase, mg of reduced NO_2^-/ 24 h/g
				total	enzymatic				
				ml O_2 / 2 min/g		% of the total			
Sedge	0–25	56,05	1,03	32,49	21,13	65	2,43	22,30	5,56
»	25–50	66,73	1,09	13,95	12,35	89	1,00	15,87	13,52
»	50–75	77,00	0,35	21,39	19,72	92	2,85	14,51	13,65
Sedge-hypnum	75–100	133,07	0,02	5,33	4,54	85	0,90	8,77	3,22
»	100–125	75,52	0,16	3,81	2,99	78	0,18	8,92	2,42
»	125–150	85,92	0,00	5,04	4,23	84	0,84	8,96	2,70
»	150–175	12,95	0,00	2,09	1,27	61	0,47	2,32	1,19
»	175–200	3,95	0,00	3,55	2,51	71	0,42	3,86	3,29
»	200–225	23,12	0,00	1,95	1,01	52	0,54	2,85	0,96
Sedge	225–250	14,13	0,00	2,71	1,50	55	0,15	2,30	13,39
»	250–275	0,78	0,00	2,67	1,65	61	0,64	3,67	13,56
Grass	275–300	0,00	0,00	1,84	1,26	68	1,40	3,95	0,80
Woody-grass	300–315	15,06	0,72	8,95	7,28	81	1,98	4,56	0,22

at a depth of 275–300 cm in the floodplain bog (grass type) the invertase activity is zero. While above and below this layer, invertase values correspond to average values in the peat profile. If we compare the obtained values of invertase activity in peat and mineral soil [10], then, according to the gradation of D.G. Zvyagintsev[11], its activity in chernozem is estimated as medium invertase (approximately 22 units). In peats, the range of values is much wider: from zero to 133.07 units, which clearly does not fit into the gradation of the invertase activity estimation proposed for mineral soils.

Proteases catalyze hydrolytic cleavage of protein substances to peptides and hydrolysis of peptides to amino acids. Protease activity in peats of the Bolshoye lowland bog varies within the range of 0.01–2.12 mg tyrosine/18 h/g (hereafter referred to as units) with higher values in the upper half-meter layer (see Table 3). Protease activity decreases to zero from a depth of 225 cm to the bedrock. A similar situation is observed in the peat profile of the floodplain bog (see Table 4). Protease activity along the profile varies from zero to 1.09 units, and becomes zero from the depth of 125 cm, i.e. significantly higher compared to the lowland bog profile.

Enzymes of the oxidoreductase class play a significant role in the biochemical transformation of peat OM. Thus, under the action of catalase, hydrogen peroxide toxic to living organisms is split into water and free oxygen, which

[11] *Zvyagintsev D.G.* Biological activity of soils and scales for evaluation of some of its indicators // Eurasian Soil Science, 1978, N 6, pp. 48–54.

in turn takes part in the oxidation of OM. The total catalase activity is divided into enzymatic, carried out at the expense of enzymes of the biological complex, and non-enzymatic, the action of which is due to the presence of manganese[12]. More attention is paid to this enzyme in scientific literature[13] [11–13].

In the peat deposit of the upland bog, the limits of variation of the total catalase activity are 0.22–0.71 ml O_2/2 min/g (hereinafter referred to as "units"). Its enzymatic part belongs to 52–76% of the total activity with higher values (59–76%) in the lower part of the profile, where scheuchzeria peats predominate (see Table 2). Catalase activity of the lowland bog peats varies from 0.78 to 5.72 units (see Table 3). High values of total catalase (5.72 and 3.30 units; type of peat – woody) were noted only in the 0–75 cm layer. In the rest of the profile, the limits of variation are 0.78–1.10 units, the distribution is uneven, the enzymatic part includes 17–44% of the total enzyme activity, its higher activity is noted in the layer 0–75 cm. The hig-hest values of both total and enzymatic activity of catalase are observed in the profile of floodplain bog (1.84–13.48 units) (see Table 4). In the 0–75 cm layer composed of sedge peat, the extreme values of enzyme activity are 13.95–32.48 units, with enzymatic catalase reaching 65–92% of the total activity. In the depth of the peat profile of the floodplain bog, the total catalase activity of the peats decreases (1.27–4.54 units) and closer to the underlying rocks becomes equal to 1.01–2.51 units. In the transition from grassy peat to woody-grassy peat, the total catalase activity increases again to 8.95 units.

By comparing the indices of total catalase activity in the studied peats, for example, with catalase activity in chernozem soils [10], its higher values in chernozem soils (from 10 to 22 ml O_2/1 min/g) become obvious, as it is estimated by the researchers themselves according to D.G. Zvyagintsev's scale (see footnote 11). In peats, the indices of total catalase vary from 0.22 to 32.48 ml O_2 / 2 min/g with predominant values in the range of 0.8–5.72 units. Taking into account that our calculations are given for 2 min, the readings in peats will be even less. Thus, the scale of catalase activity estimation for peats should be different, which we also observed when analyzing invertase activity.

Polyphenol oxidases catalyze the oxidation of phenols (mono-, di-, tri-) to quinones. Further, complex high-molecular compounds are formed. In the peats containing up to 95% of OM, humus substances account for 42.4% in upland peats and up to 55.9% in lowland peats[14] (see Table 2). The limits of polyphenol oxidase activity in the peat profile of the upland bogs vary from zero in the 25–75 cm layer to 3.41 mg 1.4 p benzoquinone/30 min/g (hereinafter referred to as units). High activity of polyphenol oxidase is noted in woody-scheuchzeria peat at a depth of 200–225 cm (3.41 units). Above this layer the enzyme activity also remains high in scheuchzeria peat at the depth of 175–200 cm – 1.81 units. The enzyme activity provides a decrease in carbohydrate content and accumulation of HA, which is observed in the peats of the upper Saim bog. The HA content in these layers is characterized by high values – 37.8 and 33.6%, respectively.

In the peats of the lowland bog Bolshoye, the limits of extreme values of polyphenol oxidase activity are equal to 0.37–1.33 units with the highest activity in the surface and lower layers of the profile (see Table 3). The same pattern is characteristic of the peats of the floodplain bog: the limits of values are 0.18–2.84 units, with the highest activity of polyphenol oxidase in the upper and lower layers of the profile (see Table 4).

It is known that the process of organic nitrogen transformation in peat occurs in several stages in aerobic and anaerobic conditions si-

[12]*Semikolennykh A.A.* Catalase activity of soils of the northern taiga (Arkhangelsk region) // Eurasian Soil Science, 2001, N 1, pp. 90–96.

[13]*Melekhina E.N., Markarova M.Y., Shchemelinina T.N., Anchugova E.M., Kanev V.A.* Secondary successions of biota in oil-polluted peat soil upon different biological remediation methods // Eurasian Soil Science, 2015, vol. 48, N 6, pp. 643–653.

[14]*Lishtvan I.I., Bazin E.T., Gamayunov N.I., Terentyev A.A.* Physics and chemistry of peat: textbook for universities. Moscow: Nedra, 1989, 304 p.

multaneously. This is due to the fact that nitrogen-containing substances of peat are represented by protein compounds and have an increased nitrogen content in the form of heterocyclic compounds. Let us focus on the biochemical process of nitrate nitrogen conversion into ammonia by means of nitrate and nitrite reductase enzymes acting sequentially.

Nitrate reductase activity in the peats of the upland bog is practically constant along the deposit profile – 3.60–4.94 mg of reduced NO_3^- /24 h/g (hereinafter referred to as "units"). High values of the enzyme are characteristic of sphagnum depression peat, scheuchzeria-sphagnum peat (4.91 units), as well as woody-scheuchzeria peat (4.80 units) (see Table 2). The activity of nitrate reductase is higher in the peat profile of the lowland bog (4.66–19.33 units), with the highest values in the surface layer (8.60–19.33 units) and in the lower part of the profile (7.88–8.89 units) (see Table 3). The highest activity of this enzyme is observed in the peat profile of the floodplain bog (8.77– 22.29 units), but up to a depth of 150 cm, where sedge and sedge-hypnum peat is represented. Below the profile the activity decreases to 2.30–4.55 units (see Table 4).

The activity of nitrite reductase in peats of the upland bog is 3.52–7.01 mg of reduced NO_2^- /24 h/g (hereinafter referred to as "units"), and varies unevenly along the profile (see Table 2). In the peat profile of a lowland bog (in grass and woody-grass peat) (see Table 2), the enzyme shows high activity (12.03–13.03 units). The lowest nitrite reductase activity (3.37–4.69 units) was observed up to a depth of 100 cm in woody peat, and a low activity (0.93–2.43 units) in woody-sedge peat (see Table 3). In the peat profile of the floodplain bog, nitrite reductase activity in extreme values corresponds to the enzyme values in the lowland bog (0.22–13.65 units). However, nitrite reductase activity varies unevenly along the profile: thus, in the 0–25 cm layer of sedge peat it is equal to 5.56 units, below the profile its activity in sedge peat reaches more than 13 units (see Table 4). In sedge-hypnum peat of the middle part of the floodplain bog profile the activity decreases to 0.95–3.22 units, in sedge peat at a depth of 225–275 cm the nitrite reductase activity increases to almost 14 units and sharply decreases to the bedrock to 0.22–0.80 units in grass and woody-grass peat. Thus, sedge peat in the profile of the floodplain bog has three degrees of enzyme activity without confirmation of the content of HA and non-hydrolyzable residue in the OM of these peats. This is partly due to the inundated character of the water regime in the floodplain bog.

Calculations of the correlation matrix between enzymes and other properties of peats at 95% confidence level showed that high correlation coefficients were obtained for peats of the upland bog: between nitrate reductase, polyphenol oxide with MnO in ash (r = 0.98), between invertase and the sum of HA (r = 0.7). In peats of the lowland bog (ash content up to 12%), a high correlation was observed between total and enzymatic catalase with MnO in ash (r = 0.9). In peats of the lowland floodplain bog (ash content up to 18%), a high relationship between catalase total and enzymatic catalase with Fe_2O_3 (r = 0.7) and MnO in ash (r = 0.9) was found. In addition, nitrate reductase correlated with the first and third fractions of HA, the correlation coefficient was the same, 0.7.

CONCLUSION

The study of the OM composition and enzymatic activity of peats of upland, lowland and floodplain bogs showed their significant difference at the type and species levels. Thus, in the peats of upland bogs of predominantly scheuchzeria type, non-hydrolyzable residue predominates in the composition of OM, high content of HA is noted, which increases down the profile. In the profile of the lowland bog, composed, as a rule, of woody peat, there is also a high content of hard-to-hydrolyze substances and hydrolysates, but to a lesser extent – HA. In the floodplain bog, peats with increased ash content prevail, from a depth of 175 cm – high-ash peats: the content of non-hydrolyzable substances is the lowest (27.3–40.4%), the content

of FA is high (21.3–30.8%). The distribution of enzymatic activity in the peat profile was found to be influenced by the species composition of peats.

The values of enzymes in the peat profile of three bogs differing in genesis – Saim, Bolshoye and Tungusovskoye – have been determined. The activity of invertase in the peats of the upland bog varies within the range of 17.24–65.92 units, lowland bog – from zero to 74.45 units, floodplain bog – from zero to 133.07 units. Protease activity in the peats of the lowland bog in extreme values is equal to 0.01–2.12 units, floodplain bog – 0.0 –1.09 units.

The limits of variation of the total activity of catalase in peats of the upland bog are 0.22–0.71 ml O_2/2 min/g, its enzymatic part belongs to 52–76% of the total activity. In the peats of a lowland bog, the activity of this enzyme varies from 0.78 to 5.72 ml O_2/2 min/g, its enzymatic part belongs to 17–81%. Lower values of both total (1.84–13.48 ml O_2/2 min/g) and enzymatic activity of catalase (52–92%) are observed in the peats of a floodplain bog.

The activity of polyphenol oxidase in the peats of the upland bog varies between 0–3.41 mg 1,4–p-benzoquinone/30 min/g, lowland peat between 0.37–1.33, and floodplain peat between 0.50–2.84 mg 1,4-p-benzoquinone/30 min/g.

Extreme values of nitrate and nitrite reductase activity in the peats of the upland bog are 3.60–4.94 mg of reduced NO_3^-/24 h/g and 3.52–7.01 mg of reduced NO_2^-/24 h/g, respectively, 4.66–19.33 mg of reduced NO_3^-/24 h/g and 0.9–13.0 mg of reduced NO_2^-/24 h/g, floodplain bog – 8.77–22.29 mg of reduced NO_3^-/24 h/g and 0.2– 13.6 mg of reduced NO_2^-/24 h/g.

The results obtained for the enzymatic activity of the peats of bogs of different genesis showed that they are incompatible with the enzyme evaluation scale developed by D.G. Zvyagintsev for mineral soils, and that this scale has yet to be developed for peats.

In the future, studies of the enzymatic activity of peats, determination of diagnostic indicators of their activity and creation of an evaluation cadastre of raw material base (peat) selection will allow, through a balanced selection of peats for agricultural production, to ensure the required quality of products, their environmental safety and economic efficiency.

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Вторичные метаболиты периллы (*Perilla frutescens* (L.) Britton) дальневосточного происхождения, идентифицированные методом тандемной масс-спектрометрии

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Perilla frutescens – монотипный род однолетних травянистых растений семейства Яснотковые. Приведена одновременная оценка присутствия как фенольных соединений в экстрактах семян *P. frutescens,* так и соединений других химических классов. Подтверждено, что семена *P. frutescens* образцов дальневосточного происхождения к-130, к-263, к-326 содержат большое количество полифенольных комплексов, являющихся биологически активными соединениями. Впервые представлен полный метаболомный состав экстрактов семян периллы. В исследовании применен метод тандемной масс-спектрометрии, включающий в себя использование жидкостной хроматографии параллельно с ионной ловушкой. Методом тандемной масс-спектрометрии идентифицировано присутствие 60 соединений, из них 41 представляют группу полифенольных соединений, а также 19 соединений других химических групп в экстрактах периллы. Идентификацию химических компонентов проводили путем сравнения их индекса удерживания, масс-спектров и фрагментации МС с базой данных домашней библиотеки на основе данных других спектроскопических методов, таких как ядерный магнитный резонанс, ультрафиолетовая спектроскопия и масс-спектрометрия. Также впервые найдено 29 химических соединений, из них 16 – полифенольной группы и 13 – других химических групп. Впервые идентифицированы в семенах периллы лигнаны: сирингарезинол и медиорезинол; кумарины: умбеллиферон и 4-гидроксикумарин; флавоны: лютеолин 7-О-глюкозид, диосметин С-гексозид, хризоэриол С-гексозид С-пентозид; флаванолы: ампелопсин, астрагалин и др. Большое разнообразие биологически активных полифенольных соединений открывает богатые возможности для создания новых лекарственных препаратов, биологически активных добавок на основе экстрактов из семян периллы, а также дальнейших исследований по функциональному и специализированному питанию, использующих в своей основе продукты из периллы.

Ключевые слова: *Perilla frutescens*, перилла, ВЭЖХ – МС/МС, тандемная масс-спектрометрия, полифенольные соединения, диаграмма Венна

Secondary metabolites of perilla (*Perilla frutescens* (L.) Britton) of Far Eastern origin identified by tandem mass spectrometry

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Perilla frutescens is a monotypic genus of annual herbaceous plants of dead nettles. The article presents a simultaneous evaluation of the presence of both phenolic compounds in *P. frutescens* seed extracts and compounds of other chemical classes. It has been confirmed that the seeds of *P. frutescens* varieties k-130, k-263, k-326 contain a large number of polyphenolic complexes, which are biologically active compounds. The complete metabolomic composition of perilla seed extracts is presented for the first time. The study utilized a tandem mass spectrometry method involving the use of liquid chromatography in parallel with an ion trap. Using tandem mass spectrometry, the presence of 60 compounds was identified, of which 41 compounds represent the group of polyphenolic compounds, as well as 19 compounds of other chemical groups in perilla extracts. The chemical components were identified by comparing their retention index, mass spectra and MS fragmentation with the home library database based on the data from other spectroscopic techniques such as nuclear magnetic resonance, UV-visible spectroscopy and mass spectrometry. Also, 29 chemical compounds were found for the first time, including 16 compounds of polyphenolic group and 13 compounds of other chemical groups. Lignans: syringaresinol and medioresinol; coumarins: umbelliferone and 4-hydroxycoumarin; flavones: luteolin 7-O-glucoside, diosmetin C-hexoside, chrysoeriol C-hexoside C-pentoside; flavanols: ampelopsin, astragalin, etc. were identified in perilla seeds for the first time. The data obtained will help intensify future research on the development and production of new drugs, dietary supplements and various functional, specialized and dietary products containing targeted perilla extracts.

Keywords: *Perilla frutescens,* perilla, HPLC – MS/MS, tandem mass spectrometry, polyphenolic compounds, Venn diagram

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INTRODUCTION

Perilla frutescens – is an annual herbaceous plant of the Lamiaceae family. It is a herbaceous plant up to 1 m high with a straight ascending tetrahedral stem. The lower leaves are large, macropodous, ovate, and the upper leaves are oblong-ovate, sessile or short-petiolate. Arrangement of the leaves is subopposite[1]. Seeds are round, small in size, light to dark brown. The weight of 1000 seeds is 1.5–2.0 g. Oil content in seeds is up to 49%. The vegetation period of the studied varieties is 124–139 days, economic yield – 1.0–1.2 t/ha. There are varieties of perilla with green and red leaves, as well as variegated. The natural range of the species covers Japan, Korea, China, Vietnam and other countries of East Asia[2]. As a naturalized plant it is found in the phytocenoses of the Black Sea coast of the Caucasus on the territory of Abkhazia. It is cultivated in many countries, including the United States and Canada, as an oilseed, spice-aromatic and honey crop. It also deserves attention as a leafy vegetable crop. In the Russian Federation, perilla is cultivated as an oilseed in the Far East, North Caucasus, Krasnodar Territory and the Rostov region[3].

The main spheres of application of perilla are food, pharmacological and paint industry. From the above-ground mass, which has a typical spicy-peppery flavor, essential oil is obtained, from the seeds – fatty oil for technical and food purposes[4]. The seeds contain up to 49% of fatty, quick-drying oil, which is used as a technical oil in the production of varnishes, olive oil, in electrical engineering, for production of pharmaceutical preparations with softening, antioxidant, antibacterial, anti-allergenic and analgesic effect[5].

A large number of secondary metabolites, including flavonoids, coumarins and other polyphenolic compounds, have been isolated from the seeds of perilla plants. These functionally important phytochemicals are known to have anti-inflammatory, anticancer, antiviral and antibacterial activities.

This article presents a simultaneous evaluation of the presence of both phenolic compounds in *P. frutescens* seed extracts and compounds from other chemical classes.

Initial metabolomic analysis revealed the presence of 60 bioactive compounds found in the presented *P. frutescens* extracts. Metabolomic analysis was carried out by multidimensional tandem mass spectrometry for three *P. frutescens* seed extracts.

The used method of tandem mass spectrometry is promising for obtaining preliminary data and analyzing a large number of varietal samples. Using this approach saves time, resources and reagents and provides an opportunity to improve the level of research in the laboratories that do not have more sophisticated equipment.

The purpose of this work is detailed metabolomic analysis by tandem mass spectrometry of Perilla seeds selected from the collection of the N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR).

Figure 1 shows *P. frutescens* plants in different growth phases.

MATERIAL AND METHODS

The seeds of three perilla specimens from the VIR collection were used as the object of

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а *б*

Рис. 1. Перилла: в фазе цветения (*а*); в фазе созревания (*б*)
Fig. 1. Perilla: in the flowering phase (*а*); in the ripening phase (*б*)

study. The seeds of collection samples for the study were obtained as a result of their cultivation at the field nursery of the Far East Experimental Station of the VIR in 2023, harvested at the phase of technical ripeness of seeds. The seeds were stored in a freezer at –15 °C for no more than a week before the experiments started.

Extraction. Fractional maceration was used to obtain highly concentrated extracts. 40 g of seeds of each perilla sample were selected for the analysis. In this case, the total amount of extractant (chemically pure methyl alcohol) was divided into three parts and successively infused on perilla seeds: with the first part, then with the second and third. The extraction test time of each part of the presented plant matrix was 7 days. High-performance liquid chromatography (HPLC) in combination with a BRUKER DALTONIKS ion trap (tandem mass spectrometry) was used to identify the target analytes in the extracts obtained by the maceration method.

High-performance liquid chromatography. To perform the separation of multicomponent mixtures, a Shimadzu LC-20 Prominence HPLC high-pressure liquid chromatograph (Shimadzu, Japan) equipped with a UV detector and a Shodex ODP-40 4E reversed-phase column (250 × 4.6, particle size 4 μm) was used. Eluted in a gradient from water to acetonitrile (A, %): 0 –4 min, 0% A; 4 –60 min, 25% A; 60 –75 min, 100% A; 75 –120 min, 100% A, flow rate 0.5 ml/min. HPLC analysis was performed using the SPD-20A UV-VIS detector (Kanda-Nishikicho 1-chrome, Shimadzu, Chiyoda-ku, Tokyo, Japan) at wavelengths of 230 and 330 and the temperature of 50 °C. The volume of the loading loop was 200 μL.

Tandem mass spectrometry. Mass spectrometric data were obtained using an amaZon SL ion trap (manufactured by BRUKER DALTONIKS, Germany) equipped with an electrospray ionization source ESI in negative and positive ion modes. The optimized parameters were obtained as follows: ionization source temperature – 70 °C, gas flow – 4 l/min, gas-nebilizer (atomizer) – 7.3 psi, kapillar voltage – 4500 V, end plate bending voltage – 1500 V, fragmenter – 280 V, collision energy – 60 eV. The mass spectrometer was used in the scan range of m/z 100 – 1,700 for MS and MS/MS. In the process of mass spectrometry, first- to fourth-order fragmentations were performed sequentially.

RESULTS AND DISCUSSION

The method of tandem mass spectrometry was used to clarify the group of secondary metabolites of the polyphenol group in perilla seeds. The clarification of metabolomic composition is an extremely important result in biochemical analysis system. Mass spectrometric study has tentatively identified 60 chemical compounds present in perilla, out of which 41 are of polyphenolic group and 19 are of other chemical groups. According to the studied literature data[6, 7] [1] 31 chemical compounds were identified.

For the first time, 29 chemical compounds of different groups were isolated in three studied samples of perilla (k-130, k-263, k-326): polyphenols – *p*-hydroxycinnamic acid [4-coumarate], galloylquinic acid O-hexoside, rosmarinic acid O-hexoside, astragalin [kaempferol 3-O-glucoside], quercetin-3-O-glucoside, dihydrocampferol [aromadendrin], afzelequin and its derivative, (epi)-catechin and its derivative, gallocatechin, cyanidin-3-O-glucoside, peonidin-3-O-glucoside, medioresinol, syringa-resinol, di-O-galloyl-rhamnose. Compounds of other chemical groups: L-glutamic acid [L-glutamate], estr-5(10)-en-3,17-diol, 3,4-dihydroxyestran-17- one, 9,10-dihydroxy-8-oxo-octadec-12-enoic acid, 3-hydroxy-2,2'-binaphthalene-1,1',4,4'-tetron, 13-trihydroxyoctadecenoic acid, fructoso-1, 6-bisphosphate[beta-D-fructofuranoso-1,6-bisphosphate], 8,8'-dihydroxy-2,2'-binaftalin-1,1',4,4'-tetron, trehalose, emodin-8-O-β-D-glucopyranoside [anthraglycoside B], 1-hydroxy-3-oxours-12-en-28-oic acid, sespendol, guanosine-5-triphosphate. Based on the data, it can be concluded that the studied perilla samples have high content of polyphenols, which enhances the nutritional and pharmacological feature.

Chemical components were identified by comparing their retention index, mass spectra and MS fragmentation with the home library database created by the Group of Biotechnology, Bioengineering and Food Systems "Advanced Engineering Schools" of the Far Eastern Federal University (Russia) based on the data of other spectroscopic methods, such as nuclear magnetic resonance, ultraviolet spectroscopy and MS, as well as by comparing the obtained experimental data with the known scientific results published in open science.

A summarized table of chemical compounds identified by tandem mass spectrometry in Perilla seed extracts with first- to fourth-order ion fragmentation is presented (see Table 1).

The most striking examples of mass spectra of ion chromatograms obtained by tandem mass spectrometry are shown in Fig. 2–4. The mass spectrum of flavanol ampelopsin in the positive ion mode obtained from perilla seed extract (sample k-326) is shown in Fig. 2.

[6]*Zhou X.-J., Yan L.-L., Yin P.-P., Shi L.-L., Zhang J.-H., Liu J.-H., Ma C.* Structural characterization and antioxidant activity evaluation of phenolic compounds from cold-pressed *Perilla frutescens* var. arguta seed flour. Food Chem., 2014, vol. 164, pp. 150–157. DOI: 10.1016/j.foodchem.2014.05.062.

[7]*Yamazaki M., Nakajima J., Yamanashi M., Makita Y., Springob K., Awazuhara M., Saito K.* Metabolomics and differential gene expression in anthocyanin chemo-varietal forms of *Perilla frutescens* // Phytochemistry, 2003, vol. 62 (6), pp. 987–995. DOI:10.3390/molecules21081007.

Табл. 1. Соединения, идентифицированные в экстрактах семян периллы (сортообразцы к-130, к-263, к-326)

Table 1. Compounds identified in perilla seed extracts (cultivars k-130, k-263, k-326)

Compound	Chemical formula	Molar weight	Retention time, *t* (min)	Adduct ion [M-H]-	Adduct ion [M + H]+	Fragmentation MC/MC			Source
						first	second	third	
1	2	3	4	5	6	7	8	9	10
Polyphenols									
Phenolic acids									
p-Hydroxycinnamic acid [4-coumarate]	$C_9H_8O_3$	164,16	7,9		163,11	145,11	117,11		*Inula gaveolens* [2], *Juglans mandshurica* [3], *Solanum tuberosum* [4], *Triticum aestivum*[8], *millet grains*[9], *Ribes meyeri* [5]
Gallic acid	$C_7H_6O_5$	170,12	8,3		188,15	146,11	118,12	118,14	*Inula gaveolens* [2], *Juglans mandshurica* [3]
Caffeic acid	$C_9H_8O_4$	180,15	6,3	341,29		179,12; 161,05			*Inula gaveolens* [2], *Juglans mandshurica* [3], Soybean leaves [6], *Perilla frutescens* (see footnote 6),
Caffeic acid-O-hexoside [Coffeoyl-O-hexoside]	$C_{15}H_{18}O_9$	342,3	18,2	341,26		179,07	135,09	135,09	*Inula viscosa* [7], *Ribes magellanicum* [8]
Dehydro-rosmarinic acid	$C_{15}H_{20}O_9$	344,31	27,8	343,27		179,06; 135,15	135,10		*Mentha*[10]
Rosmarinic acid	$C_{18}H_{16}O_8$	360,31	25,3	359,29		135,12; 161,08; 197,09	133,08		*Inula viscosa* [7], *Inula gaveolens* [2], *Perilla frutescens* (see footnote 7)
Caffeic acid-O-hexoside-O-rhamnoside	$C_{24}H_{24}O_{11}$	488,44	7,9	487,41		341,24	179,08;	143,04	Lemon, Papaya, Passion fruits[11]
Galloylquinic acid O-hexoside	$C_{24}H_{26}O_{12}$	506,45	25,3	505,35		343,27	161,09; 181,14	133,01	*Euphorbia hirta* [9]
Rosmarinic acid O-hexoside	$C_{24}H_{26}O_{13}$	522,45	22,9	521,33		359,22; 323,11	179,11; 161,04; 132,98	133,1	*Mentha* (see footnote 10)
Rosmarinic acid-O-Caffeic acid	$C_{25}H_{32}O_{13}$	540,51	23,2		541,26	522,08; 361,19; 325,15; 163,10	145,09		*Mentha* [10]
Caffeic acid hexoside dimer	$C_{31}H_{40}O_{17}$	684,6	6,6	683,43		341,25	179,03; 281,13;	161,09	Strawberry, Lemon, Cherimoya, Passion fruit (see footnote 11), *Oligomeris linifolia* [11]
Sageric acid	$C_{36}H_{32}O_{16}$	720,62	25,8	719,27		359,21	161,10	133,11	*Perilla frutescens* (see footnote 7), *Mentha* [10]

[8]*Sharma M., Sandhir R., Singh A., Kumar P., Mishra A., Jachak S., Singh S.P., Singh J., Roy J.* Comparative analysis of phenolic compound characterization and their biosynthesis genes between two diverse bread wheat (Triticum aestivum) varieties differing for chapatti (unleavened flat bread) quality // Frontiers in plant science, 2016, vol. 7, pp. 1870. DOI: 10.3389/fpls.2016.01870.

[9]*Chandrasekara A., Shahidi F.* Determination of antioxidant activity in free and hydrolyzed fractions of millet grains and characterization of their phenolic profiles by HPLC-DAD-ESI-MSn. // J. of Functional Foods, 2011, vol. 3. DOI: 10.1016/j.jff.2011.03.007.

[10]*Cirlini M., Mena P., Tassotti M., Herrlinger K.A., Niema K.M., Dall'Asta C., Del Rio D.* Phenolic and volatile composition of a dry spearmint (Mentha spicata L.) extract // Molecules 2016, vol. 21 (8), pp. 1007. DOI: 10.3390/molecules21081007.

Продолжение табл. 1

1	2	3	4	5	6	7	8	9	10
Flavone									
Apigenin	$C_{15}H_{10}O_5$	270,24	23,8		271,17	153,04; 218,01	191,11		*Inula gaveolens* [2], *Perilla frutescens* (see footnote 6)
Luteolin	$C_{15}H_{10}O_6$	286,24	21,5		287,18	226,77; 258,30; 153,17			*Inula gaveolens* [2], Potato [4], *Perilla frutescens* (see footnote 6)
Diosmetin	$C_{16}H_{12}O_6$	300,26	24,9		301,23	286,15; 257,18	258,15; 228,08; 125,21	258,16	*Inula viscosa* [7], Propolis [12]
Chrysoeriol	$C_{16}H_{12}O_6$	300,26	24,8		301,21	286,16; 255,24	258,15	229,14	*Rhus coriaria*[12], Rice[13]
Apigenin 7-O-glucoside	$C_{21}H_{20}O_{10}$	432,38	24,4		433,21	271,18; 218,08	153,05		Strawberry[14], *Grataegi Fructus* [13]
Luteolin-7-O-glucoside	$C_{21}H_{20}O_{11}$	448,4	22		449,21	287,17	153,02		*Perilla frutescens* (see footnote 7), *Lonicera japonica* [14]
Diosmetin O-hexoside	$C_{22}H_{22}O_{11}$	462,4	24,2		463,23	301,18	286,13	258,14	*Andean blueberry* [15]
Chrysoeriol C-hexoside-C-pentoside	$C_{27}H_{30}O_{15}$	594,51	19,7		595,33	457,29; 428,30; 379,27; 325,13	379,25; 325,24	351,22; 308,19	*Triticum aestivum* L.[15] [16]
Chrysoeryol O-hexoside-C-hexoside	$C_{28}H_{32}O_{16}$	624,54	20,2		625,31	463,28; 301,20	301,21	286,17	*Triticum aestivum* L. [17]
Flavanol									
Kempferol	$C_{15}H_{10}O_6$	286,24	5,9		287,19	241,18	205,46	205,46	*Inula gaveolens* [2], *Juglans mandshurica* [3], *Rhus coriaria* (see footnote 12), *Lonicera japonica* [14], *Ribes meyeri* [5]
Herbacetin	$C_{15}H_{10}O_7$	302,23	27,6		303,25	203,09; 257,14	157,07		*Lonicera caerulea* [18]
Myricetin	$C_{15}H_{10}O_8$	318,23	15,7		319,25	173,10; 218,07; 273,22	173,09; 143,10	125,16; 143,08	*Inula gaveolens* [2], *Juglans mandshurica* [13], millet grains (see footnote 9)

[11]*Spinola V., Pinto J., Castilho P.C.* Identification and quantification of phenolic compounds of selected fruits from Madeira Island by HPLC-DAD-ESI-MSn and screening for their antioxidant activity // Food Chem., 2015, vol. 173, pp. 14–30. DOI: 10.1016/j.foodchem.2014.09.163.

[12]*Abu-Reidah I.M., Ali-Shtayeh M.S., Jamous R.M., Arraes-Roman D., Segura-Carretero A.* HPLC–DAD–ESI-MS/MS screening of bioactive components from Rhus coriaria L. (Sumac) fruits // Food Chem., 2015, vol. 166, pp. 179–191. DOI: 10.1016/j.foodchem.2014.06.011.

[13]*Chen W., Gong L., Guo, Z., Wang W., Zhang H., Liu, X., Yu S., Xiong L., Luo J.* A novel integrated method for large-scale detection, identification, and quantification of widely targeted metabolites: application in the study of rice metabolomics // Mol Plant., 2013, vol. 6 (6), pp. 1769–1780. DOI: 10.1093/mp/sst080.

[14]*Alvarez-Fernandez A., Cerezo A.B., Canete A., Troncoso A.M., Garcia Parrilla M.C.* Composition of non-anthocyanin polyphenols in alcoholic-fermented strawberry products, using LC-MS (QTRAP), high-resolution mass spectrometry (UHPLC-Orbitrap-MS), LC-DAD and antioxidant activity // Journal of Agricultural and Food Chemistry, 2015, vol. 63 (7), pp. 2041–2051. DOI: 10.1021/jf506076n.

[15]*Geng P., Sun J., Zhang M., Li X., Harnly J.M., Chen P.* Comprehensive characterization of C-glycosyl flavones in wheat (Triticum aestivum L.) germ using UPLC-PDA-ESI/HRMSn and mass defect filtering // Journal of Mass Spectrometry, 2016, vol. 51 (10), pp. 914–930. DOI: 10.1002/jms.3803.

Продолжение табл. 1

1	2	3	4	5	6	7	8	9	10
Ampelopsin	$C_{15}H_{12}O_8$	320,25	22		321,25	303,20; 275,18; 243,16; 174,11	243,15; 174,11; 146,17	132,14	*Juglans mandshurica* [3], *Rnus coriaria* (see footnote 12)
Astragalin [kempferol 3-O-glucoside]	$C_{21}H_{20}O_{11}$	448,38	21,5		449,23	287,18	153,12		*Juglans mandshurica* [3], *Lonicera japonica* [14], *Ribes meyeri* [5], *Solanum tuberosum* [4]
Quercetin-3-O-glucoside	$C_{21}H_{20}O_{12}$	464,4	35,1		465,31	447,27; 257,12; 347,23;	286,16; 146,02	258,16; 153,02	*Juglans mandshurica* [3], Black soja [19], *Ribes meyeri* [5]
Tetrahydroxyflavanone									
Dihydrocampferol [Aromadendrin]	$C_{15}H_{12}O_6$	288,25	39,4		289,31	271,25; 215,11; 159,17	243,28; 215,19	183,3	*Juglans mandshurica* [3], *F. glaucescens* [20], *Camellia kucha* [21], *Phoenix dactylifera* [22]
Flavan-3-ol									
Afzelechin	$C_{15}H_{14}O_5$	274,27	18		275,21	157,04; 245,14	127,05; 157,08		*Camellia kucha* [21], *Pelargonium endlicherianum* [23]
Epiafzelechine derivative	$C_{15}H_{14}O_5$	274,27	18,6		393,3	245,12; 275,19	157,07; 245,17	157,07	Pubchem
(epi)-Catechin	$C_{15}H_{14}O_6$	290,27	13,7		291,19	261,16	243,06;	143,11	*Inula viscosa* [7], *Juglans mandshurica* [3], *Radix polygoni multiflori*[16], Black soja [19], *Triticum aestivum* (see footnote 8), millet grains (see footnote 9)
Derivative of (epi)-catechin	$C_{15}H_{14}O_6$	290,27	17,5		379,26	261,19; 275,18	179,03; 231,17; 143,17	127,04	Pubchem
Gallocatechin	$C_{15}H_{14}O_7$	306,27	39,1		307,33	289,29;	271,27;	253,36;	millet grains (see footnote 9), *G. linguiforme* [20], *Ribes meyeri* [5]
Anthocyanin									
Cyanidin-3-O-glucoside	$C_{21}H_{21}O_{11}+$	449,38	21,5		449,22	287,16	287,17		Black soybean [19], *Glycine soja* [24], *Triticum aestivum* (see footnotes 8, 13), *Ribes magellanicum* [7]
Peonidine-3-O-glucoside	$C_{22}H_{23}ClO_{11}$	498,87	24,9		463,22	301,17; 271,19	286,14	258,16	*Triticum aestivum* (see footnote 8)
Coumarins									
4- hydroxycoumarin	$C_9H_6O_3$	162,14	25,6		163,11	145,10; 135,11	117,1		*Mentha* [25], Chinese herbal formula Jian-Pi-Yi-Shen pill [26]
Umbelliferon	$C_9H_6O_3$	162,14	26,1		163,13	145,12	117,12		*F. glaucescens* [20], *Zostera marina* [27], *Lonicera caerulea* [18]

[16]*Liu Z., Liu Y., Wang C., Guo N., Song Z., Wang C., Xia L., Lu A.* Comparative analyses of chromatographic fingerprints of the roots of Polygonum multiflorum Thunb. and their processed products using RRLC/DAD/ESI-MSn // Planta Med., 2011, vol. 77, pp. 1855–1860. DOI: 10.1055/s-0030-1271200.

Продолжение табл. 1

1	2	3	4	5	6	7	8	9	10
Lignan									
Medioresinol	$C_{21}H_{24}O_7$	388,41	20	387,34		207,22; 163,15	163,17	145,09	*Inula viscosa* [7], *Bituminaria*[17]
Syringaresinol	$C_{22}H_{26}O_8$	418,4	25,4		419,27	401,18; 326,21	298,13; 154,05	252,08	*Triticum aestivum* L. (see footnote 8), *Lonicera caerulea* [18]
Flavonoid									
Di-O-galloyl-rhamnose	$C_{21}H_{24}O_{12}$	468,4	41,2		469,49	355,40; 423,46; 239,20	405,44; 353,38; 299,37	317,36; 241,22;	*Euphorbia hirta* [9]
Dihydrochalcone									
Phloretin	$C_{15}H_{14}O_5$	274,27	35,1		275,39	256,37; 173,10	238,46; 155,14	209,18; 183,11	*G. linguiforme* [20], *Lonicera caerulea* [18]
Compounds of other chemical groups									
Peptide									
L- glutamic acid [L- glutamate]	$C_5H_7NO_4$	147,12	28		147,11	129,12			*Medicago truncatula* [28], Soybean leaves [6], *Lonicera japonica* [14]
Amino acid									
Perillic acid	$C_{10}H_{14}O_2$	166,22	42,3		167,18	131,14	128,09		*Mentha* [29]
Lactone acids, vitamins									
L- ascorbic acid [vitamin C]	$C_6H_8O_6$	176,12	28,5		177,13	145,1	117,12		Strawberry, Lemon, Papaya [9], *Phoenix dactylifera* [22]
Amino acids									
L- Tryptophan	$C_{11}H_{12}N_2O_2$	204,22	8,3		205,17	188,12	146,12	118,12; 144,14	*Perilla frutescens* (see footnote 6), *Vigna unguiculata* [30]
Fatty acid									
Myristoleic acid	$C_{14}H_{26}O_2$	226,35	19,7		227,23	209,19; 191,20; 168,14	167,20; 191,18	149,16	*F. glaucescens* [20], *Maackia amurensis* [31]
Sesquiterpene									
Artemisin	$C_{15}H_{18}O_4$	262,3	19,1		263,22	182,15; 203,02; 243,24	203,14; 174,11	174,10; 146,05	*Artemisia martjanovii* [32]
Triterpenoid									
Estr-5(10)-en-3,17-diol	$C_{18}H_{28}O_2$	276,4	45,3		277,29	235,26; 149,17	119,12		*Juglans mandshurica* [3]
Omega-3 fatty acids									
linolenic acid	$C_{18}H_{30}O_2$	278,4	9,2		279,27	261,20; 223,14; 205,08; 149,10	121,2		Soybean leaves [6], Jatropha [33]

[17]*Llorent-Martinez E.J., Spinola V., Gouveia S., Castilho P.C.* HPLC-ESI-MSn characterization of phenolic compounds, terpenoid saponins, and other minor compounds in Bituminaria bituminosa // Industrial Crops and Products, 2015, vol. 69, pp. 80–90. DOI: 10.1016/j.indcrop.2015.02.014.

Окончание табл. 1

1	2	3	4	5	6	7	8	9	10
Triterpenoid									
3,4- Dihydroxyestran -17-on	$C_{18}H_{28}O_3$	292,41	44,1		293,33	275,29	257,27; 201,17;	131,15	*Juglans mandshurica* [3]
Hydroxyfatty acid									
9,10- Dihydroxy -8-oxoctadec -12-ic acid	$C_{18}H_{32}O_5$	328,44	32,5	327,42		291,31; 229,22	211,24; 165,20	209,18; 183,26	*Lonicera caerulea* [18], *Dracocephalum jacutense* [34]
Naphthoquinone									
3- Hydroxy -2,2'- binaphthalene -1,1',4,4'-tetron	$C_{20}H_{10}O_5$	330,3	5,9		331,25	303,25; 275,20; 152,18	275,22; 203,09	245,24; 175,22	*Juglans mandshurica* [3]
Fatty acid									
13- Trihydroxy octadecenoic acid [THODE]	$C_{18}H_{34}O_5$	330,5	33,8	329,42		311,34; 229,21	210,6	209,21	*Bituminaria*, Jatropha [33], *Phoenix dactylifera* [22]
Acids									
Fructose-1,6-bisphosphate [*beta-D*- fructofuranoso -1,6-bisphosphate]	$C_6H_{14}O_{12}P_2$	340,12	16,9		337,22	128,09; 146,12; 277,13;	128,1		*Medicago truncatula* [28]
Naphthoquinone									
8,8'- Dihydroxy -2,2'-binaphthalene -1,1',4,4'- tetron	$C_{20}H_{10}O_6$	346,3	24,2		347,24	319,24;	273,20;	173,08	*Juglans mandshurica* [3]
Disaccharide									
Trehalose (+FA adduct)	$C_{13}H_{24}O_{13}$	388,3	6,3	387,29		341,24	179,06; 281,16	143,1	*PubChem*
Anthraglycoside									
Emodin -8-*O-beta-D*- glucopyranoside [anthraglycoside B]	$C_{21}H_{20}O_{10}$	432,37	23,5		431,34	269,15	225,12; 197,12; 149,13	183,15; 160,99	Chinese herbal formula Jian-Pi-Yi-Shen pill [26], *Polygonum multiflorum* (see footnote 16), *Radix polygoni multiflori*[18]
Triterpenoid									
1- Hydroxy -3- oxours -12-en-28-ic acid	$C_{30}H_{46}O_4$	470,68	42,5		471,4	205,23	317,36	317,36	*Pear* [35]
Sesquiterpene alkaloid									
Sespendol	$C_{33}H_{45}NO_4$	519,7	42,9		518,5	184,13;	125,1		*Rhus coriaria* (see footnote 12), *Hylosereus polyrhizus* [36]
Nucleotide									
Guanosine -5- triphosphate	$C_{10}H_{16}N_5O_{14}P_3$	523,179	24,9		524,29	325,19; 345,17; 163,11	145,11		*Medicago truncatula* [28]

[18] *Lo Y.-H., Chen Y.-J., Chung T., Lin N.-H., Chen W.-Y., Chen C.-U., Lee M.-R., Chou C.-C., Tzen J.T.C.* Emoghrelin, a unique emodin derivative in Heshouwu, stimulates growth hormone secretion via activation of the ghrelin receptor // J. of Ethnopharmacol., 2015, vol. 159, pp. 1–8. DOI: 10.1016/j.jep.2014.10.063.

$[M+H]^+$ ion produces three fragmented ions, m/z 275.21, m/z 243.15 and m/z 174.11. The fragmented ion m/z 275.21 forms two characteristic daughter ions (m/z 243.15 and m/z 174.08). Further, the daughter ion m/z 243.15 forms three fourth fragmentation ions (m/z 215.12, m/z 172.15 and m/z 132.12).

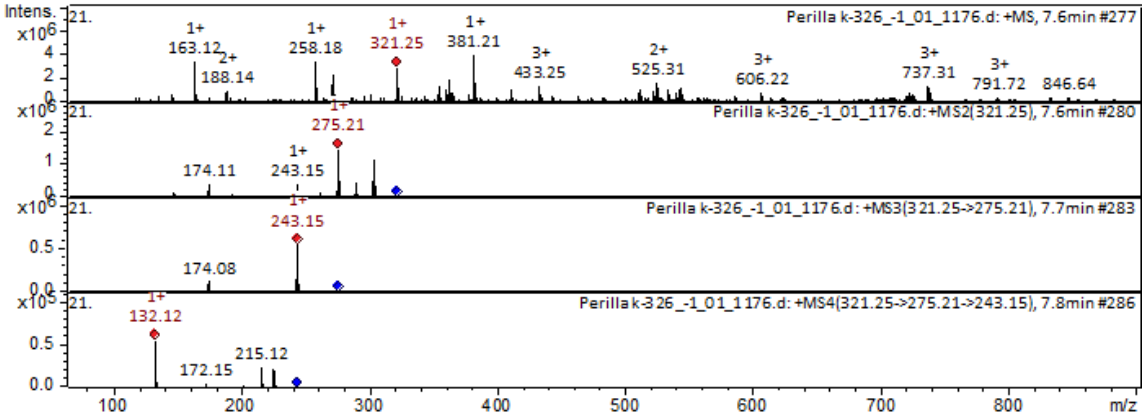

Рис. 2. Масс-спектр соединения ампелопсина, полученный из экстракта семян периллы (образец к-326). Вверху – МС-скан в диапазоне 100–1700 m/z, внизу – спектры фрагментации (сверху вниз): МС2 протонированного иона ампелопсина (275.21 m/z, красный ромб); МС3 фрагмента 275.21→243.15 m/z и МС4 фрагмента 275,21→243.15→132.12

Fig. 2. Mass spectrum of ampelopsin compound obtained from perilla seed extract (cultivar sample k-326). At the top is the MS scan in the range of 100-1700 m/z, at the bottom are the fragmentation spectra (top to bottom): MS2 of the protonated ampelopsin ion (275.21 m/z, red rhombus); MS3 of the fragment 275.21→243.15 m/z and MS4 of the fragment 275.21→243.15→132.12

In the researched scientific articles when considering similar mass spectra of *Juglans mandshurica* [3], *Rnus coriaria* (see footnote 12) this compound is classified as flavanol ampelopsin. The mass spectrum of the triterpenoid 1-Hydroxy-3-oxours-12-en-28-oic acid in the positive ion mode obtained from perilla extract (sample k-326) is shown in Fig. 3.

$[M+H]^+$ ion produces four fragmented ions (m/z 453.47, m/z 407.44, m/z 341.30 and m/z 205.24). The fragmented ion m/z 453.24 forms four daughter ions (m/z 407.46, m/z 317.37, m/z 201.25 and m/z 145.24). This compound is identified in the scientific literature as 1-Hydroxy-3-oxours-12-en-28-oic acid in pear extracts [35].

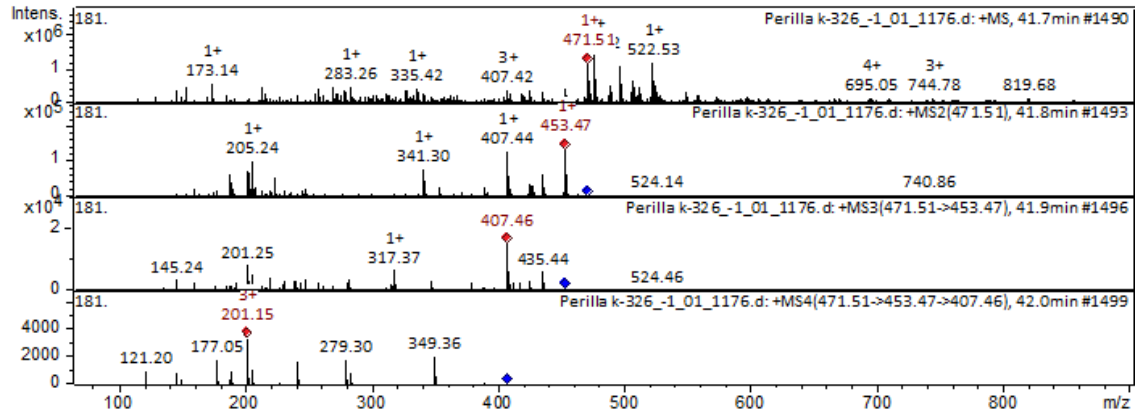

Рис. 3. Масс-спектр соединения 1-Гидрокси-3-оксоурс-12-ен-28-ой кислоты, полученный из экстракта семян периллы (образец к-326). Вверху – МС-скан в диапазоне 100–1700 m/z; внизу – спектры фрагментации (сверху вниз): МС2 протонированного иона 1-Гидрокси-3-оксоурс-12-ен-28-ой кислоты (453.47 m/z, красный ромб), МС3 фрагмента 453.47→ 407.46 m/z и МС4 фрагмента 453.47→ 407.46→ 201,15

Fig. 3. Mass spectrum of the compound 1-Hydroxy-3-oxours-12-en-28- acid obtained from perilla seed extract (cultivar sample k-326). At the top, MS scan in the range 100-1700 m/z; at the bottom, fragmentation spectra (top to bottom): MS2 of the protonated 1-Hydroxy-3-oxours-12-en-28-acid ion (453.47 m/z, red rhombus), MS3 of the fragment 453.47→ 407.46 m/z, and MS4 of the fragment 453.47→ 407.46→ 201.15

The mass spectrum of flavan-3-ol afzelequin in positive ion mode obtained from perilla seed extract (sample k-130) is shown in Fig. 4.

$[M+H]^+$ ion produces two fragmented ions, m/z 245.18 and m/z 175.13. The fragmented ion m/z 245.18 forms two daughter ions, m/z 215.11 and m/z 157.09. This compound is identified in the scientific literature as flavan-3-ol afzelequin: *Camellia kucha* [21], *Pelargonium endlicherianum* [23].

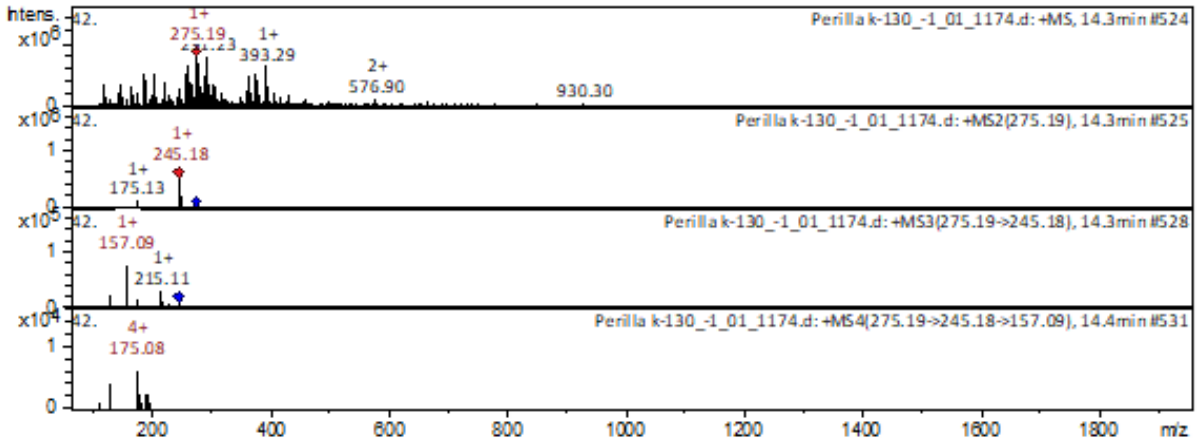

Рис. 4. Масс-спектр соединения афзелехина, полученный из экстракта семян экстракта периллы (образец к-130). Вверху – МС-скан в диапазоне 100–1700 m/z; внизу – спектры фрагментации (сверху вниз): МС2 протонированного иона афзелехина (245.18 m/z, красный ромб); МС3 фрагмента 245.18→157,09 m/z

Fig. 4. Mass spectrum of the compound afzelequin obtained from Perilla perilla seed extract (cultivar sample k-130). At the top, MS scan in the range of 100-1700 m/z; at the bottom, fragmentation spectra (top to bottom): MS2 of the protonated afzelequin ion (245.18 m/z, red rhombus); MS3 of the fragment 245.18→157.09 m/z

Thus, 41 compounds of polyphenolic group, many of which are characteristic for *P. frutescens* species, were identified in maceration extracts of perilla seeds. Undoubtedly, the dark coloration of the seeds directly affects the number of polyphenolic compounds identified in the plant. As previously stated, it is very important to accurately study the chemical composition and identify the active components responsible for the beneficial effects on the human body, since it is known that the health benefits of polyphenols are due to the fact that they help protect the body from inflammatory, cardiovascular and neurodegenerative diseases[19].

Fig. 5 presents a Venn diagram showing the coincidences and differences in the composition of identified chemical compounds in the three studied perilla samples (k-130, k-263, k-326). Following the data, perilla sample k-130 is the richest in all groups of chemical compounds. This is due to the fact that the profile of perilla seed metabolites is diverse depending on the variety and color of the seed coat, as well as on the growing area.

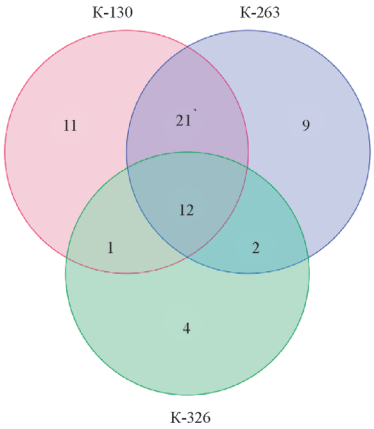

Рис. 5. Диаграмма Венна (совпадения и различия в составе идентифицированных химических соединений в трех изученных образцах периллы к-130, к-263, к-326)

Fig. 5. Venn diagram (coincidences and differences in the composition of the identified chemical compounds in the three studied perilla cultivars k-130, k-263, k-326)

[19]*Gholami A., De Geyter N., Pollier J., Goormachtig S., Goossens A.* Natural product biosynthesis in Medicago species // Food Funct. 2010. Vol. 1. P. 15–31. DOI: 10.1039/C3NP70104B.

Table 2 shows the presence of chemical compounds in the samples of perilla k-130, k-263, and k-326. It can be concluded that 12 identified chemical compounds occur in three samples (k-130, k-263, k-326): epiafzelequin derivative, (epi)-Catechin, (epi)-catechin derivative, 1-Hydroxy-3- oxours-12-en-28-oic acid, afzelequin, ampelopsin, herbacetin, myricetin,

Табл. 2. Присутствие химических соединений в образцах периллы к-130, к-263, к-326
Table 2. Presence of chemical compounds in perilla cultivars k-130, k-263, k-326

Chemical compound	Presence	Represented in the samples
Epiafzelequine derivative	3	к-130, к-263, к-326
(epi)-catechin	3	к-130, к-263, к-326
(epi)-catechin derivative	3	к-130, к-263, к-326
1- Hydroxy -3- oxours -12-en-28-ic acid	3	к-130, к-263, к-326
Afzelechin	3	к-130, к-263, к-326
Ampelopsin	3	к-130, к-263, к-326
Herbacetin	3	к-130, к-263, к-326
Myricetin	3	к-130, к-263, к-326
Phloretin	3	к-130, к-263, к-326
Rosmarinic acid	3	к-130, к-263, к-326
Sageric acid	3	к-130, к-263, к-326
Trehalose	3	к-130, к-263, к-326
4- Hydroxycoumarin	2	к-130, к-263
Apigenin	2	к-130, к-263
Apigenin 7-O- glucoside	2	к-130, к-263
Artemisin	2	к-130, к-263
Caffeic acid hexoside dimer	2	к-130, к-263
Caffeic acid-O-hexoside	2	к-130, к-263
Chrysoeriol	2	к-130, к-263
Dehydro-rosmarinic acid	2	к-130, к-263
Dihydrocampferol	2	к-130, к-263
Diosmetin	2	к-130, к-263
Diosmetin O- hexoside	2	к-130, к-263
Gallic acid	2	к-130, к-263
Galloylquinic acid O-hexoside	2	к-130, к-263
L- ascorbic acid [vitamin C]	2	к-130, к-263
Tryptophan	2	к-130, к-263
Linolenic acid	2	к-130, к-326
Luteolin	2	к-130, к-263
Medioresinol	2	к-130, к-263
Myristoleic acid	2	к-130, к-263
Perillic acid	2	к-263, к-326
Rosmarinic acid-O-caffeic acid	2	к-130, к-263
Rosmarinic acid O-hexoside	2	к-130, к-263
Sespendol	2	к-263, к-326
Beta-D-fructofuranoso-1,6-bisphosphate	2	к-130, к-263

Рис. 6. Семена периллы: *а* – образец к-130; *б* – к-263; *в* – К-326
Fig. 6. Perilla seeds: *a* – varietal sample k-130; *б* – k-263; *в* – k-326

phloretin, rosmarinic acid, sageric acid, trehalose.

In the samples k-130, k-263, 21 identified chemical compounds occur: 4-Hydroxycoumarin, apigenin, apigenin 7-O-glucoside, artemisin, caffeic acid hexoside dimer, caffeic acid-O-hexoside, chrysoeryol, dehydro-rosmarinic acid, dihydrocampferol, diosmetin, diosmetin O-hexoside, gallic acid, galloylquinic acid O-hexoside, L-ascorbic acid [vitamin C], tryptophan, luteolin, medioresinol, myristoleic acid, rosmarinic acid-O-caffeic acid, rosmarinic acid O-hexoside, beta-D-fructofuranoso-1,6-bisphosphate, rosmarinic acid-O-caffeic acid, rosmarinic acid O-hexoside, beta-D-fructofuranoso-1,6-bisphosphate.

Fig. 6 shows perilla seeds of the varieties k-130, k-263, and k-326 used in this study.

CONCLUSIONS

1. Perilla seed extracts contain a large number of polyphenol complexes, which are biologically active compounds. Fractional maceration was used to obtain highly concentrated extracts. HPLC in combination with BRUKER DALTONIKS ion trap was used to identify the target analytes in the extracts. The results of preliminary study showed the presence of 60 chemical compounds. Of them 41 compounds of polyphenolic group, many of which are characteristic for *P. frutescens* species and 19 compounds of other chemical groups. Also, 29 chemical compounds were found for the first time, of which 16 were of the polyphenolic group and 13 of other chemical groups.

2. The data obtained will help to intensify future research on the development and production of various functional food, pharmacological, cosmetic and animal products, in dietary products containing targeted extracts of *P. frutescens*.

3. A great variety of biologically active polyphenolic compounds opens up rich opportunities for the creation of new medicines, biologically active additives based on the extracts from perilla seeds, as well as further research on functional and specialized nutrition, using products from perilla as their basis.

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Продуктивность малораспространенных сельскохозяйственных культур в зависимости от сроков посева в условиях Забайкалья

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В статье представлены результаты изучения влияния сроков посева на продуктивность малораспространенных сельскохозяйственных кормовых культур: проса кормового, суданской травы, тритикале яровой, амаранта метельчатого и кормовых бобов. Исследования выполнены на опытном поле Научно-исследовательского института ветеринарии Восточной Сибири, расположенном в лесостепной зоне Забайкалья. Почва участка лугово-черноземная мучнисто-карбонатная, по гранулометрическому составу – легкий суглинок. Для определения степени влияния сроков посева на продолжительность межфазных периодов развития растений, их линейный рост, облиственность и продуктивность изучаемые сельскохозяйственные культуры высевались в различные сроки: 15 и 25 мая, 15 и 25 июня. Полученные данные свидетельствуют о том, что за счет изменения сроков посева можно влиять на продуктивность изучаемых культур и качество изготавливаемых на их основе кормов. Лучшие показатели по кормовой продуктивности и питательной ценности продемонстрировали посевы, проведенные 15 июня: урожайность зеленой массы – 18,9–30,5 т/га, сухого вещества – 3,93–5,70 т/га, выход кормовых единиц – 3,03–4,67 т/га, содержание переваримого протеина – 306–901 кг/га, валовая энергия – 38,12–57,57 ГДж/га, обеспеченность 1 к. ед. переваримым протеином – 93–193 г. Преимущество имели посевы кормовых бобов и амаранта метельчатого, характеризовавшиеся следующими показателями: урожайность зеленой массы – 29,6–30,5 т/га, сухого вещества – 5,70–5,95 т/га, выход кормовых единиц – 4,20–4,67 т/га, содержание переваримого протеина – 722–901 кг/га, валовая энергия – 52,86–57,57 ГДж/га, обеспеченность 1 к. ед. переваримым протеином – 172–193 г. Агроценозы мятликовых культур (тритикале яровая, просо кормовое, суданская трава) уступали по продуктивности: в них урожайность зеленой массы составила 14,4–18,9 т/га, сухого вещества – 2,97–3,93 т/га, выход кормовых единиц – 2,23–3,03 т/га, содержание переваримого протеина – 207–341 кг/га, валовая энергия – 28,51–38,12 ГДж/га, обеспеченность 1 к. ед. переваримым протеином – 93–121 г.

Ключевые слова: малораспространенные культуры, сроки посева, урожайность, просо кормовое, суданская трава, тритикале яровая, амарант метельчатый, кормовые бобы

Productivity of less common agricultural crops depending on the sowing dates in the conditions of Transbaikalia

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The article presents the results of the study of the influence of sowing dates on the productivity of less common agricultural fodder crops: fodder millet, Sudan grass, spring triticale, Scarlet amaranth and fodder beans. The studies were carried out at the experimental field of the Research Institute of Veterinary Medicine of Eastern Siberia located in the forest-steppe zone of Transbaikalia. The soil of the site is meadow-chernozem mealy-carbonate, light loam by granulometric composition. The studied crops were sown at different dates to determine the degree of influence of the sowing dates on the duration of interphase periods of plant development, their linear growth, foliage and productivity: May 15 and 25, June 15 and 25. The obtained data indicate that by changing the sowing dates it is possible to influence the productivity of the studied crops and the quality of forages made on their

basis. The best indicators on fodder productivity and nutritive value were demonstrated by the crops sown on June 15: yield of green mass – 18.9–30.5 t/ha, dry matter – 3.93–5.70 t/ha, yield of fodder units – 3.03–4.67 t/ha, digestible protein content – 306–901 kg/ha, gross energy – 38.12–57.57 GJ/ha, provision of 1 fodder unit with digestible protein – 93–193 g. Crops of fodder beans and Scarlet amaranth had an advantage, characterized by the following indicators: yield of green mass – 29.6–30.5 t/ha, dry matter yield – 5.70–5.95 t/ha, yield of fodder units – 4.20–4.67 t/ha, digestible protein content – 722–901 kg/ha, gross energy – 52.86–57.57 GJ/ha, provision of 1 fodder unit of digestible protein – 172–193 g. Agrocenoses of Poaceae crops (spring triticale, fodder millet, Sudan grass) were inferior in productivity: their green mass yield was 14.4 –18.9 t/ha, dry matter yield – 2.97–3.93 t/ha, yield of fodder units – 2.23–3.03 t/ha, digestible protein content – 207–341 kg/ha, gross energy – 28.51–38.12 GJ/ha, provision of 1 fodder unit with digestible protein – 93–121 g.

Keywords: less common agricultural crops, sowing dates, yield, fodder millet, Sudan grass, spring triticale, Scarlet amaranth, fodder beans

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INTRODUCTION

At present, due to the emergence of new species and varieties of forage crops, there is a need for their comparative study and adaptation to local soil and climatic conditions for subsequent use in the agro-industrial complex of the Trans-Baikal Territory.

The increasing role of forage production requires scientific and practical study of many issues related to the comparative assessment of crops, their combination and location, cultivation and use. In recent years, new high-yielding varieties of fodder crops of the Siberian ecotype have been created and disseminated, and the perception of the prospects of these crops is changing. Expansion of annual fodder crops, increase of their species diversity, clear differentiation of macro- and micro-zone distribution, improvement of varietal composition and cultivation technology are strategic objectives of fodder production in the Trans-Baikal region [1].

Within the context of striving for rational use of limited natural and climatic resources of Siberia, each of its zones, economic and landscape peculiarities of farms and weather conditions, a significant role in stabilization of fodder production in the region along with traditional crops can be played by less widespread, new for Siberia plant species. However, many authors note that at the same time they should not be considered (at the present stage and in the near future) as crops capable of replacing traditional crops. Only in the overall system, occupying "their" ecological and organizational-economic niche, they will be able to show their potential and will contribute to a fuller disclosure of the potential of traditional crops and agro-systems as a whole. At the same time, increasing the diversity of fodder plants will allow to better balance animal diets. In the course of the study, a number of promising plants for the region were identified: triticale, Scarlet amaranth, Sudan grass, fodder millet, fodder beans and other plants, the status of which in the fodder production system needs to be determined [2].

Many experts consider Scarlet amaranth (*Amaranthus paniculatus* L.) to be one of such promising plants for universal use, which was in-

cluded by N.I. Vavilov in the list of fodder plants "subject to immediate wide introduction into the culture of the USSR" as early as 1930. In 1984, the American Academy of Sciences recognized amaranth as the most promising crop of the XXI century. Amaranth is a source of biogenic calcium. Studies by E.N. Ofitserov, V.N. Zelenkov, L.A. Mikheeva have established that amaranth leaf-stem mass contains a large amount of calcium: the concentration of calcium in leaves is on average 13% per dry mass, and its maximum amount is contained in the leaves in the flowering phase (27%)[1, 2].

Triticale, which is an intergeneric alloploid combining high productivity of wheat and adaptive resistance of rye to unfavorable conditions and diseases, is widely used to produce green mass in the system of green and raw material conveyors. Triticale is a new grain crop for the Transbaikal Territory. It is characterized by high resistance to drought and grain shattering. Compared to wheat and rye, triticale grain contains more protein. This crop occupies an intermediate position between wheat and rye on the content of essential amino acids in the grain, especially lysine and tryptophan. Triticale grain is used in the confectionery industry, baking, brewing and as a concentrated animal feed. Fodder varieties of triticale are sown for green fodder and production of grain hayage silage. Triticale is a promising crop that can find its application and supplement the production of grain and fodder in the Transbaikal Territory [3, 4].

Sudan grass (*Sorghum sudanense*) is one of the most productive annual fodder crops. A distinctive feature of Sudan grass is its drought resistance. Thanks to its powerful root system, it efficiently utilizes water from deep soil layers and summer precipitation, forming high yields. Sudan grass has good bushiness and fast regrowth after mowing, so it can be effectively used in the green conveyor for making haylage, silage, hay. The vegetative mass of Sudan grass is balanced in the main nutrients and is readily eaten by animals. 1 kg of green mass contains 0.32 fodder units and 28 g of digestible protein. A valuable feature of Sudan grass is its resistance to trampling by animals, which indicates that it can be widely used as a pasture crop as well [5–8].

With the development of field fodder production, fodder millet (*Panicum*) is increasingly used as a fodder crop, the vegetative mass of which is an excellent source of green fodder and raw material for the production of high-quality hay, haylage, silage. 1 kg of millet green mass contains an average of 0.18 fodder units and 20 g of digestible protein, 0.8% fat, 6.2% fiber, 2.3% ash, 10.3% nitrogen-free extractive substances. 100 kg of hay contains 57 fodder units and 6.5 g of digestible protein. A distinctive feature of millet is a high content of dry matter and carotene in the green mass. Fodder millet is a fast-ripening, drought-resistant crop, which fully corresponds to soil and climatic conditions of the Trans-Baikal region [9, 10].

Fodder beans (*Vicia faba* L.) are characterized by high fodder value. Fodder bean green mass yield reaches 350–400 c/ha and higher, seeds – 28-30 c/ha depending on the growing conditions. The yield is largely determined by the amount of precipitation during the growing season. Fodder beans are increasingly recognized in Siberian fodder production due to their high fodder qualities (1 fodder unit contains 220–240 g of digestible protein) [11–13].

The works of a large number of scientists have established the high value of spring triticale, Sudan grass, fodder millet, Scarlet amaranth and fodder beans that give stable yields of fodder and seeds[3] [14]. Many issues of cultivation technology of these crops are insufficiently studied. In the complex of technological methods of cultivation of sparsely distributed crops, sowing dates are of great importance.

[1]*Ofitserov E.N., Ofitserova E.Kh.* Carbohydrates of amaranth seeds // Agrarian Russia, 2001, N 6, pp. 43–51.

[2]*Ofitserov E.N., Zelenkov V.N., Mikheeva L.A.* Amaranth – a source of biogenic calcium // Agrarian Russia, 2001, N 6, pp. 52–54.

[3]*Dmitriev V.I.* Raw material conveyor – the basis for obtaining highly nutritious fodder in Western Siberia // Vestnik of Omsk SAU, 2017, N 1 (25), pp. 17–22.

The purpose of the research is to study the possibility of formation of high productivity and nutritional value of low-spread crops at different sowing dates.

MATERIAL AND METHODS

The study was conducted in 2020-2022 at the experimental field of the Research Institute of Veterinary Science of Eastern Siberia, located in the Ingodin- Chita forest-steppe. The influence of the sowing dates on the growth, development and yield of sparsely distributed crops (spring triticale, Scarlet amaranth, Sudan grass, fodder millet and fodder beans) was studied.

The soil of the experimental plot is meadow-chernozem mealy-carbonate. The granulometric composition is light loam. According to the reaction of the soil solution, the arable horizon is slightly acidic, subsoil – neutral. The content of organic matter in the layer 0 –20 cm – 3,67%, total nitrogen – 0,31%. Provision of mobile phosphorus is low, exchangeable potassium – medium. The area of the sowing plot is 100 m^2, registration plot – 50 m^2. Repetition is fourfold, the arrangement of the plots is consecutive. Agrotechnics of cultivated crops corresponded to the generally accepted for this zone. Sowing was carried out by row seeder CH 16 according to the scheme of the experiment – May 15 and 25, 15 and 25 June (the sowing date of May 15 was taken as a control). Seeding rate: for Sudan grass and fodder millet – 4 million germinated seeds/ha, Scarlet amaranth – 0.5, spring triticale – 5.0, fodder beans – 1.2 million germinated seeds/ha. Sowing depth (distance from the soil surface to the sown seeds): for spring triticale – 6 cm, Scarlet amaranth – 2– 4, fodder beans – 5, Sudan grass, fodder millet – 3 – 4 cm.

All surveys and observations were carried out in accordance with the methodological guidelines [4-9].

The climate of the zone is sharply continental with low snow cold winters, hot summers and lack of precipitation. The average annual precipitation is 330–380 mm. Their main amount (85–90%) is observed in the warm period, maximum – in July–August, minimum – in May–June. In general, the regime is characterized by variability of moistening. Years with good moisture availability are replaced by satisfactory years, more often by dry years. The sum of temperatures above 10 °C during summer months is 1500...1800 °C with high average daily temperature in July (19.1 °C).

In terms of the weather conditions, the years of the study corresponded to the main features of the Trans-Baikal Territory climate. Weather conditions during the growing season were relatively favorable. During the growing season (April–September), 350 mm of precipitation was observed with the average annual norm of 276 mm. The excess of the average annual indicator amounted to 74 mm (26.6%). The average daily air temperature for the spring-summer-autumn period exceeded the norm by 0.9 °C. Hydrothermal coefficients (HTC) by months of the vegetation periods were as follows: in May – 1.02, June – 1.3, July – 1.5, August – 1.4, September – 3.5. According to these coefficients, May-August were characterized by periods with sufficient moisture, September was excessively moistened. In general, the created climatic conditions allowed plants of the studied crops to form high productivity in agrocenoses.

RESULTS AND DISCUSSION

As a result of the study, it was found that plant development, time of the phenological phases' beginning and duration were greatly influenced by hydrothermal conditions and biological features of the crops. The studied crops reacted dif-

[4]Methodological instructions for conducting field experiments with forage crops. Moscow, 1983, 197 p.

[5]Experimental works in field farming. Leningrad, 1982, 190 p.

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ferently to soil and climatic conditions during the main phases of plant development. At early sowing dates, the average daily air temperature was 5.9–9.3°C, at late sowing dates – 15.2– 20.4°C, which had a great influence on soil warming and the difference in the emergence of seedlings. The shortest period from sowing to sprouting was recorded at late sowing dates (June 15 and 25): in bluegrasses (spring triticale, fodder millet, Sudan grass) – 13–14 days, in amaranth and fodder beans – 14–18 days. A longer period was recorded at early sowing dates (May 15 and 25): in fodder millet – 19–25 days, in fodder beans, spring triticale, Sudan grass, Scarlet amaranth – 15–19 days. Subsequent periods of plant development (sprouting – budding, sprouting – tillering, sprouting – booting, sprouting – sprouting (earing), sprouting – flowering) depending on the sowing dates occurred with 1–2 days difference between May and June sowings. Period of sprouting – flowering at sowing on June 15 and June 25 in bluegrass crops was 59–62 days, in fodder beans and Scarlet amaranth – 52–54 days. At sowing on May 15 and 25, the periods were longer and amounted to 59-66 and 52–55 days, respectively (see Table 1).

Calculation of plant density showed that the largest number of seeds emerged at sowing on June 15 and 25: spring triticale – 400–425 pcs/m^2, fodder millet – 312–340, Sudan grass – 240 – 255, Scarlet amaranth – 37–39, fodder beans – 91–94 pcs/m^2. In the crops sown on May 15 and 25, field germination of the above crops was lower by 4–6, 5–10, 4–7, 7–10 and 4%, respectively. In all the studied crops, field germination increased from early sowing date (May 15) to later ones (see Table 2, Fig. 1, 2).

The same dependence on plant stand density was maintained before harvesting. At sowing on June 15 and 25, the plant density of spring triticale was 344–378 pcs./ m^2, fodder millet – 228–258, Sudan grass – 178–191, Scarlet amaranth – 30–33, fodder beans – 78–83 pcs./ m^2. At sowing on May 15 and 25, plant safety of the above crops was lower by 4–5, 2–4, 2–2, 1–2 and 4%, respectively, compared to sowing on June 15 and 25.

In the period of sprouting weed infestation in the crops conducted on May 15 and 25 with one seedbed cultivation was quite high, and the total number of annual weeds ranged from 118–125 to 147–163 pcs./m^2. In later crops (June 15 and 25) after two pre-sowing cultivations, the number of weeds in the experiment variants was lower – 81–115 and 58–81 pcs./m^2. Before harvesting the total level of weediness in the crops was low and amounted to 16–23 and 12–16 pcs./m^2 in the crops of June 15 and 25, in the crops of May 15 and 25 –24–30 and 25–33 pcs./m^2, i.e. decreased from early sowing date to later ones.

Important indicators affecting the productivity of crops are height and foliage of plants. The highest plant height by the time of harvesting was achieved in the crops sown on June 15: spring triticale – 114 cm, fodder millet – 98, Sudan grass – 123, Scarlet amaranth – 153, fodder beans – 142 cm, which is higher than in spring crops (May 15 and 25) by 2–8, 2–6, 3–7, 4–13, 4–7 cm, respectively. In the crops sown on June 25, the plant height was the lowest and amounted to 104, 88, 106, 138 and 125 cm, while leaf coverage was high – 48, 49, 58, 48 and 41% (see Fig. 3).

When assessing the response to drought, conducted according to the methodology, where yellowing of root leaves and loss of turgor are taken as a basis, it was noted that all the studied crops had drought tolerance (5 points).

One of the main indicators determining the efficiency of cultivation of forage crops in agrocenoses is the yield of green mass and dry matter, yield of fodder units, digestible protein content and other important indicators. Productivity and nutritive value of the studied crops are given in Table 3.

According to the results of comparative evaluation of low spreading agricultural bluegrass, Scarlet amaranth and fodder beans, it was established that during the growing season in the crops conducted on May 15 and 25, the following indicators were obtained: green mass yield – 11.8–25.2 and 13.1–28.0 t/ha, respectively, dry matter yield – 2.45–4.79 and 2.72– 5.32 t/ha, yield of fodder units – 1.84–4.03 and 2.05–

Табл. 1. Продолжительность межфазных периодов в период вегетации растений, дни (среднее за 2020–2022 гг.)

Table 1. Duration of the interphase periods during the vegetation period of plants, days (average for 2020–2022)

Culture	Sowing –sprouting	Sprouting – budding	Sprouting – tillering	Sprouting – booting	Sprouting – earing (heading)	Sprouting – flowering	Seed maturation
Seeding on May 15							
Spring triticale	17	–	16	32	46	62	108
Fodder millet	21	–	22	36	47	60	93
Sudan grass	18	–	22	38	52	66	98
Scarlet amaranth	19	29	–	–	–	55	92
Field beans	25	40	–	–	–	53	98
Seeding on May 25							
Spring triticale	15	–	15	29	45	61	107
Fodder millet	19	–	22	35	46	59	92
Sudan grass	16	–	23	36	50	64	98
Scarlet amaranth	17	27	–	–	–	54	92
Field beans	23	38	–	–	–	52	96
Seeding on June 15							
Spring triticale	14	–	14	26	44	60	107
Fodder millet	14	–	21	33	45	59	92
Sudan grass	14	–	21	35	45	62	98
Scarlet amaranth	16	26	–	–	–	54	92
Field beans	18	37	–	–	–	52	96
Seeding on June 25							
Spring triticale	13	–	14	26	44	60	–
Fodder millet	13	–	20	32	45	59	–
Sudan grass	13	–	21	35	45	61	–
Scarlet amaranth	14	25	–	–	–	54	–
Field beans	14	35	–	–	–	52	–

Табл. 2. Густота стояния растений в зависимости от срока посева

Table 2. Plant stand density depending on the sowing date

Culture	Sown, pcs./m^2	Number of plants, pcs./m^2	
		at seedling stage	before harvesting
Seeding on May 15			
Spring triticale	500	380	312
Fodder millet	400	292	207
Sudan grass	300	228	164
Scarlet amaranth	50	32	25
Field beans	120	86	71
Seeding on May 25			
Spring triticale	500	395	332
Fodder millet	400	300	216
Sudan grass	300	234	171
Scarlet amaranth	50	34	27
Field beans	120	89	75
Seeding on June 15			
Spring triticale	500	400	344
Fodder millet	400	312	228
Sudan grass	300	240	178
Scarlet amaranth	50	37	30
Field beans	120	91	78
Seeding on June 25			
Spring triticale	500	425	378
Fodder millet	400	340	258
Sudan grass	300	255	191
Scarlet amaranth	50	39	33
Field beans	120	94	83

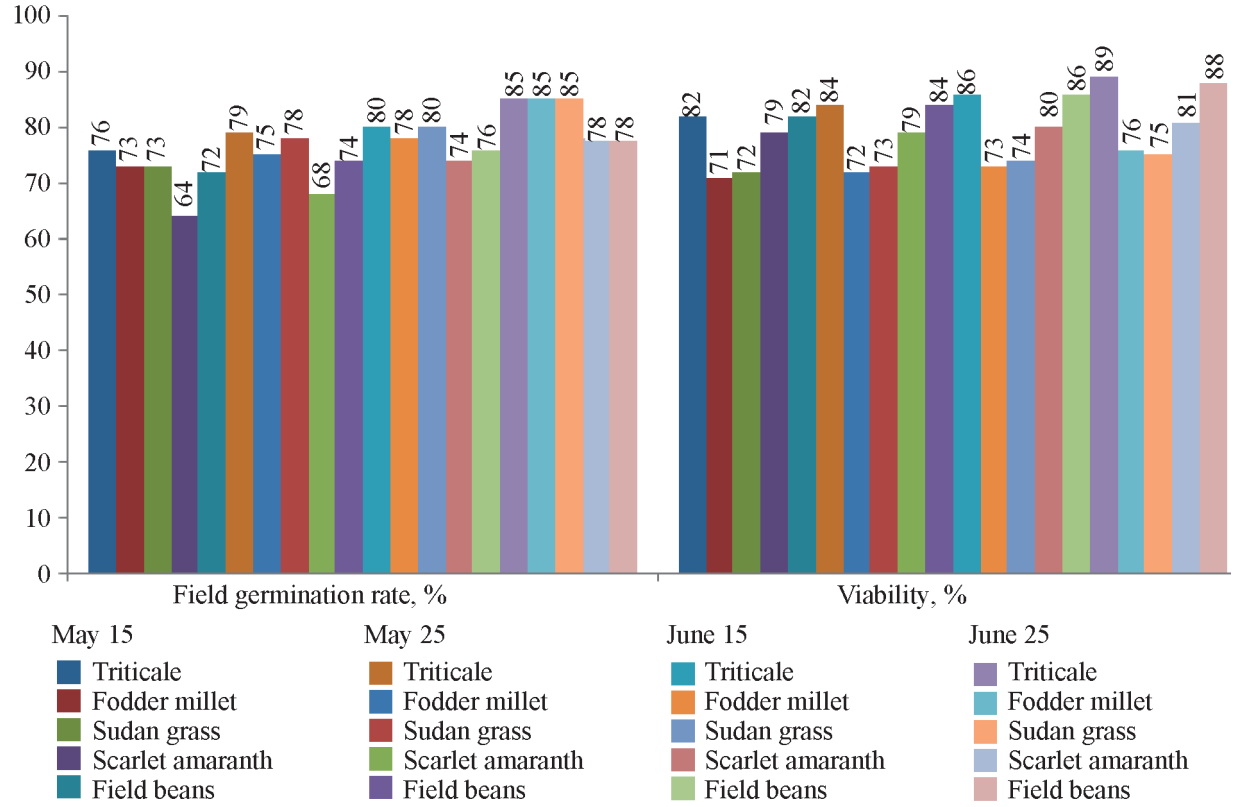

Рис. 1. Полевая всхожесть и сохранность изучаемых культур в зависимости от срока посева (среднее за 2020–2022 гг.)

Fig. 1. Field germination and safety of the studied crops depending on the sowing date (average for 2020–2022)

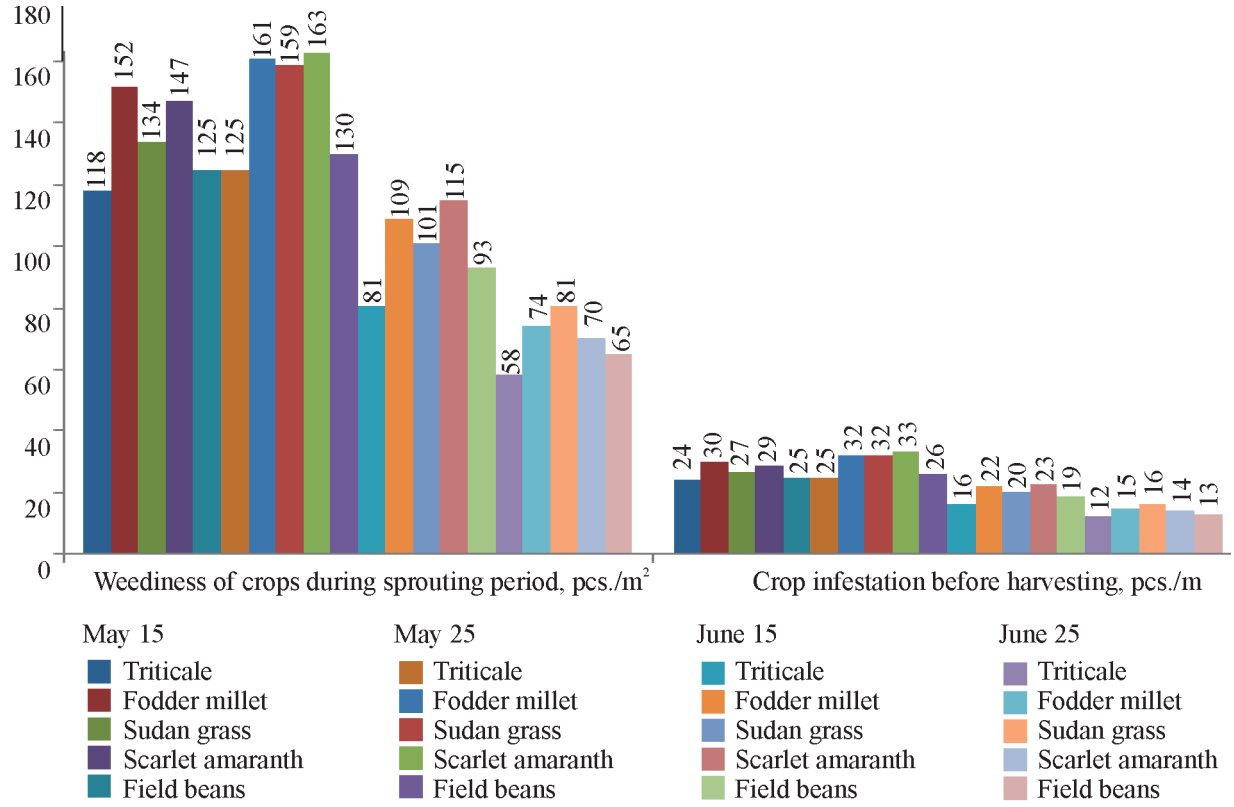

Рис. 2. Засоренность изучаемых культур в зависимости от срока посева (среднее за 2020–2022 гг.)

Fig. 2. Weediness of the studied crops depending on the sowing date (average for 2020–2022)

4.44 t/ha, digestible protein content – 166–770 and 183–850 kg/ha, gross energy – 23.65–48.62 and 26.25–54.13 GJ/ha, provision of 1 fodder unit with digestible protein – 92–192 and 90–193 g.

The crops sown on June 15 were characterized by the highest productivity and nutritive value: green mass yield – 14.4–30.5 t/ha, dry matter – 2.97–5.95 t/ha, yield of fodder units – 2.23–4.67 t/ha, digestible protein content – 207–901 kg/ha, gross energy – 28.51–57.57 GJ/ha, provision of 1 fodder unit with digestible protein – 93–193 g. Excess of the presented indicators to early sowing dates (May 15 and 25) were: 1.3–2.6 and 2.5–5.3 t/ha; 0.25–0.52 and 0.63– 1.16 t/ha; 0.18–0.39 and 0.23–0.64 t/ha; 24–41 and 51–131 kg/ha; 2.26–4.86 and 3.44–8.95 GJ/ha; 1–2 and 2.4 g; to the June 25 sowing: 3.4–6.9 t/ha; 0.72–1.95 t/ha; 0.54–1.13 t/ha; 48–214 kg/ha; 6.91-14.06 GJ/ha, respectively. In percentage terms, the exceedances ranged from 8–9 to 21–25%.

Significant excess in relation to early sowing was 1.3–2.6 and 2.5–5.3 t/ha for green mass, 0.25–0.52 and 1.60–1.63 t/ha for dry matter, 0.18–0.39 and 0.23– 0.64 t/ha for yield of fodder units; to June 25 sowing: 3.4–6.9 t/ha; 0.72–1.95 t/ha; 0.54–1.13 t/ha, respectively.

A close positive correlation (r = 0.89–0.94) between green mass and dry matter yield, fodder unit yield and plant height was observed.

The lowest productivity indicators were obtained in the June 25 crops, where the yield of green mass depending on the type of crop was 11.0–23.6 t/ha, dry matter yield – 2.25–4.32 t/ha, yield of fodder units – 1.69–3.54 t/ha, digestible protein content – 159-687 kg/ha, gross energy – 26.60–43.63 GJ/ha.

Analyzing the obtained data, it can be noted that among bluegrass crops the highest yield was formed by spring triticale and Sudan grass: green mass and dry matter – 14.0 –18.9 and 2.79 –3.93 t/ha, respectively. Scarlet amaranth and fodder beans were more productive compared to blue-

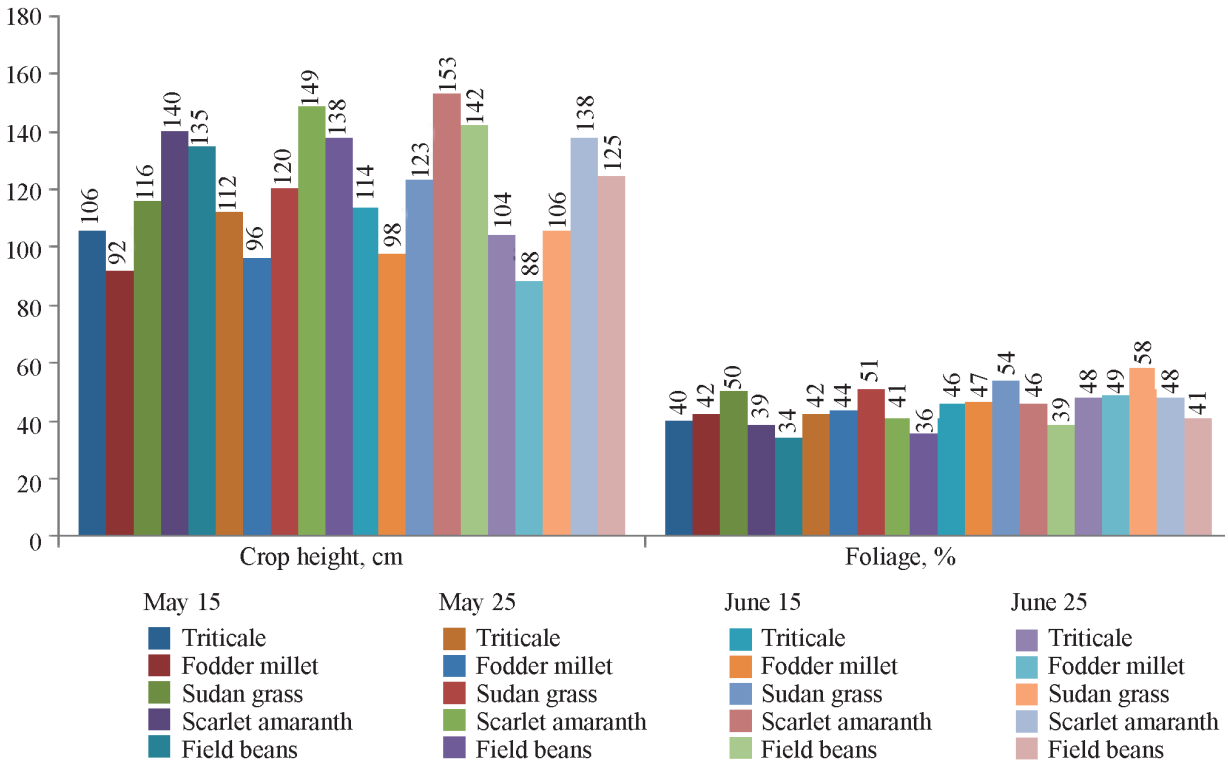

Рис. 3. Высота посевов и облиственность изучаемых культур в зависимости от срока посева (среднее за 2020–2022 гг.)

Fig. 3. Sowing height and foliage of the studied crops depending on the sowing date (average for 2020–2022)

Табл. 3. Урожайность зеленой массы и питательная ценность культур в зависимости от срока посева (среднее за 2020–2022 гг.)

Table 3. Green mass yield and nutritive value of crops depending on the sowing date (average for 2020–2022)

Culture	Sowing date	Yield, t/ha		Fodder units yield, t/ha	Digestible protein content, kg/ha	Provision of 1 f. u. with digestible protein, g	Gross energy, GJ/ha
		green mass	dry matter				
Spring triticale	May 15	15,5	3,26	2,62	262	103	32,12
	May 25	17,2	3,61	2,77	276	101	35,29
	June 15	18,9	3,93	3,03	306	101	38,12
	June 25	14,3	2,96	2,28	230	101	28,71
LSD_{05}		0,40	0,20	0,16			
Fodder millet	May 15	11,8	2,45	1,84	166	92	23,65
	May 25	13,1	2,72	2,05	183	90	26,25
	June 15	14,4	2,97	2,23	207	93	28,51
	June 25	11,0	2,25	1,69	159	94	21,60
LSD_{05}		0,35	0,19	0,13			
Sudan grass	May 15	14,9	3,01	2,35	277	121	29,65
	May 25	16,6	3,33	2,60	306	122	32,80
	June 15	18,3	3,66	2,82	341	121	35,50
	June 25	14,0	2,79	2,15	262	122	27,06
LSD_{05}		0,35	0,17	0,17			
Scarlet amaranth	May 15	24,3	4,52	3,57	599	170	44,75
	May 25	27,0	5,03	4,01	675	172	49,80
	June 15	29,6	5,95	4,20	722	172	52,86
	June 25	22,2	4,00	3,08	530	172	38,80
LSD_{05}		1,59	0,35	0,15			
Field beans	May 15	25,2	4,79	4,03	770	192	48,62
	May 25	28,0	5,32	4,44	850	193	54,13
	June 15	30,5	5,70	4,67	901	193	57,57
	June 25	23,6	4,32	3,54	687	194	43,63
LSD_{05}		0,49	0,14	0,20			

grass and formed 22.2 – 30.5 t/ha of green mass and 4.00 – 5.95 t/ha of dry matter. The same dependence between the crops was maintained on the nutritive value of the forage (yield of feed units, digestible protein content, gross energy and provision of 1 fodder unit with digestible protein).

CONCLUSION

Optimal sowing dates, which largely determine the productivity of crops, are of great importance in the technology of cultivation of the studied crops.

Due to different sowing dates, the possibility of forming differences in productivity and fodder quality has been established.

In extreme conditions of the Trans-Baikal region, it is advisable to sow Sudan grass, fodder millet, spring triticale, Scarlet amaranth and fodder beans for the production of high-quality energy-rich fodder in the second ten-day period of June (15th day), when a more favorable hydrothermal regime is established while plants pass critical phases of development, as a result plants develop a large vegetative mass and form high productivity in agrocenoses.

The best indicators on fodder productivity and nutritive value were obtained in the crops sown on June 15: yield of green mass – 18.9-30.5 t/ha, dry matter – 3.93-5.7 t/ha, yield of fodder units – 3.03–4.67 t/ha, digestible protein content – 306–901 kg/ha, gross energy – 38.12–57.57 GJ/ha, provision of 1 fodder unit with digestible protein – 93–193 g.

The excess in productivity and nutritive value relative to early sowing dates (May 15 and 25) amounted to: 1.3–2.6 and 2.5– 5.3 t/ha for green mass yield, 0.25–0.52 and 0.63–1.16 t/ha for dry matter yield, 0.18–0.39 and 0.23–0.64 t/ha for fodder unit yield, 24–41 and 51–131 kg/ha for digestible protein content, 2.26–4.86 and 3.44–8.95 GJ/ha for gross energy, 1–2 and 2.4 g for provision of 1 fodder unit with digestible protein; relative to June 25 crops: 3.4–6.9 t/ha; 0.72–1.95 t/ha; 0.54–1.13 t/ha; 48–214 kg/ha; 6.91–14.06 GJ/ha, respectively. In percentage terms, the exceedances ranged from 8-9 to 21–25%.

Crops of fodder beans and Scarlet amaranth had an advantage (green mass yield – 29.6–30.5 t/ha, dry matter – 5.70–5.95 t/ha, yield of fodder units – 4.20–4.67 t/ha, digestible protein content – 722–901 kg/ha, gross energy – 52.86–57.57 GJ/ha, provision of 1 fodder unit with digestible protein – 172–193 g).

Agrocenoses of bluegrass crops (spring triticale, fodder millet, Sudan grass) were inferior in productivity (green mass yield – 14.4–18.9 t/ha, dry matter – 2.97–3.93 t/ha, yield of fodder units – 2.23–3.03 t/ha, digestible protein content – 207–341 kg/ha, gross energy – 28.51–38.12 GJ/ha, provision of 1 fodder unit with digestible protein – 93–112 g).

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Оценка видового состава сорных растений семейства Капустные (Brassicaceae) рудеральных и сегетальных местообитаний Уссурийского городского округа Приморского края

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Приведены сведения о видовом составе сорных растений из семейства Капустные (Brassicaceae), стабильно произрастающих на территории Уссурийского городского округа Приморского края и доминирующих в агроценозах. Цели исследования: обобщить данные о наиболее распространенных (фоновых) видах растений природной и адвентивной флоры из семейства Капустные рудеральных и сегетальных местообитаний Уссурийского городского округа Приморского края; отметить виды, указанные в «Черной книге флоры Дальнего Востока» и произрастающие в черте данного городского округа; привести видовой состав травянистых растений семейства Капустные, обнаруженных в заповеднике «Уссурийский». Полевые исследования проводили традиционным маршрутно-рекогносцировочным методом в 2010–2023 гг. Осуществляли фенологические наблюдения, геоботанические описания выявленных местообитаний, сбор, определение гербарного материала и фотографирование объектов из мест произрастания. Из 23 видов семейства Brassicaceae, приведенных в работе, десять являются инвазионными в экосистемах Дальневосточного федерального округа: *Armoracia rusticana* Gaertn., Mey. et Scherb., *Berteroa incana* (L.) DC., *Brassica juncea* (L.) Czern., *Bunias orientalis* L., *Capsella bursa-pastoris* (L.) Medik., *Hesperis matronalis* L., *Lepidium densiflorum* Schrad., *Thlaspi arvense* L., *Turritis glabra* L., *Velarum officinale* (L.) Reichenb. Большинство из них, за исключением *B. juncea*, *C. bursa-pastoris* и *Th. arvense*, относятся к растениям, не причиняющим значительного ущерба на данном этапе развития. Рудеральные местообитания являются и местами сохранения биоразнообразия. В заповеднике «Уссурийский» им. В.Л. Комарова на территории Уссурийского городского округа выявлено 16 видов Капустных, из которых сегетальными являются *Barbarea orthoceras*, *B. incana*, *Th. arvense.*

Ключевые слова: Капустные, рудеральные и сегетальные местообитания, агроценозы, Уссурийский городской округ, Приморский край

Assessment of weed species composition of Cabbage family plants (Brassicaceae) of ruderal and segetal habitats of the Ussuriysk urban district of the Primorsky Territory

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The data on the species composition of weeds from the Cabbage family (Brassicaceae) that grow stably in the territory of the Ussuriysk urban district of the Primorsky Territory and dominate in agrocenoses are given in the article. Objectives of the study are: to summarize data on the most widespread (background) plant species of natural and adventive flora of the Cabbage family of ruderal and segetal

habitats of the Ussuriysk urban district of the Primorsky Territory; to note the species listed in the "Black Book of Flora of the Far East" and growing within the limits of the urban district; to cite the species composition of herbaceous plants of the Cabbage family found in the Ussuriysky Nature Reserve. Field studies were conducted using the traditional route-reconnaissance method in 2010–2023. Phenological observations, geobotanical descriptions of identified habitats, collection, identification of herbarium material and photographing of objects from growing sites were carried out. Of the 23 species of Brassicaceae cited in the paper, ten are invasive in the ecosystems of the Far Eastern Federal District: *Armoracia rusticana* Gaertn., Mey. et Scherb., *Berteroa incana* (L.) DC., *Brassica juncea* (L.) Czern., *Bunias orientalis* L., *Capsella bursa-pastoris* (L.) Medik., *Hesperis matronalis* L., *Lepidium densiflorum* Schrad., *Thlaspi arvense* L., *Turritis glabra* L., *Velarum officinale* (L.) Reichenb. Most of them, with the exception of *B. juncea*, *C. bursa-pastoris* and *Th. arvense*, are classified as plants that do not cause significant damage at this stage of development. Ruderal habitats are also sites of biodiversity conservation. In the V.L. Komarov Ussuriysky Nature Reserve, 16 species of Cabbage, of which *Barbarea orthoceras*, *B. incana*, and *Th. arvense* are segetal, were identified on the territory of the Ussuriysk Urban District.

Keywords: Brassicaceae, ruderal and segetal habitats, agrocenoses, Ussuriisk urban district, Primorsky Territory

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INTRODUCTION

Weeds are important objects of study that have not only scientific but also practical significance. Researchers interpret the term "weed plant" in different ways: from limiting the composition of weed plants to the species growing in crops only, to the inclusion of many species characteristic of uncultivated areas with disturbed natural cover in their ranks. Groupings of weed vegetation can appear in nature both as a result of anthropogenic impact and under the influence of animals, birds, ants, when natural secondary habitats appear, where more homogeneous composition of vegetation is observed than in the surrounding cenoses. Such habitats also include landslides, quarries, outcrops after earthquakes, etc. [1, 2].

Thus, the main difference between weeds and wild plants is their confinement to areas with disturbed or destroyed vegetation cover. Their species composition in a certain area is formed under the influence of environmental factors and human activity. Due to the interconnection of plant communities, plant species can move from ruderal places to the fields, therefore, much attention should be paid to the study of plants of this group growing in the immediate surroundings of the fields (forest belts, field road networks, ditches, ravines and other similar biotopes) [3].

Currently, many species of weeds have widely spread to anthropogenically disturbed territories and agrocenoses. Numerous publications provide regional lists [3-10] and information on

individual species[1] [11-13], the most aggressive of which are quarantine species in many countries and are included in the Unified List of Quarantine Objects of the Eurasian Economic Union[2]. 110 species of the Cabbage family (Brassicaceae)[3] are included in the list in the Primorsky Territory; some species are invasive in the ecosystems of the Far Eastern Federal District[4].

Research Objectives:

1) summarize data on the most common (background) plant species of natural and adventive flora of the Cabbage family of ruderal and segetal habitats of the Ussuriysk Urban District (UUD) of the Primorsky Territory;

2) identify the species listed in the "Black Book of the Flora of the Far East" and growing within the boundaries of this urban district;

3) to present the species composition of herbaceous plants of the Cabbage family found in the Ussuriysky Reserve on the territory of the UUD.

MATERIAL AND METHODS

Field studies were conducted in the Ussuriysk urban district, including the territory of the V.L. Komarov State Nature Reserve "Ussuriyskiy". The traditional route-reconnaissance method with the survey of the settlements and their vicinities was used. Phenological observations were made (2010-2023), herbarium material was collected, identified and objects from the places of growth were photographed. For identification of vascular plants and clarification of Latin names were used: "Illustrated flora of the Primorsky Territory" (see footnote 3) and "Vascular Plants of the Soviet Far East "[5]. Phenological observations were made according to the methodology of I.N. Beydeman[6].

RESULTS AND DISCUSSION

In the period from 2010 to 2023, 23 plant species from the Cabbage family were found, which are background plants of natural or adventive flora on the territory of the UUD (see the table).

Early-flowering Cabbage plants include the largest number of the plants growing in the UUD. Among them, the earliest flowering period (April - I ten-day period of May) is observed for *Cardamine leucantha*, *C. regeliana*, *Dontostemon hispidus*, *Draba nemorosa*, *Thlaspi arvense*. Cases of the beginning of flowering in May have been recorded in the following species *Armoracia rusticana*, *Barbarea orthoceras*, *Berteroa incana*, *Brassica juncea*, *Erysimum cheiranthoides*, *E. marschallianum*, *Hesperis matronalis*, *Lepidium densiflorum*, *Neslia paniculata*, *Sisymbrium luteum*, *Turritis glabra*, *Velarum officinale*. The later dates (June-July) are marked for the following *Arabis saqittata*, *Rorippa sylvestris*, *R. palustris*, the latest initial flowering is characteristic of *Arabis pendula* (July).

Repeated flowering is observed most often in such species as *B. orthoceras*, *B. juncea*. The main part of the Cabbage family plants belongs to the ecological group of mesophytes. The only hygrophyte among the studied species is *R. palustris*, the other species are xeromesophytes.

Invasive species requiring control measures and included in the "Black Book of the Flora of the Far East" are: *B. juncea*, *C. bursa-pastoris*, *Th. arvense*. The remaining seven species listed for the UUD are those that do not cause significant damage at this stage of development (see the table).

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Характеристика видов семейства Капустные (Brassicaceae) рудеральных и сегетальных местообитаний УГО Приморского края
Characterization of the Cabbage family species (Brassicaceae) of ruderal and segetal habitats of the UUD of the Primorsky Territory

Variety	Habitats		Phenological indicators	Ecological group	Note
	ruderal	segetal			
+*Arabis saqittata* (Bertol.) DC. (Wall-cress)	+	–	Fl. VI, fr. VII–VIII	Mesohygrophyte, mesotrophic, light-demanding	M, H
+*A. pendula* L. (Hanging wall-cress)	+	+	Fl. VII–VIII, fr. IX–X	Mesophyte, mesotroph	M, H
+**Armoracia rusticana* Gaertn., Mey. et Scherb.(Wild horse radish)	+	+	Fl. V–VI, fr. VII–VIII	Mesohygrophyte, eutrophic plant, light-demanding	O, F, M, H, E
+*Barbarea orthoceras* Ledeb. (Winter cress)	–	+	Fl. V–VI, fr. VII–VIII	Mesohygrophyte, mesotrophic, light-demanding	O, M, H, E, P
+**Berteroa incana* (L.) DC. (Hoary false alyssum)	–	+	Fl. V–VI, fr. VII–VIII	Xeromesophyte, mesotroph, light-demanding	O, F, M, H, T, P
+**Brassica juncea* (L.) Czern. (Indian mustard)	+	+	Fl. V– VII, fr. VII–VIII	Mesophyte, eutrophic plant, light-demanding	O, H
**Bunias orientalis* L. (Oriental bunias)	+	+	Fl. VI–VII, fr. VII–VIII	Mesophyte, mesotroph, light-demanding	F, M, H, E
+**Capsella bursa-pastoris* (L.) Medik. (Shepherd's purse)	+	+	Fl. IV–V, fr. VI–VII	Mesophyte, mesotroph, light-demanding	F, M, H, E, P
+*Cardamine leucantha* (Tausch) O.E. Schulz (Albiflorous bittercress)	+	+	Fl. IV–V, fr. VI–VII	Mesohygrophyte, mesotrophic, light-demanding	O, M, H, P
+*C. regeliana* Miq. (Regel bittercress)	+	–	Fl. IV–V, fr. VI–VII	Mesohygrophyte, mesotrophic, light-demanding	O, M, P
+*Dontostemon hispidus* Maxim. (Lanose dontostemon)	+	–	Fl. IV–V, fr. VI–VII	Xeromesophyte, mesotroph, light-demanding	O, H
+*Draba nemorosa* L. (Oak whitlow-grass)	+	+	Fl. IV–V, fr. VI–VII	Mesophyte, mesotroph, light-demanding	F, M
Erysimum cheiranthoides L. (Treacle erysimum)	+	+	Fl. V–VI, fr. VI–VII	Xeromesophyte, mesotroph, light-demanding	O, M, H, T, P
E. marschallianum Andrz. (Marshall erysimum)	+	+	Fl. V–VI, fr. VI–VII	Xeromesophyte, oligotroph, light-demanding	O, M, H
**Hesperis matronalis* L. (Dame's violet or butterfly orchid)	+	+	Fl. V–VI, fr. VI–VII	Mesophyte, mesotroph	O, H
+**Lepidium densiflorum* Schrad. (Densely flowered bird's pepper)	+	+	Fl. V–VI, fr. VII–VIII	Mesophyte, mesotroph, light-demanding	M
+*Neslia paniculata* (L.) Desv. (Ball mustard)	+	+	Fl. V–VI, fr. VII–VIII	Mesophyte, mesotroph, light-demanding	O, H
Rorippa sylvestris (L.) Besser (Forest cress)	+	+	Fl. VI– VIII, fr. VII–VIII	Mesophyte, mesotroph, light-demanding	O, M, H
R. palustris (L.) Besser (Marsh cress)	+	+	Fl. VI–VIII, fr. VIII–IX	Hygrophyte, eutrophic plant, light-demanding	O, M, H, E
+*Sisymbrium luteum* (Maxim.) O.E. Schulz (Yellow hedge mustard)	+	+	Fl. V–VI, fr. VII–VIII	Xeromesophyte, mesotroph, light-demanding	O, M, H
+**Thlaspi arvense* L. (Field pennycress)	+	+	Fl. IV–VI, fr. VI–VII	Mesophyte, mesotroph, light-demanding	M, E, T, P
**Turritis glabra* L. (Tower mustard)	–	+	Fl. V–VI, fr. VI–VII	Xeromesophyte, mesotroph, light-demanding	F, M
+**Velarum officinale* (L.) Reichenb. (Sisymbrium officinale)	+	+	Fl. V–VI, fr. VII–VIII	Mesophyte, mesotroph, light-demanding	F, M, H, E

Note. Fl. – flowering; fr. – fruiting; O – ornamental plant; F – forage; M – medicinal; H – honey plant; E – edible; T – technical; P – poisonous; * – plants listed in the "Black Book of the Flora of the Far East"; + – plants growing in the Ussuriysky Nature Reserve on the territory of the UUD.

CONCLUSION

Knowledge of the species composition of weeds that grow stably on the territory of the UUD and dominate in the agrocenoses is the basis for the development of a strategy to protect crops from them. Representatives of the Cabbage family predominate along the roadsides of field roads, on laylands and wastelands, and are weeds in crops and plantings. The most aggressive species is *B. juncea*, widespread not only on the territory of the UUD, but also in other areas of the Primorsky Territory (in fields, wastelands along the slopes of the federal, intermunicipal and local roads). Other invasive species (marked with an asterisk in the table) are slightly inferior in the degree of introduction into crops and plantings. Recently, *R. sylvestris* has invaded the vegetable gardens of private households.

Ruderal habitats can be a constant source of weed infestation in fields, so edge treatments of fields, mowing of close ruderal habitats are carried out to protect against weeds.

Ruderal habitats also serve as places of biodiversity conservation. In the Ussuriysky Reserve, we have identified 16 species of the Cabbage family on the territory of the UUD, of which *B. orthoceras*, *B. incana*, and *Th. arvense* are segmental. The last species was discovered in 1981 during surveys of ecotone plots along the road connecting the UUD and Shkotovsky District. At the first detection, single specimens were noted, but during the following years this species significantly increased its number and expanded its habitat [11]. Species of the genus *Rorippa Scop*. (*R. sylvestris*, *R. ralustris*) and *Erysimum* (Tourn.) L. (*E. marschallianum*, *E. scheiranthoides*) from the above list have not yet been found in the Ussuriysky Reserve.

At present, ways of utilizing wild food plants are being actively studied, including in the Primorsky Territory [14]. Among the species of the Cabbage family, not only medicinal species are noted (*S. luteum*, *C. bursa-pastoris*, *C. leucantha*, *V. officinale* и др.), but also fodder plants (*A. rusticana*, *B. incana*, *T. glabra*). Often medicinal plants are forage plants and vice versa.

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Повреждаемость клубней картофеля подгрызающими совками в зернотравяно-пропашном севообороте на северо-западе Российской Федерации

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Представлены результаты многолетнего мониторинга поврежденности клубней картофеля гусеницами подгрызающих совок и изучения факторов, ее определяющих. Исследования проведены в зернотравяно-пропашном севообороте на северо-западе Российской Федерации. В последние годы в отечественной и мировой научной литературе отмечено увеличение вредоносности подгрызающих совок на посадках картофеля, поэтому актуально выявление факторов, способствующих существенному ограничению поврежденности клубней картофеля гусеницами этого вредителя. По результатам исследований, проведенных в 2012–2022 гг., определено, что поврежденность клубней картофеля гусеницами совок варьирует в широких пределах – от 0,5 до 15,9%. Наиболее сильное влияние на поврежденность клубней совками оказывают погодные условия (доля влияния – 24,3%). Определяющим является период от посадки до цветения картофеля, что подтверждается статистической обработкой (r = 0,65, p < 0,05). Увеличению поврежденности клубней совками способствуют гидротермические условия в этот период, соответствующие ГТК 2,1–2,3, а также засоренность посадок многолетними двудольными видами и некоторыми малолетними. Влияние вегетативной массы всей совокупности произрастающей сорной растительности выражалось коэффициентом корреляции, равным 0,14 (p < 0,05), в том числе густоты и массы многолетних двудольных видов – 0,11 (p < 0,05) и 0,13 (p < 0,05). Одним из факторов, существенно снижающих поврежденность картофеля данным вредителем, является предпосадочная обработка клубней инсектофунгицидами. В сочетании с применением гербицидов она обеспечивала снижение доли поврежденных клубней гусеницами совок в убранном урожае на 56,8%. В то же время внесение минеральных удобрений, смена предшественника в севообороте и возделывание разных по устойчивости сортов картофеля не приводили к достоверному снижению поврежденности клубней гусеницами подгрызающих совок.

Ключевые слова: картофель, подгрызающие совки, гидротермический коэффициент, инсектофунгициды, минеральные удобрения, интегрированная система защиты растений

Damage to potato tubers by cut worms in grain-grass root-crop rotation in the north-west of the Russian Federation

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The paper presents the results of long-term monitoring of potato tuber damage by caterpillars of cut worms and study of the factors determining it. The research was carried out in grain-grass root-crop rotation in the north-west of the Russian Federation. In recent years in the domestic and world scientific literature an increase in the pest rate of cut worms on potato plantings has been observed, therefore, it is relevant to identify the factors contributing to a significant limitation of damage to potato tubers by the caterpillars of cut worms. According to the results of the studies conducted in the period 2012–2022, it was determined that the damage to potato tubers by caterpillars of cut worms varies widely – from 0.5 to 15.9%. Weather conditions have the strongest influence on tuber damage by cut worms (influence share – 24.3%). The period from planting to flowering of potatoes is determinant, which is confirmed by statistical treatment (r = 0.65, p < 0.05). Increase of tuber damage by cut worms is promoted by hydrothermal conditions during this period, corresponding to the HTC 2.1–2.3, as well as weeding of plantings with perennial dicotyledonous species and some small perennial species. The influence of

vegetative mass of the whole set of growing weed vegetation was expressed by a correlation coefficient equal to 0.14 ($p < 0.05$), including density and mass of perennial dicotyledonous species – 0.11 ($p < 0.05$) and 0.13 ($p < 0.05$). One of the factors that significantly reduce damage to potatoes by this pest is preplanting treatment of tubers with insectofungicides. In combination with the use of herbicides, it provided a 56.8% reduction in the proportion of tubers damaged by cut worm caterpillars in the harvested crop. At the same time, application of mineral fertilizers, change of the forecrop in crop rotation and cultivation of potato varieties with different resistance did not lead to a reliable decrease in damage of tubers by caterpillars of cut worms.

Keywords: potatoes, cut worms, hydrothermal coefficient, insectofungicides, mineral fertilizers, integrated plant protection system

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INTRODUCTION

Caterpillars of cut worms and larvae of click beetles are the most widespread soil-inhabiting pests of potato in the North-West region of the Russian Federation. The phytosanitary aspects of wireworm distribution in potato plantings are covered in scientific literature in sufficient detail [1–3], but such information is fragmentary with respect to the cut worm caterpillars [4]. At present, in the world and domestic scientific literature on potatoes, an increase in the harmfulness of cut worm caterpillars has been noted [4–7]. According to researchers, five species of cut worms have been found in the north-west of Russia: turnip moth (*Agrotis segetum* Denis and Schiff), heart and dart moth (*Agrotis exclamationis* L.), great brocade rustic moth (*Eurois occulta* L.), Portland moth (*Ochropleura praecox* L.) and dark swordgrass moth (*Agrotis Ipsilon* H.)[1].

Among all cut worm species, the turnip moth was clearly dominant (80.7–84.0%). Damage to potato tubers by this pest in the conditions of the region in some years can reach 48% [8]. The reasons for the occurring severe damage to potatoes by this pest are still not fully elucidated.

The purpose of the research is to study the influence of a complex of technological measures and weather conditions of potato vegetation period on the damage of tubers by cut worm caterpillars in grain-grass-root-crop rotation in the north-west of the Russian Federation.

MATERIAL AND METHODS

The research was conducted in 2012–2022 on potato plantings of the agroecological station of the Menkovo branch of the Agrophysical Research Institute (Leningrad region). The station is a seven-field grain-grass-root-crop rotation. According to crop alternation, potatoes in this rotation were placed after perennial grasses (2012-2017) or spring rape (2018-2022). In 2012–2017 a middle-early potato variety Sudarynya was grown, in 2018–2020 – an early maturity group variety Udacha, in 2021–2022 – super-early variety Meteor. Under the conditions of two-factor experiment the effect of complete mineral fertilization ($N_0P_0K_0$, $N_{65}P_{50}K_{50}$, $N_{100}P_{75}K_{75}$) and integrated plant protection system was studied.

The integrated potato protection system was as follows:

[1] *Volkov D.V., Nikolaeva Z.V.* Cut worms in potato plantings in the Pskov region // State and prospects of scientific support of agroindustrial complex: Proceedings of the scientific conference (Velikie Luki, February 8, 2023). Velikie Luki, 2023, pp. 37–39.

– treatment of the tubers before planting (2015–2018) or during planting (2012–2014) with one of the insectofungicide preparations (Prestige, SC (1.0 l/t), Celest Top, SC (0.4 l/t), Emesto Quantum, SC (0.35 l/t));

– application of herbicides 3–5 days before potato sprouting (Tornado, AS (3.0 l/ha)) and at plant height of 10–15 cm (Titus, DFC (50 g/ha) + Trend 90 (80 ml/ha));

– two to four fungicide treatments at intervals of 10–14 days (Ridomil Gold MC, WDG (2.5 kg/ha), Sektin Phenomenon, WDG (1.25 kg/ha), Infinito, SC (1.4 l/ha), Polyram, WDG (2.0 kg/ha)).

On the control the technological scheme of crop planting care was applied, consisting of two pre-emergence and two post-emergence mechanical treatments with a cultivator CON-2,8 PM coupled with a rotary harrow BRU-0,7, as well as hilling and desiccation.

The area of the crop rotation field was 0.6 hectares. The soil was soddy weak podzolic sandy loam with the humus content of 1.9%. Fertilizers were applied in spring in the form of a mixture of ammonium nitrate and azofosk across the field by a SZ-3.6 planter before plowing. Plant protection products were applied along the field with an Amazone-800 BU sprayer. The plot area was 150 m^2 (10 × 15 m). The experiment was repeated six times.

The study used the methodology of permanent test plots, which were installed in the field on the 8–10th day after planting and harvested together with the crop[2]. The area of the survey site was 1.4 m^2, which is provided for row crops with a row spacing width of 0.7 m^2. Their annual number was 36, 6 on each variant of the experiment. In tuber analysis of the yield obtained from permanent plots, the proportion of potato tubers damaged by the cut worm caterpillars and the intensity of their damage were determined in points on a unified scale[3].

In statistical processing of the data the analysis of variance and correlation in the program "Statistica 6" was used.

RESULTS AND DISCUSSION

According to the data of the tuber analysis, potato tubers damaged by cut worm caterpillars were registered annually. At the same time, they can be mostly attributed to the damage caused by the turnip moth, the caterpillars of which were regularly encountered during harvesting.

On average for the observation period (from 2012 to 2022), the proportion of the tubers with characteristic damage caused by this pest was 4.7%, varying widely from 0.5% in 2017 to 15.9% in 2022. The large range of variation in this trait was mainly due to the variability of weather conditions during the growing season of the crop. The contribution of this factor to the value of potato tuber damage according to the results of the dispersion analysis amounted to 24.3%, which significantly exceeded the influence of other factors (see Table 1).

High abundance of cut worm caterpillars, recorded in some years in the North-Western region, indicates potentially favorable weather conditions for their successful development. However, the presence of prolonged drought or prolonged low temperatures can significantly reduce the level of presence of these moths in potato plantings[4]. We observed similar effects in drought 2014, when the tuber damage amounted to 1.4%, and in 2017 under conditions of low heat availability in June and July (87 and 94% of the average annual norm) – 0.5% (see Table 2). Probably, in 2022 there were optimal conditions of moisture and temperature, which was reflected in the strong final damage of the tubers by moth caterpillars. The use of the Selyaninov hydrothermal coefficient allowed us to determine that damage to potato tubers by moth caterpillars depended most strongly on the weather conditions during the period from planting to flowering ($r = 0.65$, $p < 0.05$). The significance of weather conditions of this period is due to the fact that it is during this time period that egg-laying by females of cut worms

[2]*Zubkov A.F.* Agrobiocenological phytosanitary diagnostics. Saint Petersburg, 1995, 386 p.

[3]Methodological guidelines for registration tests of insecticides, acaricides, molluscicides and rodenticides in agriculture. Saint Petersburg, 2009, 321 p.

[4]*Pospelov S.M.* Cut worms // Cutworms – pests of agricultural crops. Moscow: Agropromizdat, 1989, pp. 11–52.

Табл. 1. Вклад факторов в поврежденность клубней картофеля гусеницами повреждающих совок на северо-западе Российской Федерации (Ленинградская область, 2012–2022 гг.)

Table 1. Contribution of factors to the damage of potato tubers by caterpillars of cut worms in the North-West of the Russian Federation (Leningrad region, 2012–2022)

Factor	Impact share, %
Weather conditions (year)	24,3*
Mineral nutrition level (MNL)	0,0
Integrated plant protection system (IPPS)	9,6
Interaction:	
year – MNL	0,7
year – IPPS	18,1*
MNL – IPPS	0,4
year – MNL – IPPS	1,5
Repetition	0,6
Random	44,7

*$p \geq 0{,}95$.

takes place (see footnote 4). Egg-laying is carried out exclusively on weed vegetation, which determines its great importance in reproduction of the cut worms. At that, preference is given to such species as field milk thistle, great plantain, lamb's quarters[5] (see footnote 4) [10].

The low level of tuber damage, corresponding to 0.5–1.8% in most years, could well be due to the large number of mechanical treatments in potato plantings, which effectively influence both the population size of the pest and its food base (see footnote 5). However, mechanical treatments are insufficiently effective against perennial weed species, which in the absence of herbicide treatments can lead to severe damage to tubers. This situation was observed in 2021 in potato plantings adjacent to rotational fields.

Under heavy weeding, mainly field thistle, the share of the damaged tubers by cut worms amounted to 29.1%, damage intensity – 21%. The situation was repeated in 2022 in potato crops of seven-field crop rotation. At the same time, it was not directly related to weediness of the field, as perennial dicotyledonous species were represented by low abundance and phytomass.

The peculiarity of grain-grass root-crop rotation is a strong weeding of potato plantings by creeping wheatgrass, as well as such species as lamb's quarters, hemp nettle, drug fumitory, common spurrey, white charlock, field milk thistle and field sorrel. The results of the correlation matrix analysis revealed a statistically significant positive relationship between tuber damage by moths and the density of field milk thistle growth ($r = 0, 12$, $r < 0.01$), great plantain ($r = 0.17$, $r < 0.01$), and Pale Smartweed ($r = 0.24$, $r < 0.01$), as well as with the phytomass of field milk thistle ($r = 0.13$, $r < 0.01$), field

Табл. 2. Многолетняя динамика метеоусловий и поврежденности клубней картофеля подгрызающими совками в зернотравяно-пропашном севообороте на северо-западе Российской Федерации

Table 2. Long-term dynamics of weather conditions and damage to potato tubers by cut worms in grain-grass root-crop rotation in the North-West of the Russian Federation

Indicator	Year										
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Sum of active temperatures, ºC	1529	1321	1627	1393	1499	1528	1516	1552	1639	1772	1711
Total precipitation, mm	441	210	170	154	342	320	176	255	392	326	334
HTC:											
entire growing season	2,9	1,6	1,0	1,1	2,3	2,1	1,2	1,6	2,4	1,8	2,0
planting – sprouting	2,6	1,3	1,5	0,8	1,4	1,7	0,1	0,4	0,8	2,0	2,0
planting – flowering	2,3	1,6	1,2	1,1	2,1	1,5	1,4	1,8	1,2	1,0	2,1
flowering – harvesting	3,7	1,7	0,8	1,1	2,6	2,9	0,8	1,3	4,3	3,2	2,0
Tuber damage, %	7,2	6,7	1,4	1,8	5,7	0,5	1,5	1,4	3,8	1,5	15,9

[5]*Zeyruk V.N., Abashkin O.V., Masyuk Y.A., Popov A.I.* Cut worms on potato fields // Plant Protection and Quarantine, 2008, N 7, pp. 44–45.

sorrel ($r = 0.14$, $r < 0.01$), and Pale Smartweed ($r = 0.19$, $r < 0.01$). Reliable correlation coefficients with damage of potato tubers by cut worm caterpillars were observed in lamb's quarters, field violet, drug fumitory, white charlock, common spurrey and shepherd's purse (see Table 3). With regard to creeping wheatgrass, a negative relationship with tuber damage by moths was more often observed. The influence of vegetative mass of the whole set of weed vegetation was expressed by the correlation coefficient equal to 0.14 ($p < 0.05$), including the density and mass of perennial dicotyledonous species – 0.11 ($p < 0.05$) and 0.13 ($p < 0.05$).

The influence of the integrated plant protection system on the damage of potato tubers by moths was clearly seen when comparing the corresponding variants in the experiment. The use of herbicides in combination with preplanting treatment of tubers with insectofungicidal preparations provided a 56.8% reduction in the share of damaged tubers by moth caterpillars in the harvested crop on average for 2015–2022. Low efficiency indicators, noted in 2012–2014, were due to the method of tuber treatment, which was carried out during planting (see Table 4). In this case, the working solution does not cover the entire surface of the tubers, which significantly affects the effectiveness of this measure. In 2021, when herbicide treatment was inexpedient due to low weediness of plantings, the reduction of tuber damage by moths at the level of 86.7% was due exclusively to the effect of tuber treatment with Emesto Quantum, SC. This confirms the great importance of tuber treatment with preparations possessing insecticidal activity in reducing their damage by cut worm caterpillars known from the literature [11–13].

Other factors that can influence potato damage by cut worms include mineral fertilizer application, preceding crop and varietal resistance.

According to the results of the dispersion analysis, it was not possible to reveal a reliable

Табл. 3. Значения коэффициентов корреляции показателей присутствия массовых видов сорных растений с поврежденностью клубней картофеля подгрызающими совками

Table 3. Values of correlation coefficients of indicators of the presence of mass weed species with damage to potato tubers by cutworms

Variety	Year										
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Lamb's quarters	0,01	–0,37*	0,22	0,21	0,28*	–0,08	–0,06	–0,18	–0,16	0,11	0,12
	0,30	–0,37*	0,11	0,24	0,28*	0,35*	0,11	–0,03	-0,14	0,07	0,05
Couch grass	0,12	–0,02	0,14	0,27*	–0,18	0,03	0,19	–0,24	-0,30	–	–0,28
	0,15	0,11	0,13	0,38*	0,07	0,02	0,26	-0,22	0,26	–	–0,29
Hemp nettle	–0,03	0,11	0,06	0,19	–0,12	0,01	–0,07	–0,17	–0,09	0,24	–0,10
	0,01	0,01	0,01	0,24	–0,05	0,25	–0,02	–0,27	–0,08	0,39	–0,10
Field violet	0,17	0,16	0,01	0,08	–0,07	0,16	–0,16	–0,02	–0,04	–0,02	0,47
	0,09	0,12	0,05	0,32*	0,55*	–0,09	–0,08	–0,02	–0,03	–0,05	0,42
Drug fumitory	0,16	0,10	–0,05	0,13	0,08	0,04	0,27	–0,16	–0,12	0,09	–0,10
	–0,12	–0,03	–0,03	0,36*	–0,07	0,10	0,08	–0,18	–0,11	–0,06	0,13
White charlock	0,33	0,19	0,14	0,18	0,02	–0,12	0,04	0,30	–0,12	0,14	–0,34
	0,23	0,19	0,02	0,22	0,29*	–0,09	0,01	0,21	–0,24	0,14	–0,45
Common spurrey	0,18	0,03	0,34*	0,37*	0,42*	0,10	0,06	–0,03	–0,16	–0,38	0,37
	0,23	–0,05	0,31*	0,37*	0,45*	–0,06	0,03	0,01	–0,03	–0,29	0,04
Milk thistle	0,06	0,12	0,01	–0,11	0,13	–0,03	0,08	–	0,20	–	0,33
	0,10	0,13	0,19	0,03	0,16	0,11	0,10	–	0,01	–	0,23
Field sorrel	–0,19	0,23	0,04	–0,10	0,15	–0,10	0,36*	0,33	–0,40	–0,20	–0,02
	–0,19	0,19	0,08	–0,10	0,28*	-0,14	0,29	0,28	0,01	–0,21	0,04
Shepherd's purse	0,17	–0,04	–0,06	0,34*	0,48	0,10	0,32	0,76*	-0,04	0,11	0,25
	–0,05	–0,28	–0,06	0,35*	0,67	–0,02	0,17	0,84*	0,18	0,19	0,15

*$p < 0,05$.

stable influence of the level of mineral nutrition of potato plantings on the degree of tuber damage by cut worm caterpillars. The average data of tuber damage by moth caterpillars tended to decrease under the influence of increasing doses of mineral fertilizers – 4.7; 4.2 and 4.0% in the variants with the application of $N_0P_0K_0$, $N_{65}P_{50}K_{50}$ and $N_{100}P_{75}K_{75}$, respectively. At the same time, in some years (2015–2016) we observed a significant multiple (6.2 and 43.0 times) decrease in the proportion of damaged tubers in the highly fertilized variant compared to the unfertilized one, in other years the situation was the opposite (see Table 5).

When potato plantings were placed after perennial grasses, the damage to the tubers by cut worm caterpillars amounted to 3.9%, after spring rape – 4.7%. Obviously, the change of the forecrop did not significantly affect the level of damage of potato tubers by moths.

Data on food preferences of the cut worm caterpillars with respect to tubers of different potato varieties are very limited in the scientific literature. According to the previously published data, the varieties Udacha and Meteor belong to the group of medium resistant varieties to moth caterpillars with the range of tuber damage from 0.7 to 5.4% [4]. During our research, the variety Udacha corresponded to its resistance group, while tubers of the variety Meteor in 2022 were damaged by the pest by 15.8%, which corresponds to varieties that are not resistant to cut worm moths. According to the results of the tuber analysis 2012–2017, the Sudarynya variety can be classified as medium resistant.

CONCLUSIONS

1. Annual damage of potato tubers by cut worm caterpillars, the share of which in some years can reach 15.9%, is observed in grain-grass root-crop rotation in the north-west of the Russian Federation.

2. Taking into account the obtained data, the strongest influence on the damage of tubers by moths is caused by weather conditions (the share of influence is 24.3%), formed in the period from planting to flowering of potatoes. Favorable are hydrothermal conditions corresponding to HTC 2.1–2.3. Weeding of plantings with perennial dicotyledonous species (field milk thistle, field sorrel and great plantain) and some short-lived species (lamb's quarters and Pale Smartweed) contributes to the increase of tuber damage by moths.

3. One of the factors significantly reducing the damage of potatoes by this pest (by 56.8%),

Табл. 4. Влияние интегрированной системы защиты посадок картофеля на поврежденность клубней подгрызающими совками

Table 4. The influence of the integrated potato planting protection system on the damage of tubers by cut worms

Year	Tuber damage, %		Reduction of tuber damage relative to the control, %
	without IPPS	with IPPS	
2012	7,2	7,1	1,4
2013	6,7	6,4	4,5
2014	1,4	1,1	21,4
2015	1,8	0,2	88,9
2016	5,7	3,8	33,4
2017	0,5	0,5	0
2018	1,5	1,0	33,3
2019	1,4	0,3	78,6
2020	3,8	2,1	44,7
2021	1,5	0,2	86,7
2022	15,9	1,8	88,7

Табл. 5. Влияние минерального питания на поврежденность клубней картофеля подгрызающими совками

Table 5. The effect of mineral nutrition on the damage of potato tubers by cut worms

Year	Fertilizer dose			Reliable significance criterion (p)
	$N_0P_0K_0$ (А)	$N_{65}P_{50}K_{50}$ (Б)	$N_{100}P_{75}K_{75}$ (В)	
2012	3,9	9,6	8,2	–
2013	6,2	7,2	6,9	–
2014	1,2	1,4	1,6	–
2015	3,1	1,7	0,5	АВ*
2016	12,9	4,0	0,3	АВ**, БВ*
2017	0,3	1,1	0	–
2018	2,7	0,6	1,2	–
2019	2,3	1,1	0,9	–
2020	4,5	3,3	3,7	–
2021	1,1	1,5	1,9	–
2022	13,2	14,9	19,3	–

*$p < 0,05$.
**$p < 0,01$.

is the pre-treatment of tubers with insectofungicides, provided by the integrated system of plant protection. At the same time, the application of mineral fertilizers, change of the forecrop in the crop rotation and cultivation of potato varieties with different resistance did not lead to a significant reduction in the damage of tubers by cut worm caterpillars.

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Эпизоотическая ситуация и молекулярно-генетическая характеристика вируса бешенства, изолированного из мозга домашнего северного оленя в Якутии

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На территории Республики Саха (Якутия) в 2001–2021 гг. бешенство зарегистрировано среди лошадей, домашних северных оленей и собак. В биоматериале от диких животных вирус бешенства (*Rabies lyssavirus)* обнаружен у песцов, красных лисиц, волков, колонков, горностаев и соболей. В Арктической зоне Якутии в 2023 г. у одного из домашних северных оленей стада с проявлением клинических признаков сильного возбуждения и агрессии к людям из образца головного мозга выделен вирус бешенства. Предположено, что заражение оленя вирусом бешенства произошло при укусе больным бешенством песцом, поскольку ареал распространения этих животных в данном регионе достаточно велик. Исследования по обнаружению вируса бешенства проведены с использованием полимеразной цепной реакции, иммуноферментного анализа и метода флуоресцирующих антител. Во всех диагностических тестах диагноз на бешенство подтвержден. Из образцов, давших положительный результат, методом ПЦР выделены фрагменты нуклеиновой кислоты и проведено определение их нуклеотидных последовательностей. Анализ нуклеотидных последовательностей вирусного генома выявил филогенетическое родство выделенного изолята вируса бешенства в Арктической зоне Якутии с вирусами бешенства, циркулирующими в некоторых районах Северо-Американского континента, включая Гренландию (два изолята), Канаду (шесть) и США (три). Выделенный изолят вируса бешенства из мозга домашнего северного оленя в Арктической зоне Якутии относится к группе штаммов американского происхождения (USA1) и филогенетически близок к штаммам, изолированным в Гренландии, Канаде и США. Изучаемый изолят вируса территориально соответствует известному антигенному варианту 3, установленному ранее на севере Азиатской части России, в частности в Якутии.

Ключевые слова: бешенство, вирус, домашний северный олень, филогенетический анализ

Epizootic situation and molecular genetic characteristics of the rabies virus isolated from the brain of domestic reindeer in Yakutia

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Rabies was registered among horses, domestic reindeer and dogs on the territory of the Republic of Sakha (Yakutia) in 2001– 2021. Rabies virus (*Rabies lyssavirus*) was detected in biomaterial from wild animals in Arctic foxes, red foxes, wolves, colts, ermine and sables. In the Arctic zone of Yakutia in 2023, rabies virus was isolated from a brain sample from one of the domestic reindeer of a herd showing clinical signs of severe agitation and aggression to humans. It is assumed that the reindeer was infected with rabies virus when bitten by a rabies-sick Arctic fox, as the range of distribution of these animals in the region is quite large. Rabies virus detection studies were conducted using polymerase chain reaction, enzyme immunoassay and fluorescent antibody method. The diagnosis of rabies was confirmed in all diagnostic tests. The nucleic acid fragments were isolated from the positive samples by the PCR method and their nucleotide sequences were determined. Analysis of the nucleotide sequences of the viral genome revealed phylogenetic relatedness of the isolated rabies virus isolate in the Arctic zone of Yakutia with the rabies viruses circulating in some areas of the North American continent, including Greenland (two isolates), Canada (six), and the United States (three). The isolate of the rabies virus from the brain of domestic reindeer in the Arctic zone of Yakutia belongs to the group of strains of American origin (USA1) and is phylogenetically close to the strains isolated in Greenland, Canada, and the USA. The studied virus isolate territorially corresponds to the known antigenic variant 3, established earlier in the north of the Asian part of Russia, in particular in Yakutia.

Keywords: rabies, virus, domestic reindeer, phylogenetic analysis

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INTRODUCTION

According to the classification of the International Epizootic Bureau (IEB), rabies is included in the list of particularly dangerous diseases. In Russia, rabies is included in the list of particularly dangerous animal diseases for which restrictive and regime anti-epidemic measures (quarantine)[1] may be established.

During 1991 – 2015 in Russia, more than 23.4 thousand farm animals, including 5.5 thousand domestic reindeer, suffered from rabies and were forcibly slaughtered. The economic damage amounted to 656.8 and 49.6 million rubles, respectively [1].

The molecular and genetic characterization of field isolates of rabies virus circulating in the organism of different species of domestic and wild animals has been studied in a number of regions of Russia, including the Republic of Tatarstan[2], Kirov region [2], Vladimir, Moscow, Tver and Ryazan regions [3, 4], Krasnoyarsk

[1]List of contagious, including especially dangerous, animal diseases for which restrictive measures (quarantine) may be established (as amended as of September 25, 2020). Order of the Ministry of Agriculture of the Russian Federation of December 19, 2011, № 476.

[2]*Gulukin A.M., Shabeykin A.A., Zaikova A.N., Polyakova I.V., Zaberezhny A.D., Hismatullina N.A., Samerkhanov I.I.* Features of the epizootic process and molecular genetic characterization of rabies virus isolates in the Republic of Tatarstan // Veterinarny Vrach, 2015, N 6, pp. 3–11.

Territory [5], Western Siberia[3], the Republic of Buryatia [6], the European region of Russia [7], Mongolia, and nearby areas of China [8]. This has allowed us to supplement the epizootic and epidemic situation of rabies and to monitor its spread. Using molecular genetic methods, cases of human deaths from rabies spread in natural foci have been confirmed [9].

According to official veterinary statistics, in 2001–2021 rabies was registered in the territory of the Republic of Sakha (Yakutia) among herd horses (one head), domestic reindeer (31 heads) and other animal species, including wild animals. In wild animal biomaterial, rabies virus (*Rabies lyssavirus*) has been detected in various years in red foxes, wolves, Siberian weasels, ermine and sables. In 2018, 15 laboratory-confirmed cases of rabies were detected in wild animals, including two in wolves and two in Arctic foxes. In addition, rabies diagnoses were confirmed in 11 domestic reindeer and a dog puppy. The rabies virus was also detected in biomaterial samples of two white foxes that were shot by hunters as part of a monitoring study in a hunting area[4].

The purpose of this work is to present a phylogenetic analysis of rabies virus isolates in the Arctic zone of Russia, including Yakutia.

MATERIAL AND METHODS

The spread of rabies among wild and farm animals on the territory of Yakutia for 2001-2023 was studied according to the data of veterinary statistics of the Department of Veterinary Medicine of the Republic of Sakha (Yakutia).

Studies on detection of rabies virus in the brain tissue of domestic reindeer were carried out in 2023 using polymerase chain reaction (PCR)[5], enzyme-linked immunosorbent assay (ELISA) and fluorescent antibody technique (FAT)[6] at the Yakutsk Republican Veterinary and Testing Laboratory.

PCR was performed in accordance with the "Instructions for use of the kit for detection of rabies virus RNA by real-time polymerase chain reaction (PCR) (Fractl BIO LLC"). The ELISA method for detection of the rabies virus antigen is based on its specific exposure to an anti-rabies antibody immobilized on a solid carrier with subsequent detection of the bound antigen; FAT is a method for detection of the rabies virus antigen by fluoresceinisothiocyanine-labeled anti-rabies antibody with the formation of characteristic luminescent complexes in the field of view of a microscope.

In the study, total RNA was extracted from the biomaterial of domestic reindeer (brain tissue) using Trizol reagent (Life Technologies Corp/ ThermoFisher Scientific, USA) according to the manufacturer's instructions. Synthesis to DNA was performed using the Revert-L kit (InterLabService, Russia). The presence of rabies virus RNA was determined by PCR using BioMaster LR HS-PCR (Biolabmix LLC, Russia) and specific primers to the nucleotide sequence of the *Rabies lyssavirus matrix protein* gene fragment (2515-2771 bp). The following oligonucleotides were used: F385-149 (5'-ATA GTGAAAAACTGCAGGGATGAGGA-3') and R387-151 (5'-ACCCAGTTCATGCCYTCMG). Amplification of a 319-nucleotide pair fragment was performed using the following program: – 95 °C – 5 sec; – 57 °C – 10 sec; – 72 °C 30 sec – 40 cycles.

PCR products were visualized by electrophoresis in 2% agarose gel stained with ethidium bromide using a gel photodocumentation system (GelDoc Go Imaging System, Bio-Rad, USA). The obtained DNA fragments were purified using an agarose gel DNA evolution kit (Bio-Silica, Russia) and sequenced on an ABI-Prism 3500 instrument using BigDye Terminator v3.1 reagent kits (ThermoFisher Scientific, USA).

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[6]GOST 26075–2013. International Standard. Animals: Methods of laboratory diagnosis of rabies (official edition). Moscow: Standardinform, 2014, 10 p.

Phylogenetic analysis of the rabies virus nucleic sequence (studied sample – Seq5rc) was performed using the minimum evolution method in the MEGA7 program [10] in comparison with the rabies virus prototypes from the GenBank database[7, 8].

RESULTS AND DISCUSSION

In May 2023 reindeer herders of one of the farms of the Nizhnekolymsky ulus, territorially located in the Arctic zone of Yakutia, noted unusual behavior of one of the domestic reindeer of the herd. Upon arrival of veterinary specialists, the animal, showing clinical signs of severe agitation and aggression towards people, was shot with a presumptive diagnosis of rabies.

The number of Arctic foxes in the tundra zone of Yakutia is estimated at 35–45 thousand, and the isolation of the rabies virus from their biomaterial is 32.5%[9]. In all likelihood, the reindeer was infected by a bite from a rabid fox.

Samples of the selected biomaterial (brain) were analyzed by PCR, ELISA and FAT methods. All diagnostic tests confirmed the diagnosis of rabies virus presence.

Nucleic acid fragments were isolated from the positive samples by PCR and their nucleotide sequences were determined. The studies were performed at the State Scientific Center of Virology and Biotechnology "Vector" of the Rospotrebnadzor (Federal Service for Consumer Rights Protection and Human Welfare, Novosibirsk).

The evolutionary history of the rabies virus isolated from the brain of domestic reindeer was established using the method of minimal evolution (ME). Evolutionary analysis was performed in the MEGA7 program.

The studied sample is Seq5rc. The prototypes of the rabies virus from the GenBank database were used in the tree. The search in the ME-tree was performed in the Close-Neighbor- Interchange (CNI)[10] algorithm using 37 nucleotide sequences of different rabies virus genovariants. The phylogenetic groups of rabies virus are shown in the figure according to the method proposed by A. Metlin et al. (2007) [10]. Five main phylogenetic groups of the rabies virus were identified.

Analysis of the nucleotide sequences of the viral genome revealed phylogenetic relatedness of the rabies virus isolate we isolated in the Arctic zone of Yakutia with the rabies viruses circulating in some areas of the North American continent, including Greenland (two isolates, Canada (six), and the United States (three) (see the figure).

The figure shows the optimal tree with the sum of branch lengths equal to 0.52 867 549, reflecting the phylogenetic relationships of rabies virus isolated from the brain of Yakutian reindeer (Minimum Evolution algorithm using nucleotide sequences of the *matrix protein* gene fragment (2515-2771 bp). Bootstrap test of 1000 repetitions).

H. Bourhy et al.[11] in studying the spread of rabies in the global area showed that viruses circulating in the populations of wild and domestic carnivores in Russia correspond to two main phylogenetic groups of viruses - arctic and cosmopolitan. The representatives of the cosmopolitan group of viruses, an extensive phylogenetic group, are distributed in the territories of Europe, the Middle East, Iran, Kazakhstan, America, and the African continent.

In turn, the group of Arctic viruses has two distinct subgroups: Arctic A proper and Arctic-like B[12]. Similar arctic-like field isolates of the rabies virus were identified by B. Boldbaatar

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[8]*Metlin A., Rybakov K., Gruzdev S., Neuvonen E., Huovilainen A.* Genetic heterogeneity of Russian, Estonian and Finnish field rabies viruses // Arch. Virol. 2007, vol. 152, pp. 1645–1654.

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[10]*Nei M., Kumar S.* Molecular Evolution and Fhylogenetick // Oxford University Press, New York, 2000.

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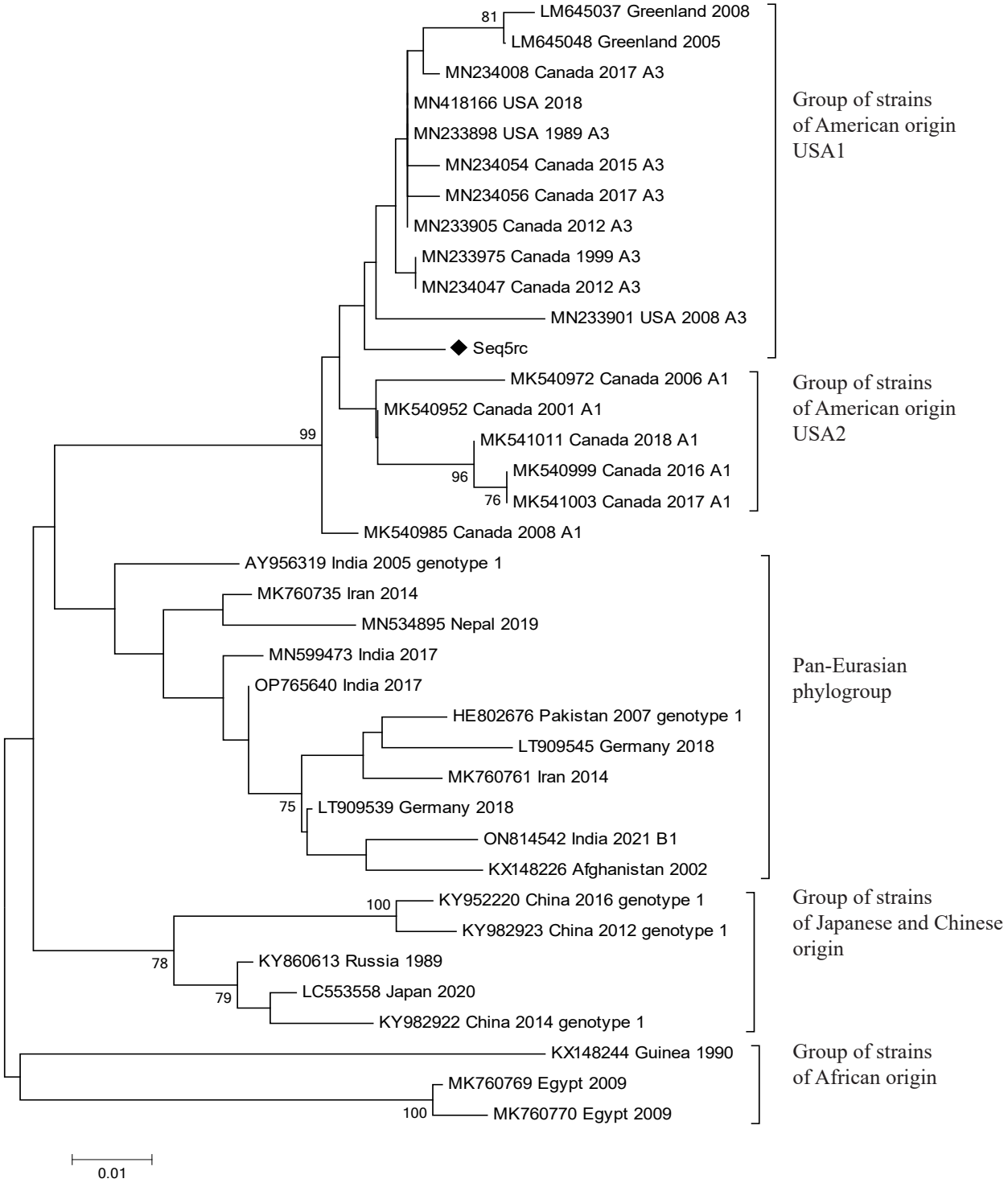
[12]*Metlin A., Rybakov K., Gruzdev S., Neuvonen E., Huovilainen A.* Genetic heterogeneity of Russian, Estonian and Finnish field rabies viruses // Arch. Virol., 2007, vol. 152, pp. 1645–1654.



Филогенетические связи вируса бешенства, изолированного из мозга домашнего северного оленя Якутии (алгоритм «Minimum Evolution» с использованием нуклеотидных последовательностей фрагмента гена *matrix protein* (2515–2771 п.н.). Бутстреп-тест 1000 повторений)

Phylogenetic relationships of the rabies virus isolated from the brain of domestic reindeer of Yakutia (Minimum Evolution algorithm using the nucleotide sequences of the *matrix protein* gene fragment (2515-2771 bp); bootstrap test of 1000 repetitions).

et al.[13] from animal biomaterial from Mongolia. According to the molecular genetic analysis performed by B. Tao et al.[14], rabies viruses of the cosmopolitan group, also arctic-like, are prevalent in China, while viruses belonging to a separate group of lyssaviruses circulating in Asia are prevalent in southern China. Isolates of lissaviruses studied by A. Metlin et al.[15] corresponded to groups C, D and E established earlier by I. Kuzmin et al.[16]

Based on the results of the phylogenetic analysis, it can be concluded that the rabies virus isolate from the brain of domestic reindeer in the Arctic zone of Yakutia belongs to the group of strains of American origin (USA1) and is phylogenetically close to the strains isolated in Greenland, Canada, and the United States. The studied virus isolate territorially corresponds to the known antigenic variant 3, established earlier in the north of the Asian part of Russia, particularly in Yakutia (see footnote 16).

CONCLUSIONS

1. In the Republic of Sakha (Yakutia) in 2001-2021 rabies was registered among horses, domestic reindeer and dogs. Rabies virus (*R. lyssavirus*) was detected in the biomaterial from wild animals in foxes, red foxes, wolves, Siberian weasels, ermines and sables.

2. In the Arctic zone of Yakutia in 2023, the diagnosis was confirmed in all diagnostic tests from the biomaterial (brain) of a domestic reindeer with clinical signs of rabies by PCR, ELISA and FAT methods. In all likelihood, the reindeer was infected with the rabies virus when bitten by a rabid fox, which has a large distribution area in the region.

3. Analysis of nucleotide sequences of the viral genome showed phylogenetic relatedness of the isolated rabies virus isolate in the Arctic zone of Yakutia with the rabies viruses circulating in the areas of the North American continent, including Greenland, Canada and the USA.

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Повышение продуктивности коров за счет использования в кормлении премиксов на основе лесных и минеральных ресурсов

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Изучено влияние премиксов на основе лесных сырьевых ресурсов (сосновой хвои, скорлупы кедрового ореха, арабиногалактана) и минеральных (бентонитовой глины, вспученного вермикулита) на молочную продуктивность коров. Эксперимент проведен в Красноярском крае на трех группах коров черно-пестрой породы (по 10 гол. в группе) в возрасте третьего отела, живой массой 530–550 кг. Контрольной группе скармливали основной рацион, 1-й опытной – дополнительно к основному рациону скармливали премикс, состоящий из бентонитовой глины, сосновой хвойной муки, скорлупы кедрового ореха, витаминно-минерального комплекса и арабиногалактана. Коровам 2-й опытной группы скармливали премикс аналогичного состава, за исключением бентонитовой глины, вместо которой в премикс включили вспученный вермикулит. Продолжительность опыта составляла 60 дней. Содержание коров было привязно-выгульным, доение – автоматическим в молокопровод. Рацион кормления соответствовал зоотехническим нормам. Изучаемые премиксы скармливали в смеси с концентрированными кормами один раз в день. Исследования проведены по общепринятым методикам с использованием современного сертифицированного оборудования. Скармливание коровам изучаемых премиксов оказало положительное влияние на молочную продуктивность в обеих опытных группах, однако наибольший прирост продуктивности по сравнению с контролем установлен у коров 2-й опытной группы, получавших премикс со вспученным вермикулитом в составе. Удой молока натуральной жирности в этой группе увеличился на 7,60%, удой базисной жирности на 14,02%, массовая доля жира в молоке на 0,23 п. п., количество молочного жира – на 14,02%, молочного белка – на 9,65%. Органолептические показатели молока подопытных коров под действием изучаемых премиксов не ухудшились и соответствовали требованиям ГОСТа к молоку высшего сорта.

Ключевые слова: молочная продуктивность коров, премикс, лесные ресурсы, природные минералы

Increasing the productivity of cows through the use of premixes based on forest and mineral resources in feeding

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The influence of premixes based on forest (pine needles, pine nut shells, arabinogalactan) and mineral (bentonite clay, expanded vermiculite) raw materials on dairy productivity of cows has been studied. The experiment was conducted in the Krasnoyarsk region on three groups of Black-and-White breed cows (10 heads per group) at the age of the third calving, with a live weight of 530–550 kg. The control group was fed the basic diet, the 1st experimental group was fed a premix consisting of bentonite clay, pine coniferous flour, pine nut shells, vitamin and mineral complex and arabinogalactan in addition to the basic diet. Cows of the 2nd experimental group were fed a premix of a similar compo-

sition with the exception of bentonite clay, instead of which expanded vermiculite was included in the premix. The duration of the experiment was 60 days. The cows were kept tethered and walking, milking was automatic in the milk pipeline. The feeding ration corresponded to zootechnical standards. The studied premixes were fed in a mixture with concentrated feeds once a day. The research was carried out according to generally accepted methods using modern certified equipment. Feeding the cows of the studied premixes had a positive effect on milk productivity in both experimental groups, however, the greatest increase in productivity compared with the control was found in cows of the 2nd experimental group who received a premix with expanded vermiculite in the composition. Milk yield of natural fat content in this group increased by 7.60%, milk yield of basic fat content – by 14.02%, the mass fraction of fat in milk – by 0.23 percentage points, the amount of milk fat – by 14.02%, milk protein – by 9.65%. The organoleptic parameters of the milk of experimental cows under the influence of the studied premixes did not deteriorate and met the requirements of the GOST (Russian National Standard) for premium milk.

Keywords: dairy productivity of cows, premix, forest resources, natural minerals

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INTRODUCTION

Ensuring food security of the population and increasing the efficiency of livestock breeding are the most important tasks of the agro-industrial complex of Russia [1]. To solve these problems, it is necessary to provide quality and balanced feeding of animals, which allows to realize their genetic potential of productivity to the fullest extent possible.

The production of new high-quality premixes is an actual direction in the domestic compound feed industry. Their use in the feeding of farm animals contributes to additional enrichment of diets with biologically active substances and increasing the digestibility of fodder nutrients, significantly stimulates physiological functions of the organism, improves animal health and reduces the cost of production [2].

Domestic premixes have high quality indicators, but their price is not always competitive, because up to 90% of the components used in their production are purchased abroad [3]. Most often these are vitamins, trace elements and amino acids obtained by chemical synthesis, but it is known that similar components of natural origin have better bioavailability for the animal organism. In this regard, the use of premixes based on non-traditional natural mineral and plant raw materials is relevant and promising to balance diets and achieve a high level of their biological value.

Useful biologically active substances required by farm animals can be extracted from various plant wastes of natural origin. In Siberia, these are primarily wastes from logging and food forest resources, in particular, pine nuts.

In Russia, the activities of forest processing enterprises annually generate about 68-74 million m^3 of wood waste, of which only 48-58% is recycled [4]. Currently, the main method of wood waste utilization continues to be burning or storage, which causes global concern about environmental sustainability and resource conservation [5].

According to the Federal Law "On Production and Consumption Waste" (as amended on 04.08.2023)[1], the development of a closed-cycle economy, in particular, the involvement of secondary resources in economic turnover, including the recycling of waste from forestry enterprises, is relevant for our country.

When harvesting coniferous timber, green tree crowns, needles, bark, chips remain as waste, and after pine nut processing - cone shells and husks. These wastes are rich in vitamins, macro- and microelements, carotenoids, essential oils, carbon and fatty acids, polyprenols, tannids, quercetins, phenolic compounds and other substances with biological activity, antioxidant and anti-inflammatory properties[2].

The valuable biologically active forest raw materials also include polysaccharide arabinogalactan, obtained from larch wood and possessing prebiotic properties. Its use in animal feeding stimulates the growth of beneficial lacto- and bifidobacteria in the gastrointestinal tract and promotes the formation of short-chain fatty acids, vital for the normal functioning of the body. In addition, arabinogalactan is able to exhibit independent immunomodulatory properties by activating the reticuloendothelial system, increasing phagocytosis, and stimulating the multiplication of spleen and bone marrow cells[3] [6].

Consumption by animals of natural phytobiotics contained in forest biomass stimulates immunity, accelerates and improves the quality of metabolic processes in the body, increases digestibility and availability of feed nutrients, hormone activity, increases the production of endogenous enzymes [7, 8].

The quality characteristics of premixes are influenced by the type of raw material used as filler in addition to the compatibility and stability of the components used in the composition and the production technology. The most common filler in premixes is bran, which requires special storage conditions. In addition, vegetable fillers are subject to mold and rancidity [9].

With the development of modern technologies, it has become possible to use porous minerals, widely distributed in nature, such as bentonite clay, vermiculite, etc., as fillers for premixes.

Mineral raw materials are used in premixes and mixed fodders to make them technological, as well as enrich with macro- and microelements in order to correct metabolism in animal organism, in particular mineral metabolism[4]. Due to their high adsorption capacity, porous minerals can reduce the level of toxic effects and eliminate feed mycotoxins, pollutant metals, radionuclides, pathogenic microorganisms and products of their vital activity from the body [10, 11]. Eating of natural minerals by animals stimulates digestibility and promotes better assimilation of forage nutrients due to the manifestation of buffering and ion exchange properties [12]. In addition, when animals are fed natural minerals, the body restores self-regulation mechanisms, maintains acid-base equilibrium and osmotic pressure, stimulates the processes of secretion,

[1]Federal Law "On Amendments to the Federal Law 'On Production and Consumption Waste' and Certain Legislative Acts of the Russian Federation" dated 04.08.2023, No. 451-FZ (wording effective as of 01.01.2024).

[2]*Ivanova O.V., Ivanov E.A., Tereshchenko V.A.* Forest resources as a source of fodder additives: recommendations. Krasnoyarsk: FRC KSC SB RAS, 2020, 32 p.

[3]*Medvedeva E.N., Babkin V.A., Ostroukhova L.A.* Arabinogalactan larch – properties and prospects for use (review) // Chemistry of plant raw materials, 2003, N 1, pp. 27–37.

[4]*Podolnikov V.E., Gamko L.N., Sezin Y.A., Sidorov I.I.* Recommendations on the use of rotten stones of Bryansk deposits in the diets of farm animals. Bryansk: Bryansk State Agrarian University, 2018, 56 p.

hematopoiesis, bone formation and excretion of underoxidized products of biological synthesis[5, 6].

When using bentonite clay in premixes, the density and moisture content of the final product, its bulkiness and homogeneity are improved, and storage time is increased[7]. At the same time, it is important to follow the recommendations for the coarseness of grinding minerals in the composition of feeds and additives for mammals (0.5-2.0 mm)[8].

The use of expanded vermiculite in premixes, which has the property of strong water holding capacity, allows introducing liquid components such as extracts, molasses, oils, medicines, etc. into the final product. At the same time premix retains its homogeneous bulk structure and does not delaminate [13].

In view of the above, the development of new premixes for cows using forest and mineral resources is an actual and demanded direction of research.

The purpose of the study was to investigate the effect of the premixes based on forest raw materials (pine needles, pine nut shells, arabinogalactan) and mineral (bentonite clay, expanded vermiculite) on the milk productivity of cows.

The objectives of the study were to investigate the milk productivity of cows and organoleptic properties of milk under the action of the studied premixes.

MATERIAL AND METHODS

The research was carried out at the farm "Mikhailovskoye" – branch of the FRC KRC SB RAS, Uzhursky district, Krasnoyarsk Territory. The scientific experiment was conducted on the dairy cows of Holsteinized Black-and-White breed at the age of the third calving with annual milk yield of 5822 kg and average live weight of 530–550 kg. Three groups of dairy cows – control and two experimental groups of 10 cows each – were formed for the experiment according to the principle of analogs, taking into account breed, age, live weight, level of milk productivity. The experiment lasted 60 days.

According to the experimental feeding conditions, the control group received the basic diet, the 1st experimental group was fed premix (215 g/head/day) in addition to the basic diet, consisting of bentonite clay (100 g/head), pine conifer meal and pine nut shell (50 g/head each), vitamin-mineral complex (10 g/head) and arabinogalactan (5 g/head); 2nd experimental group – premix (215 g/head/day), consisting of expanded vermiculite (100 g/head.), pine coniferous meal and pine nut shell (50 g/head each), vitamin-mineral complex (10 g/head) and arabinogalactan (5 g/head).

The basic diet of experimental cows consisted of grass-legume haylage – 21 kg, rapeseed cake – 1.5, mixed herbs – grass-and-legume hay – 5.0, straw – 1.0, barley – 4.8, fodder molasses – 1.6, chalk – 0.15, salt – 0.15 kg. For every 100 kg of live weight the cows consumed 3.72 EFU and 3.97 kg of dry matter. 1 kg of dry matter of the diet contained 0.94 EFU, digestible protein in 1 EFU – 92.2 g (see Table 1).

The experimental cows were kept in the same technological conditions in individual stalls using a tied- free-range method. Milking was carried out 2 times a day in the milk pipe with milking machines DUOVAC TU 200 (DeLaval, Sweden).

Experimental premixes were made from the following components:

– bentonite clay from the "10th Khutor" deposit (OOO "Bentonite of Khakassia", Russia);

– expanded vermiculite (OOO "Siver", Russia);

– coniferous meal, produced in the Department of Animal Husbandry of the Krasnoyarsk Research Institute of Agriculture using a ham-

[5]*Karmatskikh Yu.A.* Dairy productivity and milk quality when cows are fed bentonite clay // Feeding of Agricultural Animals and Feed Production, 2013, N 11, pp. 16–25.

[6]*Zholobova I.S., Borisenko V.V.* Bentonites in veterinary medicine: a brief review of the current state and prospects of development // Young Scientist, 2016, N 13 (117), pp. 929–935.

[7]*Zhukova I.N., Solovieva E.V., Kononenko S.I.* Application of bentonite in the production of premixes // News of universities. Food Technology, 2003, N 5-6, pp. 60–61.

[8]*Gamidov M.G., Bystrova E.G.* Prospects for the use of local mineral resources in animal husbandry in the Far East (review) // Achievements in the Life Sciences, 2009, N 1, pp. 153–161.

mer crusher "MOLOT-200" (Infel, Russia) from pre-extracted hot water at a temperature of 100 ° C for 20 min and dried needles of common pine (*Pinus sylvestris*);

– pine nut shells (*Pinus sibirica*) crushed on a hammer crusher;

– arabinogalactan of Dahurian larch (*Larix dahurica*) (AO "Ametis", Russia));

– vitamin and mineral complex (content in 1 kg of vitamin A – 600 000 IU, D3 – 100 000, E – 500 IU, manganese – 1.0 g, iodine – 0.2, zinc – 2.0, copper – 0.5, cobalt – 0.1, selenium – 0.02 g).

All premix components were weighed according to the dosage on electronic laboratory scales VK-300 "Massa-K" (Russia), mixed and fed to cows in individual portions during morning feeding in dry form mixed with concentrated feeds.

Milk productivity of cows was determined monthly by control milkings, taking individual average milk samples from each cow. Mass fractions of fat and protein in milk were determined on the milk analyzer "Expert Super Plem" (Combo) (OOO R&D company "Laboratorika", Russia) in the laboratory of the Department of Animal Husbandry of the Krasnoyarsk Research Institute of Agriculture.

Organoleptic evaluation of milk was carried out according to the method of VIZh[9]. Milk quality indicators were determined in accordance with GOST 282883-2015[10] and GOST R 52054-2003[11]. The experiment was set up and conducted according to the method of A.I. Ovsyannikov (1976).

Biometric processing of the experimental digital data was carried out according to the method of N.A. Plokhinsky in the computer program "Biometric analysis of quantitative traits in zootechnics" (FRC KRC SB RAS, Russia). Reliability of the difference between the groups of animals was established using the Student's *t*-criterion. The difference between the groups was considered statistically significant at $p \leq 0.05$.

Табл. 1. Показатели питательности основного рациона коров

Table 1. Nutritional indicators of the basic diet of cows

Indicator	Value
EFU per 1 kg of dry matter	0,94
Digestible protein in 1 EFU, g	92,2
Crude fiber in dry matter, %	19,17
Crude fat in dry matter, %	3,59
Sugar in dry matter, %	7,40
Metabolizable energy concentration (MEC) in dry matter, MJ	9,53
Ca : P	2,1 : 1
Sugar: protein	0,86 : 1
Starch: sugar	1,83 : 1

RESULTS AND DISCUSSION

The highest milk productivity during the experiment period was established in the cows of the 2nd experimental group, which exceeded the cows of the control and 1st experimental groups in milk yield by 7.60 ($p \leq 0.05$) and 3.25%, milk fat mass fraction by 0.23 ($p \leq 0.05$) and 0.14 p. p., respectively (see Table 2). Also, a slight tendency of increase in the mass fraction of protein in milk (by 0.06-0.09 p. p.) was observed in the experimental groups compared to the control.

The quantitative content of fat and protein in milk of the experimental cows is presented in Fig. 1.

The amount of milk fat increased significantly by 14.02% ($p \leq 0.01$) and milk protein by 9.65% ($p \leq 0.05$) in the milk of the 2nd experimental group compared to the control. No significant differences with the control were found in the milk of the cows of the 1st experimental

[9]*Fomichev Yu.P., Khripyakova E.N., Gudenko N.D.* Methodical workshop on quality control of milk and dairy products: textbook. Dubrovitsy: VIZh of Rosselkhozakademy, 2013, 236 p.

[10]GOST 28283–2015. Cow's milk. Method for organoleptic evaluation of taste and odor (amended). Intro. 2016-07-01. Moscow: JSC "Codex", 2019, 17 p.

[11]GOST R 52054–2003. Cow's milk – raw material. Technical conditions (with amendments No. 1, 2). Introduced on 2004-01-01. Moscow: JSC "Codex", 2017, 16 p.

group according to these indicators, but there was a tendency to increase the content of fat and protein by 6.82 and 7.0%, respectively.

The amount of milk of basic fat content (3.4%) during the experimental period was the highest in cows of the 2nd experimental group (1569.32 kg), which by this indicator exceeded the control counterparts by 14.02% ($p \leq 0.01$) and the cows of the 1st experimental group by 6.75% (see Fig. 2).

Organoleptic parameters of milk can change as a result of animals eating feed with sharp taste or odor, which can negatively affect its consumer qualities. In this regard, organoleptic examination of milk is a prerequisite when introducing new feed additives into the diet.

As a result of organoleptic evaluation of milk of experimental cows, it was found that in all groups it met the requirements of the highest grade according to GOST R 52054- 2003 (see Table 3).

There were no differences in the studied parameters (consistency, color, taste and odor) between the groups. At the same time, milk had no extraneous taste and odor, there was no sediment and flakes in it, which allowed concluding that eating of the premixes under study by cows does not worsen organoleptic parameters of milk.

Табл. 2. Молочная продуктивность коров за 60 дней лактации ($M \pm m$, $n = 10$)
Table 2. Milk productivity of cows for 60 days of lactation ($M \pm m$, $n = 10$)

Indicator	Group		
	control	experimental	
		1st	2nd
Milk yield, kg	1203,60 ± 33,33	1254,30 ± 78,90	1295,10 ± 22,83*
Average daily milk yield, kg	20,06 ± 0,56	20,91 ± 1,32	21,59 ± 0,38*
Mass fraction, %:			
Fat	3,89 ± 0,06	3,98 ± 0,09	4,12 ± 0,04*
protein	3,08 ± 0,04	3,17 ± 0,04	3,14 ± 0,03
Fat to protein ratio	1,26 : 1	1,26 : 1	1,31 : 1

Here and in fig. 1, 2:
*$p \leq 0,05$.
**$p \leq 0,01$.

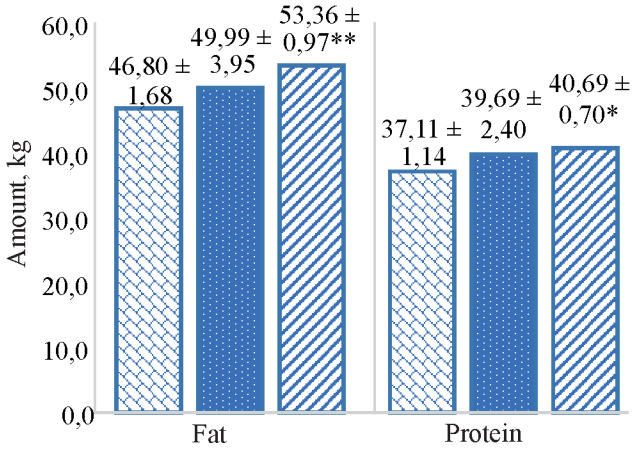

Рис. 1. Количество молочного жира и белка в молоке коров за период опыта ($M \pm m$, $n = 10$), кг

Fig. 1. Amount of milk fat and protein in cow's milk during the experimental period ($M \pm m$, $n = 10$), kg

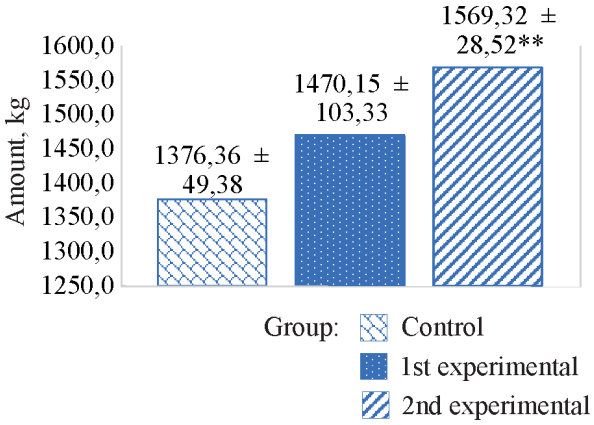

Рис. 2. Количество молока базисной жирности (в пересчете на 3,4%) за период опыта ($M \pm m$, $n = 10$), кг

Fig. 2. Quantity of milk of basic fat content (in terms of 3.4%) during the experiment period ($M \pm m$, $n = 10$), kg

Табл. 3. Результаты органолептической оценки молока коров ($M \pm m$, $n = 5$)
Table 3. Results of organoleptic evaluation of cow's milk ($M \pm m$, $n = 5$)

Group	Consistency	Color	Taste and smell	Tasting evaluation of taste and smell, score
Control	Homogeneous non-friable liquid without sediment flakes	White with yellowish tinge, uniform	Specific, clean, pleasant, slightly sweet, without extraneous odors and flavors not typical of fresh natural milk	5,00 ± 0,27
Experimental: 1st				5,00 ± 0,22
2nd				5,00 ± 0,00

CONCLUSIONS

1. Feeding cows premixes based on forest resources and natural minerals had a positive effect on milk productivity.

2. The best results were established when cows were fed premix consisting of expanded vermiculite, pine coniferous flour, pine nut shell, vitamin-mineral complex and arabinogalactan. The milk yield increased by 7.60%, the mass fraction of fat in milk increased by 0.23 p. p., the amount of milk fat increased by 14.02%, milk protein increased by 9.65, and milk of basic fat content increased by 14.02%.

3. Organoleptic parameters of milk of cows under the influence of the studied premixes corresponded to the requirements of milk of the highest grade, which indicates that the studied premixes did not have a negative effect on the taste, smell, color and consistency of milk.

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Особенности кислород-независимого метаболизма нейтрофилов у животных, сенсибилизированных неагглютиногенным штаммом бруцелл

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Представлены результаты оценки особенностей функционирования неферментных систем нейтрофилов периферической крови морских свинок до иммунизации и на 7, 14, 21, 28, 42, 55, 69, 125-е сутки после иммунизации *R*-штаммом бруцелл. Для исследования сформированы две группы морских свинок линии агути: контрольную и опытную. Опытные животные иммунизированы суспензией из штамма *Brucella abortus* 16/4 в дозе 1 млрд КОЕ/мл подкожно, контрольные свинки были интактны к бруцеллезу. Активность антимикробных систем оценивали путем определения показателей катионных белков фотометрическим способом в спонтанном и индуцированном вариантах. В качестве специфических индукторов при постановке реакции использовали экспериментальные образцы бруцеллезных антигенов. Установлено, что применение в тесте с катионными белками в качестве индукторов дезинтегратов бруцелл в концентрации 50 мкг/мл и корпускулярных антигенов в концентрации 100 мкг/мл по белку оказывает стимулирующий эффект на интенсивность выработки катионных белков в клеточной взвеси лейкоцитов. Во все сроки наблюдения произведен подсчет индексов стимуляции как отношение показателя стимулированной пробы к показателю пробы без антигенной нагрузки. В ходе исследования отмечено два пика стимулирующей активности катионных белков: максимальный подъем индексов стимуляции наблюдали на 14-е сутки после иммунизации и менее выраженный подъем – на 28-е сутки. Пик выработки агглютинирующих антител пришелся на 21-е сутки после иммунизации, комплементсвязывающих антител – на 21–28-е сутки, менее интенсивный подъем титров агглютинирующих и комплементсвязывающих антител отмечен на 69-е сутки. В эти сроки выявлено снижение стимулированной активности катионных белков нейтрофилов. Установлено, что пик активности неферментных катионных белков нейтрофилов опережает пик гуморального иммунного ответа.

Ключевые слова: антигены, катионные белки, нейтрофилы, иммунизация, *Brucella abortus*

Features of oxygen-independent metabolism of neutrophils in the animals sensitized with non-agglutinogenic Brucella strain

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The results of evaluation of the peculiarities of functioning of non-enzymatic systems of neutrophils of peripheral blood of guinea pigs before immunization and on the 7th, 14th, 21st, 28th, 42nd, 55th, 69th, 125th days after immunization with Brucella *R*-strain are presented. Two groups of agouti guinea pigs were formed for the study: control and experimental. The experimental animals were immunized with a suspension of *Brucella abortus* strain 16/4 at a dose of 1 billion CFU/ml subcutaneously; the control pigs were intact to brucellosis. The activity of antimicrobial systems was evaluated by determining the indices of cationic proteins by photometric method in spontaneous and induced variants. Experimental samples of brucellosis antigens were used as specific inducers in the reaction procedure. It was found that the use of Brucella disintegrans at a concentration of 50 μg/ml and corpuscular antigens at a concentration of 100 μg/ml by protein in the test with cationic proteins as inducers of disintegrants has a stimulating effect on the intensity of cationic protein production in the cell suspension of leukocytes. Stimulation indices were calculated at all observation periods as the ratio of the index of the stimulated sample to the index of the sample without antigen load. Two peaks

of stimulating activity of cationic proteins were observed in the course of the study: the maximum rise of stimulation indices was observed on the 14th day after immunization and a less pronounced rise on the 28th day. The peak of agglutinating antibody production was on the 21st day after immunization, complement-binding antibodies – on the 21st-28th day, less intensive rise in titers of agglutinating and complement-binding antibodies was noted on the 69th day. In these terms, a decrease in the stimulated activity of neutrophil cationic proteins was observed. The peak activity of non-enzymatic cationic proteins of neutrophils was found to be ahead of the peak of humoral immune response.

Keywords*:* antigens, cationic proteins, neutrophils, immunization, *Brucella abortus*

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The authors declare no conflict of interest.

INTRODUCTION

Brucellosis, caused by microorganisms of the genus *Brucella*, is a widespread disease affecting many species of domestic and wild animals, as well as humans. Brucellosis in cattle is caused mainly by *Brucella abortus* [1-3]. This zoonotic infection causes significant economic losses due to infertility and abortion of animals, as well as restrictions on dairy marketing and livestock trade [4-6].

Currently, vaccines, primarily live vaccines, are used for specific prophylaxis of brucellosis in animals as the most effective. The most immunogenic are agglutinogenic vaccines from brucella strains in *S*-form, less immunogenic - weakly agglutinogenic and non-agglutinogenic - from brucella strains in *SR*- and *R*-forms, respectively [3, 7].

It should be noted that non-agglutinogenic vaccines from *R*- strains of brucellae with minimal immunogenicity provide the possibility of testing blood sera of animals for brucellosis with *S*-diagnostics at any time after immunization, which does not create any problems with the detection of brucellosis carriers provoked by the vaccine [8]. This fact gives grounds to continue the search for rational schemes of immunization of animals with this type of vaccines.

As in other bacterial chronic infections, resistance to pathogens of the *Brucella* genus depends on the completeness of cell-mediated immunity, including activation of bactericidal mechanisms of phagocytes. Despite the repeatedly proven role of polymorphonuclear neutrophils in the fight against many bacterial pathogens, the function of these immunocompetent cells in brucellosis remained unstudied for a long time. On the one hand, researchers have focused on uncovering the intracellular life cycle of *Brucella* organisms in macrophages, dendritic and epithelial cells, and on the other hand, on cells of the acquired immune system rather than neutrophils involved in early proinflammatory reactions [9-13]. However, in recent years there has been a renewed interest in studying the role of these cells in the mechanism of antibrucellosis immunity.

It is known that the main ways to realize the bactericidal function of neutrophils are oxygen-dependent metabolism, in the process of which reactive oxygen species (hydrogen peroxide, superoxidanion, etc.) are formed, as well as oxygen-independent metabolism, carried out with the participation of lysozyme, cationic proteins, and hydrolytic enzymes. While the study of oxygen-dependent defense mechanisms in brucellosis infection has been addressed by some researchers, the role of the anaerobic antimicrobial system has been covered in a fragmentary manner [14–16].

In connection with the above, the problem of cell-mediated anti-brucellosis immunity in ani-

mals immunized with non-agglutinogenic vaccines is of special scientific interest.

The purpose of the study was to investigate the activity of non-enzymatic cationic proteins at different times after immunization of guinea pigs with a non-agglutinogenic strain of *B. abortus*.

MATERIAL AND METHODS

The work was carried out in the Department of Veterinary Science of the Omsk Agrarian Scientific Center. Two groups of agouti guinea pigs (males aged 4–5 months and weighing 400 –450 g) were formed for the study: control and experimental, 5 animals in each group. Experimental animals were immunized with a suspension of *B. abortus* strain 16/4 at a dose of 1 billion CFU/ml subcutaneously; control pigs were intact to brucellosis.

Blood samples for determination of the amount of cationic proteins and serological reactions were taken in accordance with the plan of the experiment: before immunization and on the 7th, 14th, 21st, 28th, 42nd, 55th, 69th, 125th day after administration of the immunobiological preparation.

The amount of non-enzyme cationic proteins in peripheral blood neutrophils of experimental and control guinea pigs was determined by spectrophotometric method without antigen treatment (spontaneous variant) and with antigen treatment (stimulated variant) (Khaitov R. M., 1995). The results were recorded on a multichannel immunoassay analyzer "Fluorofot STD-Less-486-M" (manufactured in Russia) at a wavelength of 492 nm. The results were recorded in conditional optical density units (c.op. d. u.).

Stimulation indexes (SI) were calculated during all periods of observation as the ratio of the index of the stimulated sample to the index of the sample without antigenic load. Disintegrants (D_R and D_S) and corpuscular antigens (C_R and C_S) made from brucellae, typical (*S*) and modified (*R*) forms were used as inducing load for the reaction. The concentration of antigens was standardized by the protein content in the final product on a semi-automatic biochemical analyzer EMP- 168 Vet (manufacturer Emperor, China) using the reagent kit for protein determination "HOSPITEX DIAGNOSTICS".

Blood serum of guinea pigs in all periods of observation was investigated according to GOST 34105-2023 "Animals. Laboratory diagnostics of brucellosis. Serologic methods" in agglutination reaction (AR) and complement binding reaction (CBR) with standard diagnostics and experimental samples of *R*-brucellosis antigens.

To characterize the immune response, the geometric mean of antibody titers ($\log^2 M$), expressed in negative logarithm at base 2, was used, which was determined by the formula

$$\log^2 M = \frac{\Sigma \log_2 a_i n_i}{N},$$

where $\log_2 a_i$ – negative logarithm of each of the titrations of the series; n_i – number of sera of a given titer; N – total number of observations.

Digital material was processed using methods of variation statistics, including calculation of arithmetic mean (M) and arithmetic mean error (m). The statistical significance of differences in the mean was evaluated by the Student's t-criterion.

RESULTS AND DISCUSSION

At the initial stage of research, we evaluated the effect of antigenic load on the content of cationic proteins (CPs) in neutrophils.

For this purpose, peripheral blood was collected from guinea pigs before and after immunization to determine the content of cationic antimicrobial proteins of neutrophils after their treatment with different specific inducers. As specific inducers disintegrants (D_S, D_R) and corpuscular antigens (C_S, C_R) produced by us from *B. abortus* strains (located in the bioresource collection of the organization) in typical *S*- and modified R-forms in concentrations of 25, 50, 100 and 200 μg/ml were used.

According to the results of the conducted experiment, different specific activity of brucellosis antigens at stimulation of cell suspension of leukocytes was established, which was characterized by a pronounced increase in the concentration of cationic proteins at introduction as

an inducer of disintegrants at a concentration of 50 μg/ml. At the same time, when corpuscular antigens were used, a higher concentration of 100 μg/mL was required to obtain an identical effect.

In a similar study conducted in a control group of guinea pigs, cationic protein values were independent of the concentration of the administered activators.

In order to detect changes in the neutrophil CP content, studies were carried out before inoculation and on the 7th, 14th, 21st, 28th, 42nd, 55th, 69th and 125th day after inoculation of guinea pigs with *B. abortus* 16/4. The activity of antimicrobial peptides was evaluated both with the use of specific inducers at optimal concentrations and without antigenic load. The results are summarized in the Table.

Cytophotometric parameters of CP content in guinea pigs before immunization were characterized by the following values: 1.39 ± 0.05 c. op. d. u. when the reaction was performed with inactivated neutrophils, 2.22 ± 0.31 and 1.14 ± 0.06 c. op. d. u. when they were stimulated with D_R and D_S disintegrants, respectively, and 1.87 ± 0.05 and 1.68 ± 0.06 c. op. d. u. when treated with corpuscular antigens C_R and C_S (see the Table).

On the 7th day after inoculation, the studied indices did not differ significantly from the values of CP, established by us at the beginning of the experiment, except for the C_R antigen, which significantly suppressed the production of this bactericidal component of neutrophils.

Later (from the 14th to the 28th day), a significant decrease in the concentration of CP in the reaction without antigenic stimulation of phagocytes was observed, with the average group values during this period ranging from 0.61 ± 0.06 to 0.85 ± 0.10 c. op. d. u. Incorporation of D_R disintegrate into the neutrophil suspension contributed to the suppression of antimicrobial peptide production, especially on the 21st day after vaccine administration, when the most significant decrease in neutrophil CP concentration was observed, to 0.70 ± 0.04 c. op. d. u. vs. 2.22 ± 0.31 c. op. d. u. before the immunization. When D_S disintegrate was used as a stimulant, on the contrary, some tendency to increase the level of CP in neutrophils was observed. In contrast to disintegrates when treating the cell suspension with C_R antigen, the functional activity of neutrophils was depressed by 2.2 and 1.6 times ($p < 0.001$) on the 21st and 28th days, respectively, and by C_S antigen by 1.36 ($p < 0.05$) and 2.1 times ($p < 0.001$) on the 14th and 21st days.

Содержание неферментных катионных белков у морских свинок в разные сроки после иммунизации *B. abortus* 16/4, у. е. оп. пл.
The content of non-enzymatic cationic proteins in guinea pigs at different times after immunization of *B. abortus* 16/4, c.u. op. pl.

Study period, days	Vaccination option				
	without antigenic load	stimulated			
		disintegrate		corpuscular antigen	
		D_R	D_S	C_R	C_S
Before immunization	1,39 ± 0,05	2,22 ± 0,31	1,14 ± 0,06	1,87 ± 0,05	1,68 ± 0,06
7th	1,43 ± 0,02	2,07 ± 0,20	1,27 ± 0,11	1,04 ± 0,08***	2,17 ± 0,16
14th	0,61 ± 0,06***	1,67 ± 0,26	1,69 ± 0,30	1,99 ± 0,29	1,23 ± 0,16*
21st	0,83 ± 0,06***	0,70 ± 0,04[2]	1,08 ± 0,04	0,85 ± 0,02***	0,81 ± 0,05***
28th	0,85 ± 0,10***	1,56 ± 0,20	1,25 ± 0,24	1,16 ± 0,11***	1,65 ± 0,22
42nd	1,34 ± 0,19	0,95 ± 0,08*	1,09 ± 0,07	2,18 ± 0,30	1,92 ± 0,30
55th	1,31 ± 0,04	0,83 ± 0,19*	1,06 ± 0,10	1,26 ± 0,03***	0,74 ± 0,10***
69th	2,55 ± 0,12***	1,48 ± 0,16	2,36 ± 0,22**	1,37 ± 0,13*	1,90 ± 0,04*
125th	2,05 ± 0,12**	1,51 ± 0,04	1,37 ± 0,33	1,09 ± 0,18**	1,10 ± 0,15*

* $p < 0,05$.
** $p < 0,01$.
*** $p < 0,001$.

On the 42nd and 55th days the spontaneous activity of CP production was restored to the level registered before immunization, starting from the 69th day it increased with a high degree of reliability.

A decrease in neutrophil CP content was observed during stimulation with *R*-antigens, especially on the 42nd and 55th days after immunization when interacting with disintegrate and on the 55th, 69th and 125th days with corpuscular antigen. The concentration of antimicrobial peptides decreased 1.36–2.8 times ($p < 0.05$). When D_S and C_S antigens were used as an inducer, the characteristic feature was an increase in the number of neutrophil CPs on the 69th day after immunization by 2.1 ($p < 0.01$) and 1.13 times ($p < 0.05$), respectively, relative to the values we recorded at the beginning of the experiment.

In all the observed periods, stimulation indices were also calculated as the ratio of the stimulated sample to the sample without antigenic exposure. The average group values of these indices are presented in Fig. 1.

When *Brucella* disintegrates and corpuscular antigens were used as inducers, two peaks of stimulating activity of CP were observed. The maximal rise of the stimulation indexes (SI) was observed already on the 14th day after immunization and less intensive on the 28th day. It should be noted that when neutrophils interacted with C_R antigen, a repeated surge of activity was detected on the 42nd day after the immunization.

In the control group of guinea pigs, the group average level of cationic proteins did not change significantly throughout the study period. The spontaneous production of cationic proteins ranged from 1.31 ± 0.08 to 1.39 ± 0.04 c. op. d. u. When the samples were stimulated with D_R disintegrate, the cationic proteins ranged from 1.25 ± 0.10 to 1.27 ± 0.12 c. op. d. u., D_S disintegrate from 1.18 ± 0.08 to 1.21 ± 0.03 c. op. d. u., C_R antigen from 1.26 ± 0.18 to 1.34 ± 0.03 c. op. d. u., C_S antigen from 1.23 ± 0.13 to 1.30 ± 0.11 c. op. d. u.

Subsequently, the data obtained were compared with the results of the serologic studies (see Fig. 2).

It was found that the geometric mean antibody titers in the study of the blood serum in the AR reached maximum values on the 21st day after immunization, whereas in the CBR on the 21st–28th day. Subsequently, on the 69th day another less intensive rise in the antibody titers was noted. It should be noted that on the 21st and 69th days the level of stimulated activity of neutrophils, on the contrary, decreased.

No agglutinating and complement-binding antibodies were observed in the control group of animals during all periods of the study.

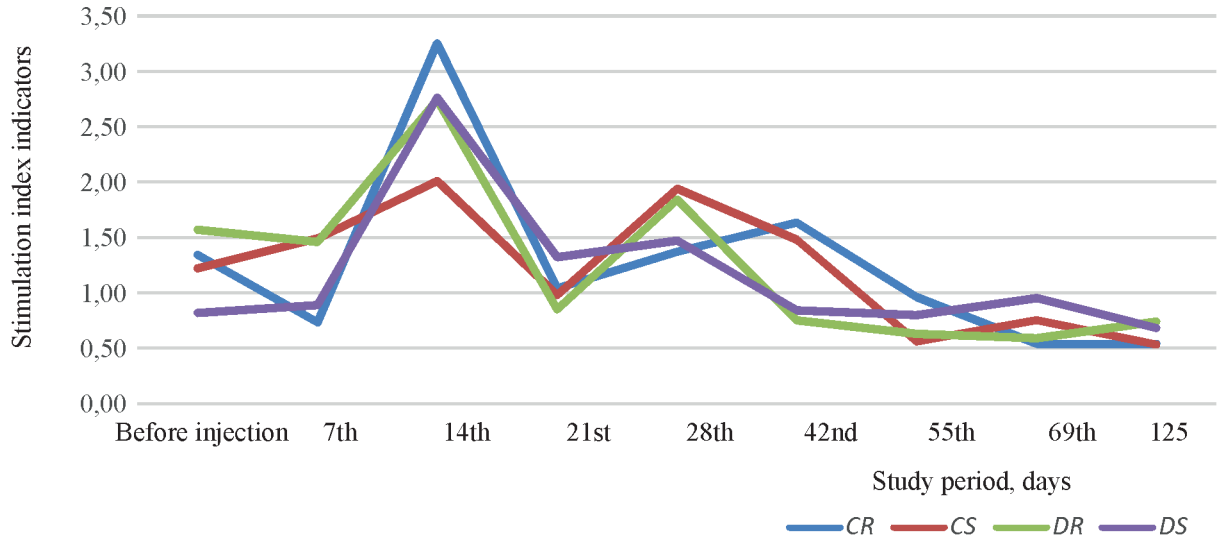

Рис. 1. Динамика изменений индекса стимуляции КБ у морских свинок, иммунизированных *B. abortus* 16/4
Fig. 1. Dynamics of changes in the CP stimulation index in guinea pigs immunized with *B. abortus* 16/4

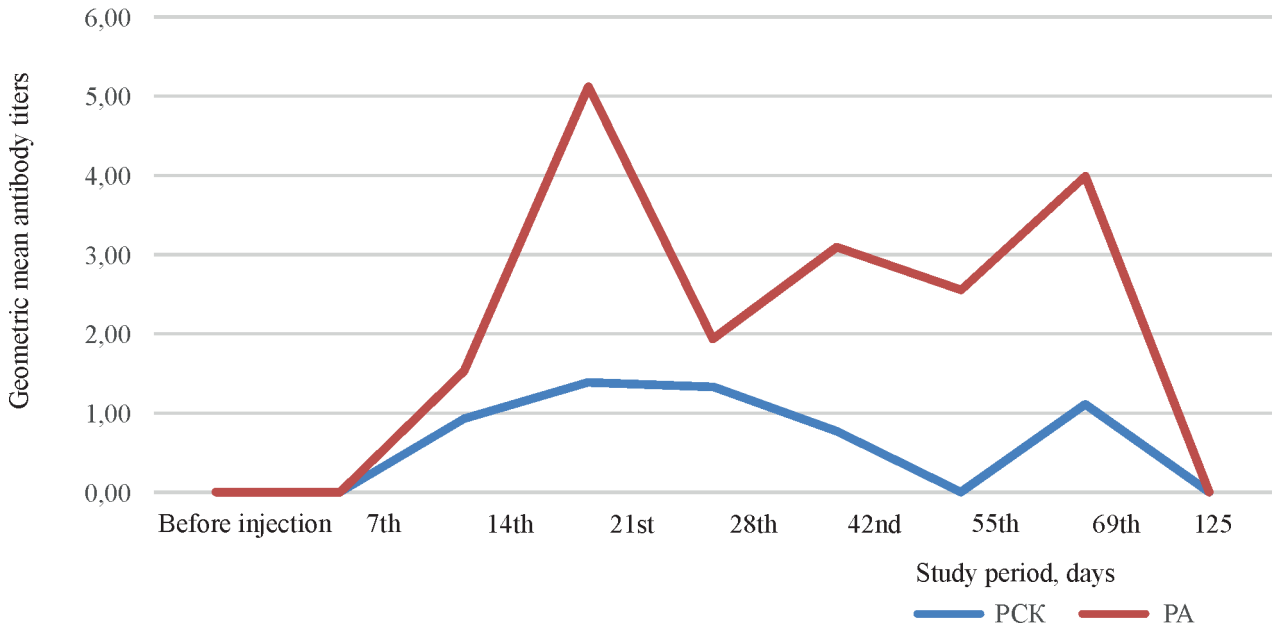

Рис. 2. Динамика изменения средних геометрических титров антител у морских свинок, иммунизированных *B. abortus* 16/4

Fig. 2. Dynamics of changes in the mean geometric titers of antibodies in guinea pigs immunized with *B. abortus* 16/4

CONCLUSION

Based on these studies, it can be concluded that the use of brucellosis antigens designed by us as inducers in the test with cationic proteins has a stimulating effect on the cell suspension of leukocytes isolated from guinea pigs immunized with brucellae of the non-agglutinogenic strain *B. abortus* 16/4. The maximum specific activity was detected using *Brucella* disintegrates at a concentration of 50 μg/mL, corpuscular antigens of 100 μg/mL. Non-enzymatic cationic proteins of neutrophils showed the most pronounced activity on the 14th day after administration of the immunobiologic preparation, ahead of the peak of humoral immune response on 7 days.

For a more detailed understanding of the mechanisms of cell-mediated immunity in *Brucella* sensitization, an in-depth study of the functional state of neutrophils is necessary.

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Эффективность использования покрытия кормового стола «Луг Здоровья»

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В статье представлены результаты оценки использования полимерного покрытия кормового стола «Луг Здоровья» в сравнении с бетонным кормовым столом. Исследование проведено в условиях молочного животноводческого комплекса Кировской области на дойных коровах черно-пестрой голштинизированной породы в лактационный период. Бетонные кормовые столы, применяемые для коров в период стабилизации лактации, на момент проведения эксперимента имели средний износ, тогда как покрытие кормового стола «Луг Здоровья» оставалось гладким и ровным на протяжении 6 мес. Исследование микробной обсемененности покрытий кормовых столов показало, что уже через месяц после начала эксперимента в 1-й опытной группе, где использовали покрытие «Луг Здоровья», число микробных клеток было ниже на 54,7% ($p < 0,05$) по сравнению с бетонным столом. Количество несъеденных остатков корма на кормовых столах с покрытием «Луг Здоровья» было меньше по сравнению с бетонным кормовым столом ($p < 0,05$), что свидетельствует о лучшей поедаемости кормосмеси с данного покрытия. При переводе коров с полимерного покрытия на бетонное уже со второго месяца лактации наблюдали снижение среднесуточных удоев на 0,9 кг. К четвертому месяцу лактации снижение удоя составляло 4,8 кг молока на 1 гол. в сутки. При переводе коров с бетонного кормового стола на имеющий полимерное покрытие отмечено увеличение молочной продуктивности на 0,4–1,3 кг на 1 гол. в сутки. В первые три месяца потребление корма со стола с полимерным покрытием выросло на 2,3–5,6% в сравнении с бетонным. За 5 мес лактации коровы с покрытия кормового стола «Луг Здоровья» съели корма на 6,8–8,6% больше, чем с бетонного, что и обусловило бóльшую продуктивность животных за анализируемый период. Использование полимерного покрытия кормового стола «Луг Здоровья» позволило получить дополнительную прибыль в размере 20 460 р. и окупить затраты на его установку уже на 39-й день.

Ключевые слова: кормление, лактирующие коровы, поедаемость кормосмеси, кормовой стол, продуктивность

Efficiency of using the "Meadow of Health" feed table cover

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The results of using the polymer cover of the feed table "Meadow of Health" in comparison with the concrete feed table are presented. The research was carried out in the conditions of the dairy livestock complex of the Kirov region on milk cows of the Black-and-White Holstein breed during the lactation period. Concrete feed tables for cows during the lactation stabilization period at the time of carrying out had average wear, while the cover of the feed table "Meadow of Health" remained smooth and even for 6 months. The study of microbial contamination of feed table covers showed, that already one month after the beginning of the experiment, the number of microbial cells was 54.7% lower ($p < 0.05$) in the 1st experimental group, where the "Meadow of Health" cover was used, compared to the concrete table. The amount of uneaten feed residues on the feed tables with the "Meadow of Health" cover was less in comparison with the concrete feed table ($p < 0.05$), which indicates better palatability of forage mixture from this cover. When transferring cows from polymer cover to concrete from the 2nd month of lactation, a decrease in average daily milk yields by 0.9 kg was observed. By the 4th month of lactation, the reduction in milk yield was 4.8 kg of milk per head per day. When transferring cows from a concrete feed table to a polymer one, there was an increase in milk productivity by

0.4–1.3 kg per head/day. In the first 3 months, the consumption of feed from a polymer-coated table increased by 2.3–5.6% compared to the concrete one. During 5 months of lactation, cows from the cover of the feed table "Meadow of Health" ate feed by 6.8–8.6% more than from concrete, which led to greater productivity of the animals during the analyzed period. The use of the polymer cover of the feed table "Meadow of Health" allowed to get additional profit in the amount of 20,460 rubles and recoup the costs of its installation already on the 39th day of use.

Keywords: feeding, lactating cows, feed mixture palatability, feed table, productivity

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INTRODUCTION

Feeding of lactating cows on modern dairy complexes in most cases is organized from the so-called feed table. The surface of the feed table in the process of use ceases to be smooth, gradually potholes, cracks and other irregularities are formed on it, in which the residues of feed mixture accumulate, which makes it difficult to clean the feed table and can lead to the development of undesirable microflora [1–5].

This problem can be solved by using different kinds of feed table coatings, which eliminate irregularities, prevent moisture and useful substances from the feed mixture from being drawn out into the concrete base, as well as particles of the feed table base – gravel, sand, cement – from getting into the animal's food pathway [6–11].

The objectives of the study were to investigate the surface condition and microbial contamination of the feed table with and without the "Meadow of Health" coating, to evaluate the feed mixture digestibility and productivity of lactating cows when using the coating and without it.

MATERIAL AND METHODS

The study was conducted at the dairy livestock complex of the agricultural production cooperative "Konyp" of the Kirovo-Chepetsk district of the Kirov region on dairy cows of the Black-and-White Holstein breed during the lactation period. Four groups of animals (18 animals each), each of which corresponded to a certain section (technological group), were formed for the experiment by the analogy method. The experiment lasted from November 2021 to March 2022. Feeding of cows of the 12th and 13th technological groups was organized from the polymer feed table "Meadow of Health", cows of the 11th and 14th technological groups ate feed from the concrete feed table (see Table 1). The usual on-farm diet in the form of a feed mixture distributed by a mobile feeder twice a day was used to feed the animals.

The condition of the feed table surface was evaluated on a 5-point scale, where:

5 points – the surface is visually smooth and even, without hollows, chips and cracks;

4 points – there are minor chips and hollows up to 10 mm deep;

Табл. 1. Схема эксперимента
Table 1. Experiment scheme

Group	Number of heads	Feed table cover	Section (technology group)
1st (experimental)	18	“Meadow of Health”	12th
2nd (experimental)	18	»	13th
3rd (control)	18	Concrete	11th
4th (control)	18	»	14th

3 points – there are chips and hollows up to 30 mm deep;

2 points – there are chips and hollows up to 50 mm deep;

1 point – there are chips and hollows up to 100 mm deep;

0 points – there are chips and hollows more than 100 mm deep, there may be cracks [12, 13].

Studies on microbial contamination of the surface of feed tables were conducted in the Kirov regional veterinary laboratory three times: 1, 2 and 5 months after the beginning of the experiment and installation of the feed table "Meadow of Health". For this purpose, lavage materials were taken from each feed table using a sterile cotton swab moistened with sterile isotonic sodium chloride solution.

The amount of uneaten feed residue was assessed before the morning feeding on a 5-point scale during 4 months:

0 points – there's no feed left at all;

1 point – some feed is scattered, residues are less than 5%, indicating the need to increase the amount of feed;

2 points – a thin layer of feed, 5–7% residue. This is a desirable result, something to strive for, provided the animals are fed in the next hour;

3 points – feed layer 5.1–7.6 cm, residues 25–50%, indicating overfeeding or poor digestibility;

4 points – feed layer more than 7.6 cm, residues more than 50%;

5 points – the feed is untouched [14, 15].

Milk productivity of cows during 4 months of lactation was studied on the basis of control milking data.

Economic indicators of the use of polymer coating of the feed table "Meadow of Health" in comparison with concrete feed table were calculated on the basis of the selling price of 1 kg of milk in 31 rubles and the cost of polymer coating width of 0.75 m with installation in 1950 rubles for 1 linear metre.

RESULTS AND DISCUSSION

Concrete feed tables used for cows in the period of lactation stabilization had average depreciation at the time of the study. The results of surface evaluation of the concrete feed table, as well as the table with the "Meadow of Health" coating are presented in Table 2.

Table 2 shows that for 6 months of use the surface of the feed table with "Meadow of Health" coating remained visually smooth and even, without hollows, chips and cracks, its condition was rated 5 points. The concrete feed table was moderately deteriorated, with chipping and hollows. The use of concrete feed table in such condition leads to more moisture accumulation in the existing "potholes", development of bacteria in them, formation of unpleasant odor and further destruction of the concrete.

To assess the microbial contamination of coated and uncoated feed tables, lavage materials were taken from its surface from three locations. Pathogenic and opportunistic forms of microorganisms in the lavage materials from feed tables were not detected. The results of the studies are presented in Table 3.

In general, a tendency to decrease microbial contamination of the feed table with the "Mead-

Табл. 2. Оценка состояния поверхности кормового стола, балл
Table 2. Feed table surface condition assessment, points

Period	Feed table cover	
	“Meadow of Health”	Concrete
Before the start of the study	5	3
After the study began:		
in 30 days	5	3
in 60 days	5	3
in 90 days	5	3
in 6 months	5	3

ow of Health" coating in comparison with the concrete feed table was noted. Thus, already a month after the beginning of the study in the 1st experimental group the number of microbial cells was lower by 54.7% ($p < 0.05$) compared to the 3rd group, where the concrete feed table was used. The indicators of the 2nd and 3rd groups differ by 3.7 times, the differences are reliable ($p < 0.05$). The decrease in microbial contamination in groups 1–3 in the samples taken 5 months after the beginning of the experiment, compared to the previous results, is probably due to deeper cleaning of feed tables before taking lavage materials. Excess of the indicators in tens of times in the lavage materials from the feed table of group 4 in the last study is probably due to some unaccounted factor during sampling or during the analysis.

Uneaten feed residues on feed tables were also monitored during the experiment (see Table 4).

The amount of uneaten feed residues on feed tables with "Meadow of Health" covering was less in comparison with concrete feed table both in each of the months of the study and in general for the whole period. Significant differences in November were observed between the 1st and 4th experimental groups ($p < 0.05$), and between the 2nd and 3rd, 2nd and 4th groups ($p < 0.05$). In January, reliable differences in uneaten residues were found between the 1st and 3rd, as well as between the 1st and 4th groups ($p < 0.05$).

Consequently, cows were significantly better at eating feed from the "Meadow of Health" cover than from the concrete feed table.

The analysis of feeding rations for lactating cows has shown that the applied diets fully cover the need of the animals in nutrients and correspond to their productivity level.

Табл. 3. Результаты оценки микробной обсемененности кормовых столов
Table 3. Results of microbial contamination assessment of feed tables

Group (section)	Microbial infestation, thousand m.s.c.		
	in 1 month	in 2 months	in 5 months
1th (12th)	20,50 ± 7,19*	27,25 ± 0,35	3,05 ± 1,65
2nd (13th)	–	25,80 ± 1,20	2,05 ± 1,36*
3rd (11th)	37,50 ± 3,75	25,65 ± 2,45	7,60 ± 1,80
4th (14th)	13,85 ± 2,05	21,15 ± 5,85	310,00 ± 160,00
On average:			
"Meadow of Health"	20,50 ± 4,60	26,53 ± 0,66	2,55 ± 0,92
concrete table	21,73 ± 6,87	23,40 ± 2,90	158,80 ± 109,04

Note. *$p < 0,05$, **$p < 0,01$, ***$p < 0,001$.

Табл. 4. Результаты оценки кормовых столов по количеству несъеденных остатков корма, балл
Table 4. Results of feed tables assessment by the amount of uneaten feed residues, points

Group (section)	November	December	January	February	On average for the whole period
1st (12th)	1,86 ± 0,08^{x}	1,97 ± 0,05	2,00 ± 0,04*^{x}	2,00 ± 0,00	1,96 ± 0,07
2nd (13th)	1,81 ± 0,09*^{x}	1,97 ± 0,03	2,07 ± 0,06	2,00 ± 0,00	1,96 ± 0,06
3rd (11th)	2,00 ± 0,00	2,07 ± 0,05	2,17 ± 0,07	2,07 ± 0,05	2,08 ± 0,04
4th (14th)	2,14 ± 0,08	2,07 ± 0,07	2,17 ± 0,07	2,10 ± 0,06	2,12 ± 0,07
On average:					
"Meadow of Health"	1,84 ± 0,09	1,97 ± 0,05	2,04 ± 0,05	2,00 ± 0,00	1,96 ± 0,08
concrete table	2,07 ± 0,08	2,07 ± 0,06	2,17 ± 0,07	2,09 ± 0,05	2,10 ±0 ,06

Note. When comparing with group 3:*$p < 0,05$, **$p < 0,01$, ***$p < 0,001$; when comparing with group 4:
$^{x}p < 0,05$, $^{xx}p < 0,01$, $^{xxx}p < 0,001$.

Based on the data of control milkings, the milk productivity of cows during 4 months of lactation was studied depending on the section from which the animal was moved to which one, i.e. whether it ate feed from polymer or concrete covering of the feed table during the whole period of the study or whether the covering of the sections was changed. Depending on the sections of cow movement during lactation, we have identified four possible variants of changing feed table coverings (see Table 5).

Data of control milkings are presented in Table 6. When the cows were fed from the polymer-coated feed table "Meadow of Health" an increase in milk production was observed from the first month of operation throughout 4 months. At feeding from concrete fodder table, the milk yield increased insignificantly by the second month of lactation, and from the third – fourth months the decrease of milk productivity was observed.

Lactation of a cow is usually divided into the following periods: milking, stabilization and decline. During each of the periods the cow can move from one section to another in accordance with the accepted milk production technology due to the change of feeding rations and productivity level. At the same time, not all sections can be equipped with polymer covering of the feed table. Therefore, we have studied all possible variants of changing feed tables associated with the transfer of animals in the process of lactation (see Table 7).

When the cows were transferred from polymer coating to concrete coating, a decrease in average daily milk yield by 0.9 kg was observed already from the second month of lactation. By the fourth month of lactation the decrease in milk yield amounted to 4.8 kg per 1 head per day. When transferring cows from concrete feed table to polymer one, the increase in milk productivity by 0.4–1.3 kg per 1 head per day was recorded.

Табл. 5. Варианты изменения покрытия кормовых столов в процессе перемещения лактирующих животных

Table 5. Variants of feed table cover changes during lactating animal movements

Group (section)	Feed table cover	
	preceding	successive
1st (12, 13th)	Polymer	Polymer
2nd (12, 13th)	»	Concrete
3rd (11, 14th)	Concrete	»
4th (11, 14th)	»	Polymer

The level of feed consumption by cows of different groups is presented in Table 8.

Feed consumption per group before the beginning of the experiment was approximately at the same level. During the first three months of the study, the increase in feed intake from the concrete table was insignificant and amounted to 0.5–1.0 t per group per month, whereas feed intake from the polymer-coated table increased by 2.3–2.8 t during this period, i.e. feed intake from the polymer-coated table increased by 2.3–5.6% more than from the concrete feed table.

During 5 months of lactation, cows from the feed table "Meadow of Health" ate 6.8-8.6% more fodder than from the concrete one, which

Табл. 6. Среднесуточные удои коров по результатам контрольных доений, кг (n = 18)

Table 6. Average daily milk yields of cows based on the results of control milkings, kg (n = 18)

Feed table cover	Section	Milk yield by months			
		November	December	January	February
"Meadow of Health"	12th	28,4 ± 1,9	29,6 ± 2,0	30,3 ± 3,0	32,1 ± 2,1
»	13th	22,9 ± 2,4	24,0 ± 2,0	–	–
Concrete	11th	28,5 ± 1,6	28,6 ± 1,5	27,3 ± 1,6	–
»	14th	27,5 ± 1,4	27,6 ± 1,5	27,6 ± 2,2	25,1 ± 2,3

Табл. 7. Среднесуточные удои коров по результатам контрольных доений при движении групп, кг
Table 7. Average daily milk yields of cows based on the results of control milkings during group movement, kg

Change of the feed table cover	Section	Milk yield by months			
		December	January	February	March
From polymer to concrete	12th	29,5 ± 2,0	28,6 ± 2,0	28,3 ± 2,1	24,7 ± 2,1
»	13th	22,8 ± 2,0	21,8 ± 2,1	21,2 ± 1,9	19,2 ± 2,0
From concrete to polymer	14th	26,1 ± 1,8	27,4 ± 1,7	–	–
»	11th	–	29,4 ± 1,9	29,8 ± 2,0	25,3 ± 2,0

Табл. 8. Потребление корма за месяц, т
Table 8. Feed consumption per month, tons

Month	Feed table section/cover			
	14th/concrete	11th/ concrete	13th/ polymer	12th/ polymer
November	48,3	48,0	48,8	50,5
December	48,0	48,7	51,7	52,5
January	48,8	49,0	51,6	52,8
February	47,6	49,2	50,8	51,9
March	46,0	47,9	50,6	51,6
Total	238,7	242,8	253,5	259,3

caused higher productivity of the animals during the analyzed period.

Based on the obtained data of milk productivity of cows, the economic efficiency of the research results was calculated (see Table 9).

The use of the polymer coating "Meadow of Health" made it possible to get additional profit and recoup the cost of its installation already on the 39th day of use. Thus, the profit from milk, additionally obtained with the use of the polymer coating, already in the first month of lactation reached 20,460 rubles.

CONCLUSION

The use of the polymer coating "Meadow of Health" makes it possible to level the surface of

Табл. 9. Экономическая эффективность использования полимерного покрытия кормового стола «Луг Здоровья»
Table 9. Economic efficiency of the use of polymer cover of the feed table "Meadow of Health"

Indicator	Section			
	13th	12th	11th	14th
Number of cows, heads	18	18	18	18
Milk yield in November (before the polymer cover use), kg	12 411	15 360	13 941	15 399
Milk yield in December (1 month of polymer cover use), kg	12 969	16 020	14 016	15 438
Increase in milk yield per cow per day, kg	1,13	1,22	0,1	0,1
Milk increment compared to November (uncovered), kg	+ 558	+ 660	+ 75	+ 39
Sales price of 1 kg of milk, rubles	31,00	31,00	31,00	31,00
Additional profit, thousand rubles	+ 17 298	+ 20 460	+ 2325	+ 1209
Cost of 1 linear meter of coating “Meadow of Health” with installation, thous. rubles.	1950			
Cost of 13.5 linear meters of “Meadow of Health” cover for 18 cows with installation, thousand rubles	26 325			
Cover payback, days	46	39	–	–

the feed table to an ideal state, eliminating all its defects for a long time. In addition, the study found that the use of such a coating significantly ($p < 0.05$) reduces microbial contamination of the surface of the feed table in 0.6–3.6 times, prevents the development of the undesirable microflora, as well as secondary fermentation of the feed mixture.

The analysis of feeding rations for lactating cows showed that the applied rations fully cover the need of the animals in nutrients and correspond to the level of their productivity. At the same time feed mixture on polymer coating is distributed in greater quantity.

When the cows were fed with polymer-coated feed table "Meadow of Health" from the first month of operation during 4 months of lactation there was an increase in milk productivity. When cows were fed from the concrete feed table, milk yields increased insignificantly by the second month of lactation, and from the third to the fourth months of lactation, a decrease in milk productivity was observed.

When the cows were transferred from polymer coating to concrete coating, a decrease in average daily milk yield by 0.9 kg was recorded already from the second month of lactation. By the fourth month of lactation the decrease in milk yield amounted to 4.8 kg of milk per 1 head per day. At transfer of the cows from a concrete feed table to a polymer-coated one, an increase in milk productivity by 0.4–1.3 kg per 1 head per day was observed.

The amount of uneaten feed residues on the polymer-coated feed table was significantly ($p < 0.05$) less than on the concrete one. During 5 months of lactation, cows on the "Meadow of Health" coated feed table ate 6.8-8.6% more feed than on the concrete one. The increase in feed mixture eatability ensured stable growth of milk productivity – 1.2 kg per 1 head per day.

Profit from the sale of milk additionally obtained by using the polymer coating reached 20,460 rubles in the first month of lactation. The cost of purchasing and installing the polymer coating "Meadow of Health" paid off in 39–46 days (assuming average depreciation of the previous concrete feed table).

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История изучения ринопневмонии лошадей

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Представлены материалы по истории изучения ринопневмонии лошадей. Изучение ринопневмонии началось в середине XIX в. Вначале болезнь назвали инфлюэнцией, а затем ее стали дифференцировать как самостоятельные заболевания: грипп, инфлюэнца, заразный катар верхних дыхательных путей, инфекционная плевропневмония. В 1933 г. американскими учеными Dimock и Edwards установлено, что у больных инфлюэнцией лошадей отмечаются аборты. После исследования полученных данных они установили вирусную этиологию заболевания. Начиная с 1941 г. высказывались мнения что грипп и вирусный аборт лошадей одно и то же заболевание, но протекающее в различных формах. Сначала нервная форма герпеса вируса лошадей была зафиксирована в Норвегии в 1966 г., затем в Соединенных Штатах Америки, Канаде и европейских странах. В СССР в 1955 г. Н.Н. Олейником зарегистрирован вирусный аборт лошадей. Впоследствии ринопневмония лошадей была исследована К.П. Юровым. Впервые изоляцию и идентификацию вируса осуществили К.П. Юров и Н.Н. Крюков в 1969, 1970 гг. от жеребят, больных респираторным заболеванием на конефермах Рязанской области. В 1995 г. основана референтная лаборатория Международного эпизоотического бюро (МЭБ) по ринопневмонии лошадей. На базе этой лаборатории разработаны методы диагностики и профилактики ринопневмонии у лошадей. В Европе, Азии и Африке, а также на обоих субконтинентах Северной и Южной Америки широко распространено данное заболевание. На всех континентах существует большая часть лошадей, которые имеют антитела к вирусу этой инфекции. По литературным данным, герпес вируса лошадей зарегистрирован в ряде европейских стран, в том числе в странах СНГ и России.

Ключевые слова: инфекционная болезнь, лошади, вакцина, ринопневмония, табунное коневодство

History of equine rhinopneumonia research

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Materials on the history of the study of equine rhinopneumonia are presented. The study of rhinopneumonia began in the mid-19th century. At first the disease was called Influenza, and then it began to be differentiated as independent diseases: grippe, Influenza, contagious catarrh of the upper respiratory tract, infectious pleuropneumonia. In 1933, American scientists Dimock and Edwards found that abortions were noted in horses with influenza. After examining the findings, they determined the viral etiology of the disease. Since 1941, opinions have been expressed that influenza and equine viral abortion are the same disease, but occurring in different forms. The nervous form of equine herpes virus was first reported in Norway in 1966, then in the United States, Canada, and European countries. In the USSR in 1955, N.N. Oleinik registered viral abortion of horses. Subsequently, rhinopneumonia of horses was investigated by K.P. Yurov. The virus was first isolated and identified by K.P. Yurov and N.N. Kryukov in 1969, 1970 from the foals with respiratory disease on horse farms in the Ryazan region. The Office International des Epizootics (OIE) reference laboratory for equine rhinopneumonia was established in 1995. Methods of diagnosis and prevention of rhinopneumonia in horses have been developed on the basis of this laboratory. Equine rhinopneumonia is widespread in Europe, Asia and Africa, as well as in both subcontinents of North and South America. There is a large proportion of

horses on all continents that have antibodies to this infection virus. According to literature data, equine herpes virus has been reported in a number of European countries, including CIS countries and Russia.

Keywords: infectious disease, horses, vaccine, rhinopneumonia, herd horse breeding

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In the early 20th century, the term "Influenza" was used to describe almost all common febrile diseases of horses. Dimock and Edwards in 1932 showed for the first time that a species of microorganism different from bacteria causes contagious epizootic abortion in mares [1].

Around that period, experimental studies on infection of mares with materials from aborted fetuses were initiated. According to the results of these studies it was found that infection with filtered viral agent can cause abortions in horses. In a further study, pathologic changes, including intranuclear inclusions in fetal pneumocytes and hepatocytes, were noted in the aborted fetuses. Thus, the term "equine viral abortion" appeared. Subsequently, equine abortion virus was cultured *in vivo* and *in vitro* and detailed pathologic findings were published[1] [2].

In 1941, Hungarian scientists Manninger and Csontos noted cases of abortion with similar symptoms, recorded in Kentucky (USA). According to the development of symptoms, they observed a mild course of influenza when pregnant mares were inoculated with bacteriologically sterile filtrate of aborted fetuses with viral abortion lesions [3]. Salyi in 1942 also confirmed that the gross and microscopic lesions noted in the aborted fetal material were similar to those observed in Kentucky [1]. Kress in 1941 pointed out that viral abortion was pneumotropic due to the prevalence of bronchopneumonia in horses that become infected through contact with the aborted material.

Doll et al. in 1954 first investigated a respiratory infection associated with viral abortion of mares. Young horses inoculated with this virus showed similar symptoms to those described as equine influenza, but the cause had not been identified at that time. Based on the results of their research, it is clear that viral abortion of mares is a factor that contributes to the development of epizootic respiratory disease in young horses [1]. Doll et al. had only to confirm that some of the suspected influenza virus isolates were exactly the same as the viral abortion of mares [1].

In another study, Bryans et al (1957) suggested that the causative agent formerly known as viral mare abortion should be considered a respiratory virus because of the severity of the major histologic lesions in the respiratory tracts of young and aborted foals[2]. The authors therefore named the resulting disease viral pneumonitis and the causative agent as equine viral pneumonitis virus. In 1959, Rhinopneumonia virus subtypes 1 and 2 were described on the basis of their antigenic differences. The probable pathogenicity of the infectious agents differed: subtype 1 was most frequently isolated from aborted f etuses, subtype 2 was isolated from upper respiratory tracts [4, 5].

In 1963, electron microscopy showed that the virus belongs to the herpes group [6]. In 1966,

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the first nervous manifestation of the equine herpes virus (EHV-1) infection was reported in Norway [1]. After that, the nervous form of the EHV-1 infection was described in practical veterinary epidemiology in every country. Meanwhile, in some countries with developed horse breeding (European countries, USA, Canada), a significant increase in the incidence of central nervous system lesions in horses was observed in 2010–2021 [7]. Outbreaks of nerve-paralytic infection are associated with the spread of neuropathogenic strains of the rhinopneumonia pathogen [8]. Asymptomatic course of equine rhinopneumonia is also possible. In 1981, based on a comparative analysis of restriction profiles, the classification of the two EHV-1 subtypes was changed, and they are now classified as two different types of virus [9]. The subtype of the pathogen EHV-1 was left the same name (EHV- 1), while the second subtype of EHV-1 was named EHV-4 [2].

Rhinopneumonia of horses was first diagnosed in the USSR in 1955 by N.N. Oleinik according to clinical data and pathological and morphological changes corresponding to the data obtained from epizootological sources. The causative agent of the infection was most likely the horses that were returned to Russia from West Germany in the early 50s of the XX century [10].

The works of K.P. Yurov can be emphasized among the Russian scientists. He first described the nervous form of rhinopneumonia in 1984, created vaccines against equine rhinopneumonia, compiled a number of instructions and methodological guidelines for diagnosis and control of equine viral diseases, which are successfully used in veterinary practice[3] [11]. One of such widely used methods is immunoenzyme analysis, which K.P. Yurov proposed for diagnostics of equine rhinopneumonia in 2006 together with his student V.V. Korzhov. Also, for retrospective diagnosis of equine rhinopneumonia in the hemagglutination inhibition reaction, a special technique was developed[4].

Equine rhinopneumonia was first registered in the Republic of Sakha (Yakutia) by M.P. Neustroev in 1993. However, until 2002, the equine herpesvirus was not registered in the official statistical reporting of the veterinary service of Yakutia. There were no objective data on the scale of virus circulation in the republic. M.P. Neustroev in 2001 established that rhinopneumonia has immunosuppressive abilities, which complicate the course of the strangles disease. The simultaneous course of rhinopneumonia, strangles and salmonellosis in horses has been proven [12]. From 2002 to 2022, equine herpesvirus was observed in 100 sites in 16 districts of the Republic of Sakha (Yakutia). The highest number of equine diseases was registered in Amginsky, Khangalassky, Nyurbinsky, Tattinsky, and Suntarsky districts, i.e. in those municipalities where the main horse population of Yakutia is concentrated.

The highest number of unfavorable sites was recorded in 2004, then the situation improved annually. In 2014-2016 in the republic only one unfavorable site per year was registered (see the figure). This may be due to the low level of serologic research.

According to our data, in 2004–2010, 827–1044 samples per year were examined, in 2015–2016 – only 189–283. Starting from 2017, no serologic tests were performed due to the lack of ELISA kit in the Republic of Sakha (Yakutia). The immunization rate also decreased: from 8419 and 11,040 in 2012 and 2013 to 2834 and 5111 in 2015 and 2016, respectively.

Circulation of rhinopneumonia virus was observed in the Amginsky district (villages Bolugur Pokrovka, Chakyr), Kobyaisky district (Kobyai, Mastakh), Megino-Kangalassky district (Khara, Khoroobut), Nyurbinsky district (Maljagai, Malykai, Megezhek, Nyurbachan), Oymyakonsky district (Tomtor), Suntarsky district (Khadan,

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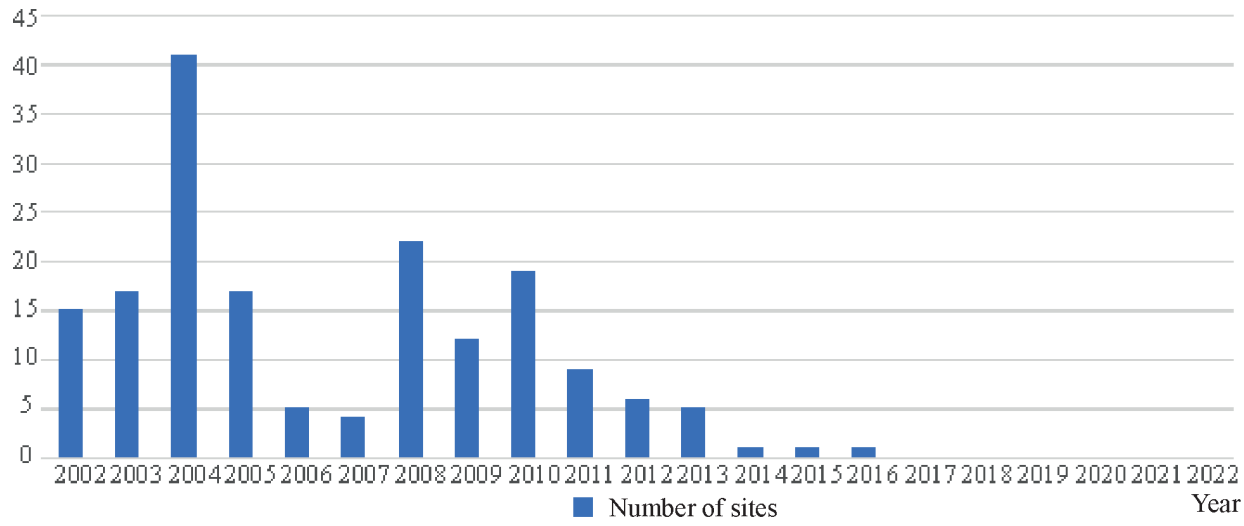

Динамика числа неблагополучных пунктов по ринопневмонии в Республике Саха (Якутия) с 2002 по 2022 г.

Dynamics of the number of the disadvantaged rhinopneumonia sites in the Republic of Sakha (Yakutia) from 2002 to 2022.

Zharkhan, Elgay, Togoy Sela, Kempendyai, Kyundyaye), Srednekolymsky district (Oyusardakh), Tattinsky district (Debdirge, Walba, Kharbalaakh, Chimnaii, Chychymakh, Borobul), Tomponsky district (Keskil, Krest-Khaljai), Ust-Aldansky district (Borogontsy, Sottintsy), Khangalassky district (Bulgunnyakhtakh, Nemyugyuntsy, Oktemtsy), Churapchinsky district (Khatyly, Khakhyyakh, Kytanakh), as well as in the vicinity of Yakutsk (Khatassy village).

In our research from 2018 to 2021, 101 blood serum samples were collected from young horses from different regions of the Republic of Sakha (Yakutia). Of these, antibodies to rhinopneumonia virus were detected in 61 samples (60.3%), 40 samples (39.7%) were negative. It can be concluded that rhinopneumonia virus circulates among young horses in horse breeding farms of the Republic of Sakha (Yakutia).

For the prevention and treatment of equine rhinopneumonia, scientists of the Yakutsk Research Institute of Agriculture under the leadership of M.P. Neustroev developed ат inactivated vaccine against rhinopneumonia, trivalent inactivated vaccine against rhinopneumonia, horse strangles and salmonellosis, bivalent inactivated vaccine against rhinopneumonia and horse salmonellosis, and inactivated combined vaccine against rhinopneumonia and horse strangles for young horses [12–14].

The immunogenicity of the combined vaccine with respect to the viral component was 75%, and the immunogenicity of the bacterial component in mongrel white mice was 80%. The combined vaccine under production conditions showed high anti-epizootic efficacy of 97,2%.

The economic efficiency was calculated according to the “Methodology for determining the economic efficiency of veterinary measures” approved by the Ministry of Agriculture and Food of the Russian Federation and approved by the Department of Veterinary Medicine of the Ministry of Agriculture and Food of the Russian Federation (1997). In order to increase the informativeness of perception and for the convenience of calculations of the used formulas, the calculation of efficiency was carried out per 100 young animals. Conducted in a fairly long period (2016-2022) studies in the central group of uluses (districts) showed a significant prevalence of rhinopneumonia and foal strangles. Territorially, about 60% of the horse population is concentrated in the central group of uluses of Yakutia.

It has been established that in certain years in the Republic of Sakha (Yakutia) strangles and rhinopneumonia were registered annually in the Namsky, Khangalassky, Ust-Aldansky, Tattinsky, Amginsky and Megino-Kangalassky

districts. Rhinopneumonia and equine typhoid fever in the acute phase can spread to 65% of the foal population.

According to calculations, in the absence of vaccination, the economic damage per 100 head of young animals will amount to 555.5 thousand rubles. After the introduction of the combined vaccine, the damage per 100 head will decrease to 8.25 thousand rubles, or by 67.3 times. Economic effect on 100 heads will amount to 617 thousand rubles, on 12 370 thousand heads – 76 322,9 thousand rubles. At introduction of the development in a separate farm we will receive two indicators characterizing the economic effect. It will amount to 6.17 thousand rubles per one head of animal and 8.81 rubles of profit per one ruble of costs. In the Republic of Sakha (Yakutia) as a whole, the total economic effect, according to our calculations above, will amount to 76 million 322.9 thousand rubles.

There are no data on the spread of rhinopneumonia in other subjects of Siberia and the Far East, possibly due to the lack of diagnostic and scientific studies.

There are many countries in which equine rhinopneumonia is widespread. This applies to Europe, South Asia, Africa and North America. Antibodies to rhinopneumonia virus have been registered on all continents. At present, equine rhinopneumonia is becoming a significant problem of horse breeding in many regions of the Russian Federation, the Republic of Kazakhstan [15], the Kyrgyz Republic [16].

It should be noted that equine rhinopneumonia is included in the "List of contagious, including especially dangerous, animal diseases, for which restrictive measures (quarantine) can be established" (orders of the Ministry of Agriculture of the Russian Federation dated December 19, 2011). According to the order of the Ministry of Agriculture of the Russian Federation No. 649 of September 23, 2021, which approved the rules of control and prevention of rhinopneumonia, scheduled diagnostic and preventive measures should be carried out. Paragraph 31 of the order stipulates that meat obtained from the slaughter of sick animals, after heat treatment, can be used as raw material only for the preparation of feed and feed additives for animals.

CONCLUSIONS

1. The given data of foreign and domestic literature show that equine rhinopneumonia still remains an unsolved problem of veterinary medicine. Literature data and analysis of the reporting data of the Department of Veterinary Medicine of the Republic of Sakha (Yakutia) showed that equine rhinopneumonia is significantly spread not only in the Republic, but also in other subjects of the Russian Federation, where herd horse breeding is developed.

2. In the Russian Federation, diagnostic tests should be expanded and new regulations for rhinopneumonia control should be implemented in all entities, which will increase the productivity of herd horse breeding and enable biosecurity to be ensured.

3. A combined vaccine against rhinopneumonia and strangles for young horses has been developed. Immunogenicity of viral composition of the vaccine amounted to 75%, strangles composition – 80%. Approval and introduction of the combined vaccine into production will increase the effectiveness of prophylactic measures for respiratory diseases of young horses.

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Динамические особенности виброщекового измельчителя кормового зерна

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Вибрационный способ измельчения кормового зерна может быть реализован в различных конструкциях измельчителей, однако предпочтение следует отдавать динамическим схемам машин, поскольку такие системы способствуют энергосбережению и повышению надежности всей конструкции. Анализ всей совокупности информации по вибрационным измельчителям, разработанным в различных отраслях хозяйства, позволил сформулировать основные требования к динамическим системам этих машин. К ним относятся следующие: обеспечение вибрации точек рабочих органов по определенным законам; осуществление самосинхронизации вибровозбудителей (в случае парного вибропривода); обеспечение минимальной амплитуды несущей системы измельчителя, на которой укреплены вибровозбудители; обеспечение максимальной амплитуды рабочего органа измельчителя; компактность вибропривода; отсутствие паразитных колебаний. В связи с этими требованиями заслуживают особого внимания вибрационные щековые измельчители для кормового зерна. Близкие по технической сущности измельчители успешно применяют в горном деле. В таких измельчителях проявляются важные для технологии различные вибрационные динамические эффекты. Цель настоящей работы – повышение технического уровня вибрационного измельчителя кормового зерна на основе использования эффектов самосинхронизации вибровозбудителей и интенсификации выгрузки измельченного материала. Получена математическая модель динамики вибрационного щекового измельчителя кормового зерна, учитывающая его конструктивные особенности и взаимодействие рабочих органов с технологической средой. Установлено, что из двух возможных режимов синхронизации устойчив синхронно-синфазный режим. Аналитический анализ показал технологическую работоспособность динамической схемы виброщекового измельчителя в данном режиме синхронизации, при этом динамика измельчителя отвечает практически всем другим указанным требованиям.

Ключевые слова: кормовое зерно, вибрационный измельчитель, требования к динамическим схемам, самосинхронизация вибровозбудителей

Dynamic features of vibrating jaw crusher of feed grain

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The vibration method of feed grain crusher can be realized in various designs of crushers, but preference should be given to dynamic machine schemes, as such systems contribute to energy saving and

increase the reliability of the whole structure. The analysis of the totality of information on vibrating crushers developed in various branches of economy allowed formulating the main requirements to the dynamic systems of these machines. These include the following: providing vibration of points of the working bodies according to certain laws; implementation of self-synchronization of vibro-exciters (in the case of a pair of vibro-drive); ensuring the minimum amplitude of the load-bearing system of the crusher, on which the vibro-exciters are mounted; ensuring the maximum amplitude of the working body of the crusher; compactness of the vibro-drive; absence of parasitic vibrations. Due to these requirements, vibrating jaw crushers for feed grain deserve special attention. Crushers close in technical essence are successfully used in mining. In such crushers, various vibratory dynamic effects important for the technology are manifested. The purpose of this work is to increase the technical level of the vibrating crusher of feed grain on the basis of using the effects of self-synchronization of vibration exciters and intensification of discharging the crushed material. The mathematical model of dynamics of the vibrating jaw crusher of feed grain, taking into account its design features and interaction of working bodies with the technological medium, is obtained. It is found that of the two possible synchronization modes, the synchronous-synphase mode is stable. Analytical analysis has shown the technological operability of the dynamic scheme of the vibrating jaw crusher in this synchronization mode, while the dynamics of the crusher meets almost all other specified requirements.

Keywords: feed grain, vibrating crusher, requirements to dynamic circuits, self-synchronization of vibration exciters

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INTRODUCTION

Vibratory method of feed grain milling reduces specific energy costs in comparison with hammer crusher [1]. At the same time, the structure of the crushed product to a greater extent meets the requirements formulated by zootechnical science for ruminants[1].

Vibratory method can be realized in various designs of shredders, but preference should be given to dynamic schemes of machines, as such systems contribute to energy saving and increase the reliability of the whole structure [2–10].

The analysis of the totality of information on vibrating shredders developed in various branches of economy allowed us to formulate the main requirements to the dynamic systems of these machines, which should[2]:

– provide vibrations of the points of the working bodies according to certain laws;

– conduct self-synchronization of vibration exciters (in case of paired vibration drive);

– ensure minimum amplitude of the shredder support system on which the vibrating exciters are mounted;

– ensure maximum amplitude of the shredder's working body;

– meet the criterion of compactness of the vibration motor;

– ensure that there are no parasitic oscillations.

[1]*Tabaev A.V.* Features of the granulometric composition of the crushed product formed in a vibrating crusher // Studenthood of Russia: century XXI: Proceedings of VIII All-Russian youth scientific and practical conference. Orel: N.V. Parakhin Orel State Agrarian University, 2022, vol. 3, pp. 270–276.

[2]*Levin A.M., Fedorenko I.Ya.* Requirements for dynamic systems of vibrating crushers of fodder grain // Agrarian science to agriculture: Proceedings of the XVIII International scientific-practical conference Barnaul: Altai State Agrarian University, 2023, B. 1, pp. 134–137.

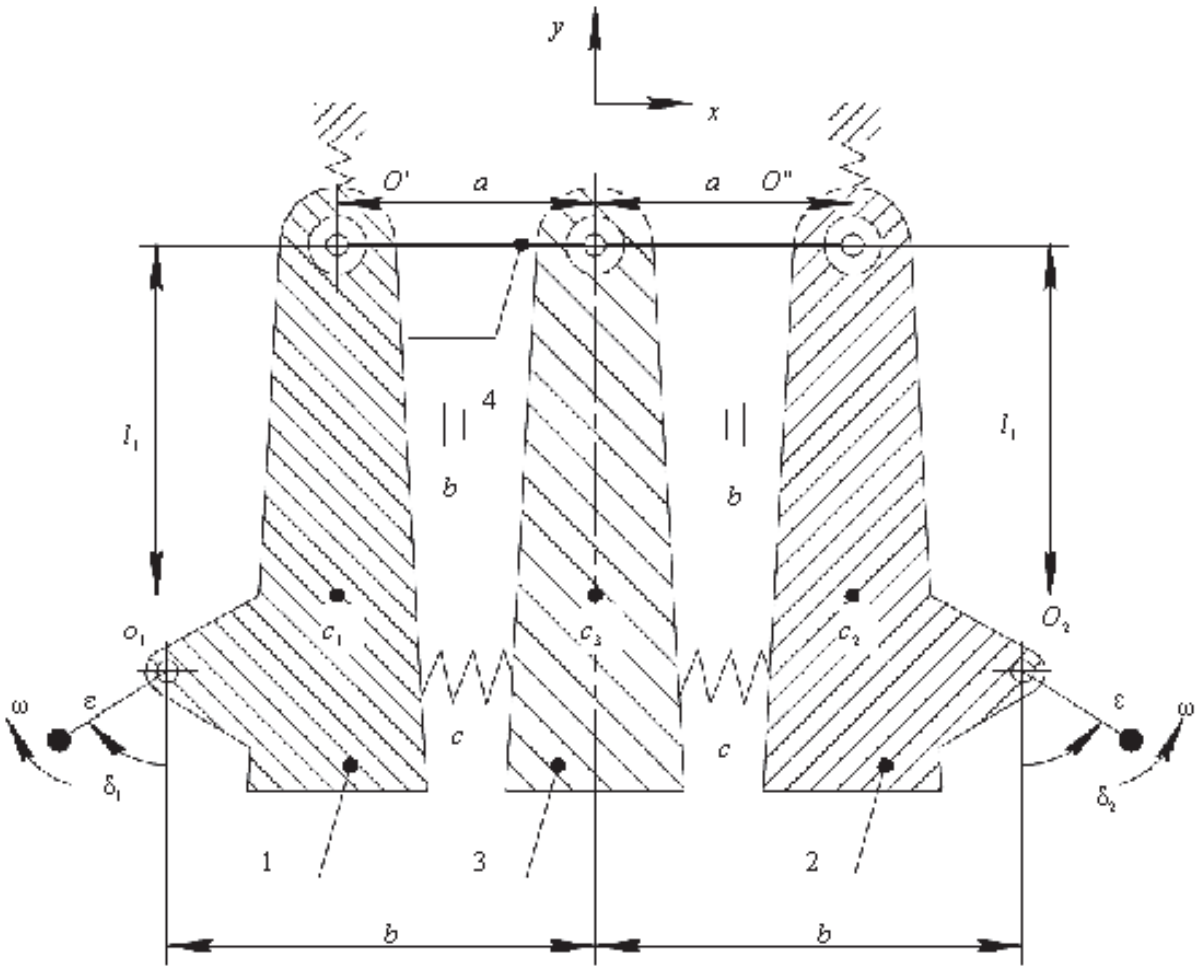
In connection with these requirements, vibrating jaw crushers for feed grain deserve special attention. Similar in technical essence crushers are successfully used in mining[3, 4]. Various vibration dynamic effects important for technology are manifested in such crushers[5].

The purpose of the research is to increase the technical level of the vibrating crusher of feed grain on the basis of using the effects of self-synchronization of vibration exciters and intensification of discharging the crushed material.

MATERIAL AND METHODS

The design of a vibrating jaw crusher for feed grain developed by us is protected by the patents of the Russian Federation No. 2759864, 2787723. Its dynamic scheme is made according to the method[6] and is presented in the figure.

The scheme includes two active (vibrating) jaws *1* and *2*, performing in the operating mode synchronized, symmetrical angular oscillations relative to the transverse axis of the machine. The middle jaw *3* has no vibrating motor, so it



Расчетная динамическая схема виброщекового измельчителя с двумя самосинхронизирующимися вибровозбудителями, трехмассная

Calculated dynamic diagram of a vibrating jaw crusher with two self-synchronizing vibration exciters, three-mass

[3] *Vaisberg L.A., Zarogatsky L.P., Turkin V.Y.* Vibrating crushers. SPb.: VSEGEI Publishing House, 2004, 306 p.

[4] *Revnivtsev V.I., Denisov G.A., Zarogatsky L.P., Turkin V.Y.* Vibration disintegration of solid materials. Moscow: Nedra, 1992, 430 p.

[5] *Kartavyi A.N.* Resource-saving principles of design of technological vibrating machines // Mining equipment and electromechanics, 2009, N 3, pp. 28–37.

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can be called passive. The frame of the crusher is idealized as a softly cushioned absolutely rigid weightless rod *4*. Each of the jaws can rotate in its pivot located at the top. Thus, each of the jaws is a physical pendulum. The pivots are located at a distance *a* from each other. The centers of gravity of all the jaws in the position of static equilibrium lie on the verticals passing through the centers of the pivots and are located at a distance l_1 from the centers of their pivots.

Let's consider that the frame springs are very soft, so their stiffness is close to zero.

The rotation centers of identical unbalance (inertial) vibration exciters are located at similar points of jaws *O*1 and *O*2, located at a distance l_2 from the pivot axes.

The crushed material enters from above into the gaps between the active and passive jaws. The viscoelastic properties of the process load are modeled by viscous and elastic elements *b* and *c*. As generalized coordinates of the whole crusher system we take the horizontal *x* and vertical *y* displacements of the pivot center of the middle jaw *3*, the absolute rotation φ of the rod *4*, as well as the jaw rotations φ_1, φ_2 and φ_3, counted from the vertical. We consider that the jaw unbalances rotate uniformly with the same angular velocity, but in opposite directions according to the laws of

$$\delta_1 = \omega t;\ \delta_2 = \omega t + \alpha, \qquad (1)$$

where ω – eccentric weight angular velocities; α – eccentric weight rotation phase shift.

The starting angles of the eccentric weight rotations can be seen in the figure.

The equations of small oscillations of the whole crusher system as well as of all three jaws at synchronous oscillations of vibrating exciters with arbitrary phasing α have the following form:

$$M\ddot{x} + Ml_1(\ddot{\varphi}_1 + \ddot{\varphi}_2 + \ddot{\varphi}_3) = m_0\varepsilon\omega^2[\sin\omega t - \sin(\omega t + \alpha)]; \qquad (2)$$

$$M\ddot{y} = m_0\varepsilon\omega^2[\cos\omega t + \cos(\omega t + \alpha)]; \qquad (3)$$

$$M\alpha^2\varphi = -m_0\varepsilon\omega^2\alpha[\cos\omega t - \cos(\omega t + \alpha)]; \qquad (4)$$

$$(I + ml_1^2)\ddot{\varphi}_1 + ml_1\ddot{x} + mgl_1\varphi_1 + b(\dot{\varphi}_1 - \dot{\varphi}_3)l_1^2 + c(\varphi_1 - \varphi_3)l_1^2 = m_0\varepsilon\omega^2 l_2 \sin\omega t; \qquad (5)$$

$$(I + ml_1^2)\ddot{\varphi}_2 + ml_1\ddot{x} + mgl_1\varphi_2 + b(\dot{\varphi}_2 - \dot{\varphi}_3)l_1^2 + c(\varphi_2 - \varphi_3)l_1^2 = -m_0\varepsilon\omega^2 l_2 \sin(\omega t + \alpha); \qquad (6)$$

$$(I_3 + m_3 l_1^2)\ddot{\varphi}_3 + ml_1\ddot{x} + mgl_1\varphi_3 + b(\dot{\varphi}_1 + \dot{\varphi}_2 - 2\dot{\varphi}_3)l_1^2 + c(\varphi_1 + \varphi_2 - 2\varphi_3)l_1^2 = 0; \qquad (7)$$

where *M* – total weight of the crusher components involved in oscillating movements; $m = m_1 = m_2$ – the weight of each active jaw with eccentric weight; m_3 – passive jaw weight; $I = I_1 = I_2$ – central moment of inertia of each active jaw with eccentric weight; I_3 – central moment of inertia of the passive jaw; m_0, ε – eccentric weight mass and its centering error; α – phase angle characterizing the eccentric weight movement.

The obtained mathematical model includes differential equations of reciprocating movements of the entire crusher system (2), (3). Equation (4) models the angular vibrations of the frame in the drawing plane; equations (5), (6) characterize the forced oscillations of the active jaws around their suspension points; equation (7) describes possible angular oscillations of the passive jaw.

RESULTS AND DISCUSSION

The first thing that we need to find out from the mathematical model (2) – (7) is the possibility of self-synchronization of the vibration exciters mounted on the active jaws. Here a rare case is presented, when the vibration exciters are installed not on a common bearing system, but on two separate bearing systems (jaws), which are not directly rigidly connected to each other.

Self-synchronization of mechanical vibration exciters consists of two or more unbalanced rotors driven by induction motors, on a fixed base, having different rotational speeds ω_1 and ω_2. These rotors, mounted on a common movable base, rotate with the same average speed ω and a certain phasing [6, 7].

From the figure we can see that in this crusher we need such self-synchronization of vibrat-

ing exciters, at which the jaws synchronously squeeze the material in the gaps between the active and passive jaws and also synchronously move aside to release the crushed material. With the accepted starting points for the angular displacement of the eccentric weights it can be seen that synchronous in-phase rotations of the unbalances are necessary, at which

$$\alpha = 0, \quad (8)$$

whereas the angles $\delta_1 = -\delta_2$.

Substituting the value (8) into equations (2) – (7), there will be

$$M\ddot{x} + Ml_1(\ddot{\varphi}_1 + \ddot{\varphi}_2 + \ddot{\varphi}_3) = 0; \quad (9)$$

$$M\ddot{y} = 2m_0\varepsilon\omega^2\cos\omega t; \quad (10)$$

$$M\alpha^2\ddot{\varphi} = 0; \quad (11)$$

$$(I + ml_1^2)\ddot{\varphi}_1 + ml_1\ddot{x} + mgl_1\varphi_1 + b(\dot{\varphi}_1 - \dot{\varphi}_3)l_1^2 + c(\varphi_1 - \varphi_3)l_1^2 = m_0\varepsilon\omega^2 l_2\sin\omega t; \quad (12)$$

$$(I + ml_1^2)\ddot{\varphi}_2 + ml_1\ddot{x} + mgl_1\varphi_2 + b(\dot{\varphi}_2 - \dot{\varphi}_3)l_1^2 + c(\varphi_2 - \varphi_3)l_1^2 = -m_0\varepsilon\omega^2 l_2\sin\omega t; \quad (13)$$

$$(I_3 + m_3l_1^2)\ddot{\varphi}_3 + ml_1\ddot{x} + mgl_1\varphi_3 + b(\dot{\varphi}_1 + \dot{\varphi}_2 - 2\dot{\varphi}_3)l_1^2 + c(\varphi_1 + \varphi_2 - 2\varphi_3)l_1^2 = 0. \quad (14)$$

Let us first consider differential equations (12) and (13). When adding the right and left parts of these equations, 0 is obtained in the right part. Consequently, the left parts should be identical, i.e., the forces in the system of two active jaws are mutually balanced at a given self-synchronization mode. As a consequence, $\varphi_3 = 0$. We conclude that at the considered mode of self-synchronization of vibration exciters, the middle (passive) jaw should be stationary with respect to its angular oscillations around the suspension point.

Taking into account this information, as well as the condition $\varphi_1 = -\varphi_2$ from equation (9) it follows that

$$M\ddot{x} = 0; x = 0. \quad (15)$$

Thus, there should be no horizontal translational oscillations of the whole system at this synchronization mode.

The law of vertical rectilinear oscillations of the entire crusher system follows from the equation (10):

$$\ddot{y} = (2m_0\varepsilon/M)\cos\omega t. \quad (16)$$

Active jaw swing equations (12) – (13) taking into account $\ddot{x} = 0$ and $\varphi_3 = 0$ and will be as follows

$$(I + ml_1^2)\ddot{\varphi}_1 + mgl_1\varphi_1 + b\dot{\varphi}_1l_1^2 + c\varphi_1l_1^2 = \Phi_0l_2\sin\omega t, \quad (17)$$

$$(I + ml_1^2)\ddot{\varphi}_2 + mgl_1\varphi_2 + b\dot{\varphi}_2l_1^2 + c\varphi_2l_1^2 = -\Phi_0l_2\sin\omega t, \quad (18)$$

where $\Phi_0 = m_0\varepsilon\omega^2$.

After adding similar terms in these equations, we obtain

$$(I + ml_1^2)\ddot{\varphi}_1 + l_1(mg + cl_1)\varphi_1 + b\varphi_1l_1^2 = \Phi_0l_2\sin\omega t; \quad (19)$$

$$(I + ml_1^2)\ddot{\varphi}_2 + l_1(mg + cl_1)\varphi_2 + b\varphi_2l_1^2 = -\Phi_0l_2\sin\omega t. \quad (20)$$

Let us reduce these equations to the standard form:

$$\ddot{\varphi}_1 + 2n\varphi_1 + \omega_0^2\varphi_1 = Q_0\sin\omega t; \quad (21)$$

$$\ddot{\varphi}_2 + 2n\varphi_2 + \omega_0^2\varphi_2 = -Q_0\sin\omega t; \quad (22)$$

где $2n = \frac{bl_1^2}{I + ml_1^2}$; $\omega_0 = \sqrt{\frac{(mg + cl_1)l_1}{I + ml_1^2}}$;

$$Q_0 = \frac{\Phi_0}{I + ml_1^2}. \quad (23)$$

Equations (21), (22) represent the usual linear models of forced oscillations, the solutions of which are well known and are given in textbooks on the theory of oscillations. Thus, each of the active jaws in the first approximation makes sinusoidal angular oscillations around its pivot, which is required for technological reasons. In this case, the oscillation range is the same for both jaws, and their movements are synchronized.

In addition, the entire crusher system, including the jaws, vibrates vertically in a straight line.

The combination of these movements is very useful for the jaws, because the entire crusher system is in the lowered position when the jaws are clamped. When the system is lifted, the cheeks are unclamped and the crushed material remains in the lower position. This facilitates its rapid evacuation from the chambers of the chopper and prevents over-milling of the grain.

Theory and practice of synchronization show[7] that in this case there can be another type of synchronization – counter-phase, in which

$$\alpha = \pi. \quad (24)$$

Substitution of value $\alpha = \pi$ into the initial equations (2) – (7) results in:

$$M\ddot{x} + Ml_1(\ddot{\varphi}_1 + \ddot{\varphi}_2 + \ddot{\varphi}_3) = 2m_0\varepsilon\omega^2 \sin\omega t; \quad (25)$$

$$M\ddot{y} = 0; \quad (26)$$

$$M\alpha^2\ddot{\varphi} = -2m_0\varepsilon\omega^2 \cos\omega t; \quad (27)$$

$$(I + ml_1^2)\ddot{\varphi}_1 + ml_1\ddot{x} + mgl_1\varphi_1 + b(\dot{\varphi}_1 - \dot{\varphi}_3)l_1^2 + c(\varphi_1 - \varphi_3)l_1^2 = m_0\varepsilon\omega^2 l_2 \sin\omega t; \quad (28)$$

$$(I + ml_1^2)\ddot{\varphi}_2 + ml_1\ddot{x} + mgl_1\varphi_2 + b(\dot{\varphi}_2 - \dot{\varphi}_3)l_1^2 + c(\varphi_2 - \varphi_3)l_1^2 = m_0\varepsilon\omega^2 l_2 \sin\omega t; \quad (29)$$

$$(I_3 + m_3 l_1^2)\ddot{\varphi}_3 + ml_1\ddot{x} + mgl_1\varphi_3 + b(\dot{\varphi}_1 + \dot{\varphi}_2 - 2\varphi_3)l_1^2 + c(\varphi_1 + \varphi_2 - 2\varphi_3)l_1^2 = m_0\varepsilon\omega^2 l_2 \sin\omega t. \quad (30)$$

As can be seen from these equations, the mode of counter-phase synchronization is completely unsuitable for the technological process. Active jaws oscillate in one phase, i.e. they have no mutual oscillations relative to each other. Consequently, there is practically no compression of the material to be crushed. This compression can be increased by increasing the inertia of the middle passive jaw. However, there are negative factors of this synchronization mode, caused by difficulties with discharging of the crushed material from the working chambers. In this case, there are no movements of the jaws along the *y*-axis, contributing to unloading, but there are movements along the *x*-axis, preventing it. There are also rotary parasitic oscillations of the whole system.

In this regard, the in-phase synchronization mode is certainly preferable to the counter-phase one for technological reasons. However, in dynamic systems the synchronization mode that is stable is implemented, so it is necessary to prove the stability of the required synchronization mode and the instability of the other mode.

For this purpose, let us use the integral criterion for the stability of synchronous motions (see footnote 7).

It is formulated as follows: stable synchronous motions correspond to the minimum of the Lagrangian *L* of the mechanical system averaged over the oscillation period.

The mathematical formulation of this criterion can be written as follows:

$$L^* = \frac{\omega}{2\pi}\int_0^{2\pi/\omega} L\,dt = \frac{\omega}{2\pi}\int_0^{2\pi/\omega} (\mathrm{T} - \Pi)\,dt \to \min \quad (31)$$

Consequently, we conclude that $L_1^* < L_2^*$. This means that the in-phase mode required by technological considerations is stable. The experience of development of vibrating crushers in the mining industry testifies to the stability of this particular mode: if the crusher is a symmetric dynamic system (as in our case), such a synchronization mode necessarily exists and is stable [7].

Thus, the dynamic scheme of this crusher is quite workable, and the required synchronization of vibrating exciters is set automatically. The disadvantage of this dynamic scheme of the crusher is noted: unbalances of vibrating exciters are fixed on vibrating jaws, so their bearings are subjected to high dynamic loads. Otherwise, this dynamic scheme meets the requirements listed in the introduction.

CONCLUSIONS

1. The mathematical model of dynamics of a vibrating jaw crusher of fodder grain, taking

[7] *Blekhman I.I.* Vibrational mechanics: nonlinear dynamic effects, genera approach, applications. Singapore, New Jersey, London, Hong Kong: World Scientific Publishing Co. Pte. Ltd. 2000. vol. 509. DOI: 10.1142/9789812794659.

into account its design features and interaction of working bodies with technological medium, is obtained.

2. It is established that out of two possible modes of synchronization the synchronous-synphase mode is stable. The analysis has shown technological operability of the dynamic scheme of the vibrating jaw crusher in this mode of synchronization, at the same time it meets practically all other requirements listed above.

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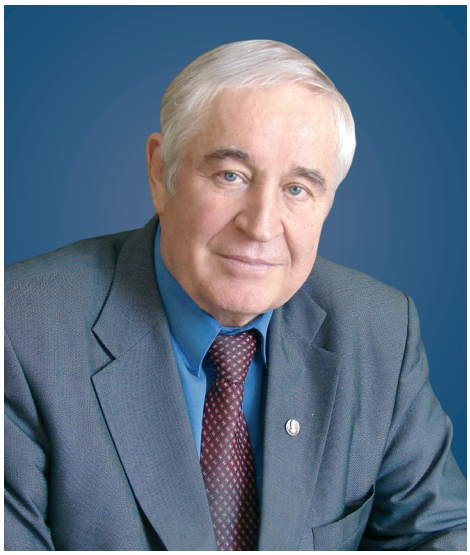
Александр Семенович Донченко



Руководителю Института экспериментальной ветеринарии Сибири и Дальнего Востока, академику РАН, доктору ветеринарных наук, профессору Александру Семеновичу Донченко 25 июня исполняется 85 лет.

Александр Семенович родился в 1939 г. в г. Чите в семье военнослужащего. В период Великой Отечественной войны семья Донченко проживала в Северо-Казахстанской области в совхозе «Кзыл-Аскерский» («Красный воин») Пресновского района Казахской ССР. Глава семьи Семен Васильевич Донченко был участником Великой Отечественной войны. В июне 1945 г. майор С.В. Донченко перевез семью в Белорусскую ССР на новое место своей службы – в г. Пружаны Пружанского района. А.С. Донченко в 1946 г. поступил в первый класс Пружанской средней школы. Последующие восемь классов он учился в средней школе г. Слуцка Белорусской ССР. После отставки в 1954 г. из Советской армии С.В. Донченко переехал с семьей в Северо-Казахстанскую область Казахской ССР.

В 1956 г. А.С. Донченко окончил среднюю школу в селе Пресновка Пресновского района Северо-Казахстанской области Казахской ССР. Трудовую деятельность начал в совхозе «Приишимский» Сергеевского района Северо-Казахстанской области в качестве тракториста. В 1960 г. окончил ускоренный (2,5 года) курс Ленинского сельскохозяйственного техникума (с. Покровка Явленского района Северо-Казахстанской области), получил среднее специальное образование – зооветтехник, начал работать веттехником в совхозе «Приишимский».

В 1960 г. поступил в Алма-Атинский зооветеринарный институт, который с отличием окончил в 1965 г., получив высшее специальное образование – ветеринарный врач. После окончания института его распределили в Актюбинский сельхозтехникум (г. Темир Актюбинской области Казахской ССР) преподавателем ветеринарных дисциплин. Далее в течение двух лет проходил службу в Министерстве охраны общественного порядка (МООП, Казахская ССР, Алма-Ата) в качестве офицера-инспектора ветеринарно-карантинной службы.

В 1968 г. поступил в очную аспирантуру Казахского научно-исследовательского ветеринарного института (КазНИВИ) ВО ВАСХНИЛ (Алма-Ата). После окончания аспирантуры защитил кандидатскую диссертацию «Экономическая эффективность комплексных ветеринарных мероприятий, некоторые вопросы диагностики при искоренении туберкулеза крупного рогатого скота» (1972 г.) в Киргизском сельскохозяйственном институте (г. Фрунзе). В течение 6 лет

работал директором Гурьевской научно-исследовательской ветеринарной станции (НИВС, г. Гурьев Гурьевской области Казахской ССР), затем старшим научным сотрудником в КазНИВИ (Алма-Ата). В 1979 г. получил приглашение директора Института экспериментальной ветеринарии Сибири и Дальнего Востока (ИЭВСиДВ СО ВАСХНИЛ, Новосибирск) академика ВАСХНИЛ А.А. Свиридова принять участие в конкурсе по избранию заведующего лабораторией туберкулеза сельскохозяйственных животных этого института.

В марте 1979 г. Александр Семенович был избран по конкурсу заведующим лабораторией туберкулеза сельскохозяйственных животных ИЭВСиДВ СО ВАСХНИЛ.

Одновременно с работой в качестве заведующего лабораторией в 1988 г. назначен заместителем директора института по научной работе. С февраля 1996 г. по март 2012 г. Александр Семенович работал директором этого института. В 1990 г. защитил докторскую диссертацию «Туберкулез крупного рогатого скота, верблюдов и овец» (1990 г.). В этом же году Высшей аттестационной комиссией (ВАК) при Совете Министров СССР ему присвоено звание профессора по специальности «ветеринарная микробиология».

В марте 1997 г. на общем собрании Сибирского отделения Россельхозакадемии А.С. Донченко избран заместителем председателя президиума СО РАСХН, в 2001 г. – первым заместителем. 19 ноября 2004 г. Александр Семенович приступил к работе в качестве председателя СО РАСХН. 17 февраля 2005 г. на общем собрании он был избран председателем СО РАСХН, членом президиума и вице-президентом РАСХН.

Правительство Российской Федерации 25 октября 2013 г. утвердило реорганизацию Российской академии сельскохозяйственных наук (РАСХН) в Федеральное агентство научных организаций (ФАНО) РФ. СО РАСХН было реорганизовано в Сибирское отделение аграрных наук ФАНО РФ. Руководителем этой научной организации был назначен А.С. Донченко. 30 сентября 2015 г. на базе СО аграрных наук ФАНО РФ был организован Сибирский федеральный научный центр агробиотехнологий (СФНЦА) РАН. 9 марта 2016 г. издан приказ ФАНО РФ об организации СФНЦА РАН, с 5 апреля 2016 г. А.С. Донченко был назначен научным руководителем этого Центра.

20 марта 2018 г. согласно заявлению по собственному желанию Александр Семенович перешел работать в ИЭВСиДВ – научное подразделение СФНЦА РАН – главным научным сотрудником лаборатории туберкулеза сельскохозяйственных животных. С 31 мая 2021 г. согласно приказу № 199-лк директора СФНЦА РАН он назначен научным руководителем ИЭВСиДВ с одновременным выполнением обязанности главного научного сотрудника лаборатории туберкулеза сельскохозяйственных животных. С октября 2023 г. стал руководителем ИЭВСиДВ СФНЦА РАН.

В 2014 г. в связи с реорганизацией трех государственных академий Российской Федерации (РАН, РАМН и РАСХН) А.С. Донченко избран академиком РАН и членом Президиума РАН, включен в состав бюро Совета академии по координации деятельности региональных отделений и региональных научных центров РАН. В 2015 г. одновременно стал заместителем председателя СО РАН по науке.

А.С. Донченко как директор ИЭВСиДВ СО РАСХН, председатель СО РАСХН, руководитель СО аграрных наук ФАНО РФ, заместитель председателя СО РАН многие годы курировал научные направления аграрной науки Сибири, в том числе по животноводству, ветеринарной медицине и переработке сельхозпродукции в Сибирском регионе и на Крайнем Севере, активно занимался вопросами внедрения научных разработок в сельскохозяйственное производство. Его научно-исследовательская деятельность как ученого посвящена проблемам зоонозов домашних животных, созданию научно обоснованных технологий в животноводстве и ветеринарной медицине, разработке новых ветеринарных диагностикумов, систем специфической защиты животных от болезней, созданию противотуберкулезных химиопрепаратов, ветеринарных приборов, селекции типов и пород сельскохозяйственных животных (овец, пантовых оленей и яков).

Для внедрения в животноводство Александром Семеновичем (в соавторстве) предложено более 85 научных разработок, утвержденных Научно-техническим советом и ГУ ДВ, МСХ СССР и РФ, а также научно-техническими советами управлений сельского хозяйства или министерств сельского хозяйства субъектов Сибирского федерального округа и Дальневосточно-

го федерального округа. Кроме того, для сельскохозяйственной практики предложено 80 методических рекомендаций, ТУ, проектов, учебных пособий и учебников, справочников и положений, многие из которых внедрены в сельхозпроизводство субъектов Сибирского региона.

А.С. Донченко участвовал в разработке на основе биотехнологических методов эффективных тест-систем для диагностики туберкулеза, классической чумы свиней, инфекционного ринотрахеита и вирусной диареи крупного рогатого скота. Им предложен высокоэффективный противотуберкулезный химиопрепарат ниазон, с помощью которого оздоровлены от туберкулеза многие неблагополучные по туберкулезу крупного рогатого скота пункты. Совместно с учеными ГНЦВиБ «Вектор» (р.п. Кольцово Новосибирского района) разработаны способы повышения естественной резистентности организма животных с помощью иммуномодуляторов (полирибонат, ридостин). Препараты используются и как адъюванты для повышения протективных свойств слабоиммуногенных вакцин против туберкулеза (БЦЖ) и мыта лошадей. Иммуномодуляторы и технологии их применения внедрены в ветеринарную практику. Многие научные разработки А.С. Донченко защищены авторскими свидетельствами, патентами и селекционными документами Российской Федерации. Как директор ИЭВСиДВ СО РАСХН, заведующий лабораторией туберкулеза животных и заведующий отделом теоретической общей инфектологии, А.С. Донченко помимо выполнения НИР принимал активное участие в освоении новых диагностикумов, ветеринарных препаратов и ветеринарных аппаратов и разнообразных противоэпизоотических систем ветеринарных мероприятий в хозяйствах Сибири, позволяющих профилактировать, купировать и ликвидировать туберкулез, бруцеллез, эпидермит баранов, болезни телят, ринотрахеит и ряд других инфекций. Многие годы он руководил сибирской подсекцией, организованной при ИЭВСиДВ СО РАСХН, секции инфекционных болезней сельскохозяйственных животных Отделения ветеринарной медицины РАСХН.

А.С. Донченко в соавторстве опубликовано 882 научные работы, в том числе более 85 книг, монографий, учебников, справочников, учебных пособий, научно-методических рекомендаций. Научные разработки защищены 30 авторскими свидетельствами, патентами, документами о селекционных достижениях. Он является соавтором Алтае-Саянской породы маралов (2007 г.), типа зугалайский агинской породы овец (2016 г.), типа породы домашних яков – Сарлык (2021 г.). Под его научным руководством и консультацией защищено 23 докторских, 30 кандидатских диссертаций. Ученики А.С. Донченко успешно трудятся в Новосибирской, Омской, Челябинской, Амурской областях, Приморском и Алтайском краях, республиках Саха (Якутия), Алтай, Таджикистане, Казахстане, Монголии и Канаде.

А.С. Донченко как заведующий кафедрой эпизоотологии, микробиологии и паразитологии Новосибирского государственного аграрного университета (1997–2019 гг.) уделял большое внимание подготовке практических ветеринарных специалистов для сибирских субъектов Российской Федерации.

В регионах Сибири многие годы успешно функционировали организованные по предложению А.С. Донченко научно-образовательно-производственные комплексы – новая форма интеграции науки, образования и производства.

Более 20 лет А.С. Донченко исполнял обязанности председателя специализированного совета по защите докторских диссертационных работ при ИЭВСиДВ СО РАСХН и СО аграрных наук ФАНО РФ. На протяжении многих лет он возглавляет редакцию журнала «Сибирский вестник сельскохозяйственной науки», является членом редколлегии четырех других научных журналов (одного зарубежного).

А.С. Донченко был дважды избран депутатом Новосибирского областного совета (1999–2002 гг., 2002–2005 гг.), где занимался научными проблемами сельскохозяйственного производства, развитием природных ресурсов и охраной окружающей среды Новосибирской области.

Председатель СО РАН, академик РАН,
доктор химических наук В.Н. Пармон

Директор СФНЦА РАН, член-корреспондент РАО,
доктор биологических наук К.С. Голохваст

К юбилею Галины Моисеевны Гончаренко

Доктору биологических наук, главному научному сотруднику лаборатории биотехнологии Сибирского научно-исследовательского и проектно-технологического института животноводства (СибНИПТИЖ) СФНЦА РАН Галине Моисеевне Гончаренко 3 мая 2024 г. исполнилось 70 лет.

Галина Моисеевна в 1978 г. закончила Алтайский сельскохозяйственный институт по специальности «Зоотехния». Работала главным зоотехником Быстроистокского совхоза, затем в 1980 г. поступила в аспирантуру при СибНИПТИЖе. В 1987 г. защитила диссертацию на соискание ученой степени кандидата сельскохозяйственных наук, в 2010 г. ею защищена докторская диссертация по специальности 06.07.01 «Разведение селекция, генетика и воспроизводство сельскохозяйственных животных». Галина Моисеевна является ведущим специалистом в области изучения генетики сельскохозяйственных животных, руководит крупной региональной лабораторией по иммуногенетической, молекулярно-генетической экспертизе и селекционному контролю качества молока (свидетельства о регистрации в государственном племенном регистре № 007872, 007919, 007920). При этом особое внимание она уделяет использованию генетических маркеров (группы крови, SNPs) в селекции крупного рогатого скота, свиней, овец. Исследования направлены на решение вопросов по контролю правильности записей происхождения молодняка, выявления маркеров, связанных с продуктивностью, популяционно-генетической характеристикой отдельных популяций, стад, линий. Галина Моисеевна является соавтором породы крупного рогатого скота молочного направления продуктивности Сибирячка (авторское свидетельство № 67216 от 08.02.2018). Она принимала участие в проведении исследований по генетической характеристике породы с использованием иммуногенетического и ПЦР-анализа.

Г.М. Гончаренко успешно подготовила четыре кандидата наук и была руководителем трех выпускных квалификационных работ. В настоящее время она руководит подготовкой двух кандидатских диссертаций.

Галина Моисеевна – член двух диссертационных советов Новосибирского государственного аграрного университета. Неоднократно являлась членом ГАК в НГАУ, научным экспертом Российского фонда фундаментальных исследований и Российской академии наук. Г.М. Гончаренко принимает активное участие в конференциях разного уровня, агрофорумах, семинарах, ведет наставническую деятельность среди молодых специалистов, привлекая их к научно-исследовательской работе.

Результаты исследований Галины Моисеевны опубликованы в более 110 научных работах. Она награждена почетными грамотами губернатора Новосибирской области, департамента агропромышленного комплекса Новосибирской области, министерства образования, науки и инновационной политики Новосибирской области и медалью И.И. Синягина.

Поздравляем Галину Моисеевну с прекрасной юбилейной датой и желаем ей крепкого здоровья, душевных сил для новых свершений и претворения в жизнь своих творческих замыслов, счастья, неиссякаемой энергии, хорошего настроения и всех благ.

Директор СФНЦА РАН, член-корреспондент РАО,
доктор биологических наук К.С. Голохваст,
коллектив СибНИПТИЖа СФНЦА РАН

К 70-летию Виктора Александровича Рогачева

Доктору сельскохозяйственных наук, заведующему лабораторией кормления сельскохозяйственных животных, технологий кормов СибНИПТИЖ СФНЦА РАН Виктору Александровичу Рогачеву 5 мая 2024 г. исполнилось 70 лет.

Виктор Александрович в 1977 г. с отличием окончил Новосибирский сельскохозяйственный институт по специальности «Зоотехния». Сначала он работал младшим научным сотрудником в отраслевой лаборатории технологии производства молока Кемеровского филиала НСХИ, затем 2 года служил в Советской армии командиром огневого взвода гаубичной батареи.

В 1984 г. поступил в очную аспирантуру при СибНИПТИЖе. В 1987 г. защитил диссертацию на соискание ученой степени кандидата сельскохозяйственных наук, в 2005 г. – докторскую диссертацию «Методы повышения питательной ценности кормов и продуктивности сельскохозяйственных животных». Занимаясь научно-исследовательской работой в должности младшего, старшего, ведущего и главного научного сотрудника, заведующего лабораторией, Виктор Александрович зарекомендовал себя высококвалифицированным специалистом с творческим подходом к делу.

Основные направления научно-исследовательской деятельности В.А. Рогачева связаны с разработкой рецептов комбикормов и биотических добавок из местного природного сырья, совершенствованием технологий заготовки объемистых и концентрированных кормов, оптимизацией системы кормления и рационов сельскохозяйственных животных различных видов по нормируемым элементам питания.

В течение многих лет Виктор Александрович занимался оценкой продуктивного и физиологического действия энергопротеиновых добавок (ЭПД), изучением консервирующих свойств электрохимически активированных водно-солевых растворов (ЭАР), поиском эффективных методов инактивации антипитательных соединений фуражного зерна рапса, ржи, сои и других культур, оценкой эффективности использования различных химических реагентов и бактериальных заквасок при заготовке объемистых кормов.

В.А. Рогачев провел длительные комплексные эксперименты по оценке целесообразности применения в климатических условиях Сибири технологии заготовки плющеного фуражного зерна повышенной влажности (восковой спелости), технологии заготовки травяных рулонов с герметичной упаковкой в пленку, занимался совершенствованием технологии производства патоки из зерна различных фуражных культур. Им проведена серия опытов по изучению

влияния новых кормовых добавок на сохранность, продуктивность и физиологические показатели сельскохозяйственных животных различных видов.

Много лет Виктор Александрович занимается разработкой рецептов и оценкой эффективности использования в рационах перепелов кормовых добавок направленного действия, содержащих компоненты, получаемые из природного сырья (скорлупа кедрового ореха, хвоя сосны, радиола розовая, арабиногалактан, облепиха, чага, сапропель и др.). Предложения, сделанные на основе полученных в исследованиях результатов, апробированы в ряде хозяйств Новосибирской области (ОПХ «Элитное», ФГУП «Кремлевское», ОАО «Никольское», ОАО «Большеникольское» и др.). В.А. Рогачев хорошо известен ученым-аграриям и многим руководителям сельскохозяйственных предприятий, поскольку исследования, проводимые им, являются перспективными, а полученные результаты используются в производстве.

В.А. Рогачев – один из авторов книг «Соя в Западной Сибири» и «Животноводство на личном подворье и в крестьянском (фермерском) хозяйстве», шести методических рекомендаций, в которых излагаются теоретические положения и практические методы повышения эффективности сельскохозяйственного производства. Он опубликовал 157 научных работ, имеет 7 патентов Российской Федерации.

Помимо профессиональной деятельности В.А. Рогачев занимается творчеством. Он академик Петровской академии наук и искусств, рекордсмен России в номинации «Рекорды мастеровых России». Им изготовлена уникальная коллекция самых маленьких в России, исторически достоверных образцов древнерусского защитного и наступательного вооружения X–XVII вв., написана и проиллюстрирована книга «Крепка броня на поле брани». Виктор Александрович постоянный участник различных фотоконкурсов: «Природа Сибири», «Природа родного края» и др. Он двукратный победитель Международного фотоконкурса «Мир глазами биолога» (Барнаул) в номинации «Микромир». Имя В.А. Рогачева занесено в книгу «Рекорды и достижения Новосибирска (Новониколаевска)».

Поздравляем Виктора Александровича с юбилеем и желаем ему хорошего самочувствия, удачи, новых успехов в профессиональной и художественной деятельности.

Директор СФНЦА РАН, член-корреспондент РАО,
доктор биологических наук К.С. Голохваст,
коллектив СибНИПТИЖа СФНЦА РАН

AUTHOR GUIDELINES

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

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

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

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

Section name	**Code and name of the scientific specialty in accordance with the Nomenclature of Scientific Specialties, for which academic degrees are awarded**
Agriculture and chemicalization	4.1.1. General agriculture and crop production 4.1.3. Agrochemistry, soil science, plant protection and quarantine
Plant growing and breeding	4.1.1. General agriculture and crop production 4.1.2. Plant breeding, seed production and biotechnology
Plant protection	4.1.3. Agrochemistry, soil science, plant protection and quarantine
Fodder production	4.1.1. General agriculture and crop production 4.1.2. Plant breeding, seed production and biotechnology 4.1.3. Agrochemistry, soil science, plant protection and quarantine
Zootechnics and veterinary medicine	4.2.3. Infectious diseases and animal immunology 4.2.4. Private zootechnics, feeding, technology of feed preparation and production of livestock products 4.2.5. Breeding, selection, genetics, and animal biotechnology
Mechanization, automation, modelling and dataware	4.3.1. Technologies, machinery and equipment for the agro-industrial complex
Agriproducts processing	4.3.3. Food systems
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- an article has not been published before in any other journal;
- an article is not subject to review in any other journal;
- all co-authors agree with the publication of the current version of the article.

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Example wording: "The author declares no conflict of interest".

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8. The main body of the article. When presenting original experimental data, it is recommended to use subheadings:

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Part of a book

Kholmov V.G. Minimum tillage of coulisse-strip fallow for spring wheat with intensification of arable agriculture in southern forest-steppe of Western Siberia// Resource-saving tillage systems. Moscow: Agropromizdat, 1990. pp. 230-235.

Periodical publication

Pakul A.L., Lapshinov N.A., Bozhanova G.V., Pakul V.N. Technological grain qualities of spring common wheat depending on the system of soil tillage // Siberian Herald of Agricultural Science. 2018. vol. 48. № 4. pp. 27-35. DOI: 10.26898/0370-8799-2018-4-4.

REFERENCES (in English):

References are compiled in the same order as the Russian version, according to the following rules:

Names and surnames of the authors are given in the established way of transliteration, English title of the article, *transliteration of the name of the Russian-language source (for example through the site: https://antropophob.ru/translit-bsi) = English title of the source*. The order of presentation for a monograph is the following: city, English name of the publisher, year, number of pages; for a journal: year, number, pages). (In Russian).

Example: Author A.A., Author B.B., Author C.C. Title of article.

Transliteration of the authors. English title of the article.

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

Transliteration of the source = English name of the source

Monograph

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

Part of a book

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

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FOOTNOTES:

Quated $text_1$.

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

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The purpose of the journal is to promptly inform scientists and practitioners of agricultural production about the latest achievements of agricultural science. The "Siberian Herald of Agricultural Science" publishes original articles on fundamental and applied problems in the following areas: general agriculture and crop production; plant breeding, seed production and biotechnology; agrochemistry, soil science, plant protection and quarantine; fodder production; infectious diseases and animal immunology; private zootechnics, feeding, technology of feed preparation and production of livestock products; breeding, selection, genetics, and animal biotechnology; technologies, machinery and equipment for the agro-industrial complex.

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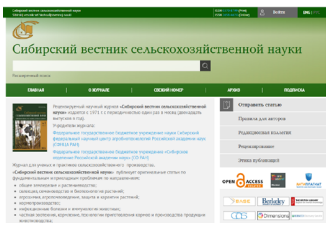

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