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SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

УЧРЕДИТЕЛИ: СИБИРСКИЙ ФЕДЕРАЛЬНЫЙ НАУЧНЫЙ ЦЕНТР АГРОБИОТЕХНОЛОГИЙ РОССИЙСКОЙ АКАДЕМИИ НАУК; СИБИРСКОЕ ОТДЕЛЕНИЕ РОССИЙСКОЙ АКАДЕМИИ НАУК

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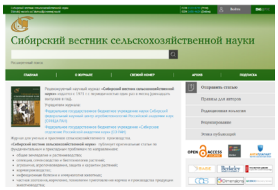

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Наследование основных селекционных признаков реципрокными гибридами ярового ячменя в условиях Красноярской лесостепи

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Приведены результаты изучения наследования основных хозяйственно ценных признаков ячменя в системе реципрокных скрещиваний и оценка по комбинационной способности родительских форм в условиях Красноярской лесостепи в 2023, 2024 гг. Объектами исследований стали шесть сортов ярового ячменя сибирской селекции, один зарубежный сорт и 12 гибридов F_1, созданных на их основе. Почва опытного поля – чернозем обыкновенный маломощный. Предшественник – чистый пар. Содержание гумуса в почве 3,4–4,0%, нитратного азота – 5,3–5,7 мг/кг почвы, фосфора – 18,8–22,2 мг/100 г, калия – 13,7–15,0 мг/100 г почвы. По тепло- и влагообеспеченности 2023 г. отличался засушливыми условиями с ГТК 0,86, в то же время 2024 г. был избыточно увлажненным с ГТК = 1,86. Посев проводили в оптимальные для культуры сроки 25–27 мая. Площадь питания растения 2 × 20 см. Повторность трехкратная. По итогам проведенной оценки достоверно высокую общую комбинационную способность показали сорта только по числу зерен в колосе. Указанный признак наследовался преимущественно по типу положительного сверхдоминирования – 50,0% комбинаций (H_p > +1,00). Сорта ярового ячменя Такмак, Оленек и Талан показали высокую общую комбинационную способность по озерненности колоса (g_i = 0,36–0,96) и меньшую специфическую комбинационную способность (σ = 0,06–0,49) во все годы изучения, что свидетельствует о перспективности использования этих сортов в гетерозисной селекции. Выделены перспективные гибридные комбинации с комплексом хозяйственно ценных признаков: Буян × Саломе, Саломе × Буян, Оленек × Саломе, Саломе × Абалак, Такмак × Саломе, Саломе × Такмак.

Ключевые слова: ячмень, наследование, изменчивость, селекционные признаки, общая комбинационная способность

Inheritance of the main selection traits by reciprocal hybrids of spring barley in the conditions of the Krasnoyarsk forest-steppe

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The results of the study of the inheritance of the main economically valuable traits of barley in the reciprocal crossing system and the assessment of the combination ability of seed parents in the conditions of the Krasnoyarsk forest-steppe in 2023–2024 are presented. The objects of research were 6 varieties of Siberian spring barley, 1 foreign variety and 12 F_1 hybrids created on their basis. The soil of the experimental field was thin common chernozem. The forecrop was complete fallow. The content of humus in the soil was 3,4–4,0%, nitrate nitrogen – 5,3–5,7 mg/kg of soil, phosphorus –

18,8–22,2 mg/100 g of soil, potassium – 13,7–15,0 mg/100 g of soil. In terms of heat and moisture supply, 2023 was characterized by dry conditions with the HTC of 0.86, while 2024 was excessively humidified with the HTC of 1.86. Sowing was carried out at the optimal time for the culture on May 25–27. The feeding area of the plant was 2×20 cm. The repetition was 3-fold. According to the results of the assessment, the varieties showed a reliably high total combination ability only by the number of grains per ear. This feature was inherited mainly by the type of positive overdomination – 50.0% of the combinations (H_p > + 1.00). The varieties of spring barley Takmak, Olenek and Talan showed a high total combination ability by the ear grain content (g_i = 0,36–0,96) and a lower specific combination ability (σ 0,06–0,49) in all years of the study, which indicates the prospects for using these varieties in heterosis selection. Promising hybrid combinations with a complex of economically valuable traits have been identified: Buyan × Salome, Salome × Buyan, Olenek × Salome, Salome × Abalak, Takmak × Salome, Salome × Takmak.

Keywords: barley, inheritance, variability, selection traits, overall combinational ability

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INTRODUCTION

The development and acceleration of the breeding of new high-yielding barley varieties necessitates the use of a comprehensive approach, including both an understanding of the genetic mechanisms that determine productivity and an active search for and utilization of genetic diversity in the source material [1–4]. A key role in this regard is played by the study of the inheritance of the main traits and elements of barley productivity – plant height, productive tillering, the number of grains per ear, the weight of 1000 grains, and grains per plant[1] [5]. The results obtained by various researchers on the inheritance of these selective traits are contradictory. Some authors favor their high heritability and the decisive contribution of seed parents, while others attribute the maximum phenotypic expression of traits to favorable conditions and the interaction of genotype with environment[2–4] [6, 7]. In this regard, for more effective selection of seed parents and further use of selected donors, it is

[1]*Filippov E. G., Paramonov A. V.* Inheritance of quantitative traits of spring barley during the creation of source material in the conditions of the Rostov region // Grain Economy of Russia, 2011, N 4, pp. 47–52.

[2]*Hanifi-Mekliche L., Gallais A.* Heterosis, genetic effects and value of F2s and doubled-haploid lines in barley breeding // Agronomie, 1999, vol. 19 (6), pp. 509–520.

[3]*Shchennikova I., Kokina L., Butakova O.* Combining ability of six row barley varieties // Agricultural Science Euro-North-East, 2010, N 3 (18), pp. 14–17.

[4]*Aniskov N.I.* Selective and genetic aspects in barley feature inheritance in the Western Siberia conditions // Bulletin KrasSAU, 2010, N 6 (45), pp. 51–55.

necessary to study the variability and inheritance of the main economically valuable traits under specific conditions of selection[5] [7–10].

Currently, breeding research is aimed at finding reliable donors not for a single, but for a complex of economically valuable traits. At the same time, the selected donors, while possessing high overall combining ability, should not transmit other negative traits, such as a tendency to lodging in conditions of heavy rainfall, susceptibility to diseases and pests, low drought tolerance, etc. It is worth noting that the inclusion of such reliable donors in crosses significantly increases the efficiency of the breeding process [11–13].

The purpose of the study is to investigate the inheritance and combining ability of spring barley varieties for the main breeding traits of productivity in reciprocal crosses.

MATERIAL AND METHODS

Experiments were conducted in the conditions of an open Krasnoyarsk forest-steppe (UAE "Minino", Krasnoyarsk Krai). The soil is ordinary chernozem, medium-deep, low-humus, heavy loamy soil with evidence of wind and water erosion. In 2023, the soil was characterized by a low humus content (according to Tyurin) of 4.0%, a low nitrate nitrogen content (N-NO_3) (rapid ionometric method) of 5.3 mg/kg of soil, a very high content of available phosphorus (P_2O_5) of 22.2 mg/100 g of soil, and a high exchangeable potassium (K_2O) content of 15.0 mg/100 g. In 2024, low humus (3.4%) and N-NO_3 (5.7 mg kg soil) contents were recorded, along with high P_2O_5 (18.8 mg/100 g) and K_2O (13.7 mg/100 g) contents. The soil solution pH in the aqueous extract during the study years was neutral – 6.1. The forecrop was complete fallow.

The agrometeorological conditions of the growing seasons during the study years varied greatly, which made it possible to evaluate the F_1 hybrids under a variety of conditions. Overall, 2023 turned out to be relatively dry, with an HTC of 0.86 for the entire period (see Table 1). Drought was observed quite frequently in the first and second ten-day periods of May (0.62 and 0.53, respectively), the first ten-day period of June (0.27), the first ten-day period of July (0.11), and the first and third ten-day periods of August (0.05 and 0.19). Insufficient moisture for vegetation was observed only in the third ten-day period of June (1.01) and the second ten-day period of July (0.93). The 2024 growing season, unlike 2023, was characterized by excess moisture with a HTC of 1.86. Drought conditions were observed only in the second ten-day period of May (0.40) and the third ten-day period of June (0.00); all other periods were sufficiently and excessively moist. Despite abundant precipitation, the influence of increased heat supply contributed to a shortened growing season and, as a result, the formation of reduced productivity of varieties and hybrids.

The crossings were carried out in 2022 using the castration method with forced pollination. For this purpose, six varieties of Siberian selection, included in the State Register of Breeding Achievements mainly for Western and Eastern

Табл. 1. Фактические показатели ГТК за вегетационный период по декадам месяца
Table 1. Actual HTC indicators for the vegetation period by ten-day periods of the month

Year	May			June			July			August			For vegetation
	I	II	III	I	II	III	I	II	III	I	II	III	
2023	0,62	0,53	2,47	0,27	1,13	1,01	0,11	0,93	1,37	0,05	1,60	0,19	0,86
2024	1,10	0,40	1,30	1,60	3,10	0,00	2,40	4,20	3,90	1,20	1,90	1,20	1,86
Long-time average annual	1,14	0,96	1,10	0,84	1,05	1,10	1,00	1,39	1,86	1,08	1,58	1,14	1,19

[5] *Filippov E.G., Alabushev A.V.* Breeding spring barley: monograph. Rostov on Don: ZAO “Kniga”, 2014, 208 p.

Siberia in different years, were used: Buyan (Kedr × Jo 1345, 2012), Abalak (U-53-8515 × Sa 46925, 2013), Olenek (U-101-1112 × Acha, 2014), Tanai (G-20275 × G-20191, 2014), Talan (Nutans 86 × G-20397, 2016), Takmak (Priazovsky 9 × U-20-704, 2019) and one variety of German selection Salome (2016). According to data from previous ecological variety trials conducted in 2021–2023, Siberian-bred varieties are characterized by a growing season of 69–98 days, a 1,000-grain weight of up to 46.4 g, and a yield of up to 5.44 t/ha. The choice of the Salome variety as one of the seed parent varieties was primarily due to its short stem height (52.4–58.5 cm), lodging resistance under local conditions, synchronized shoot development, and grain size (up to 50.3 g). However, some disadvantages include lower drought tolerance and sensitivity to nutrient deficiencies in the soil. As a result of the conducted crosses, 12 reciprocal F_0 combinations were obtained. F_1 hybrids and parental forms were sown manually in rows 1.5 m long at the optimal time for the crop, May 25–27, in 2023 and 2024. The feeding area of an individual plant was 2 × 20 cm. Three replicates were performed.

After harvesting, the yield structure elements were analyzed and the traits inheritance patterns were determined. Hypothetical and competitive heterosis were determined using the D.S. Omarov's method[6], and general and specific combining ability were determined according to B. Griffing[7] using the DIAS[8] program. The Takmak variety was used as the standard for calculating competitive heterosis.

RESULTS AND DISCUSSION

The results of the two-factor analysis of variance showed that in the conditions of the Krasnoyarsk forest-steppe, the contribution of variance to the total variability of all traits for the genotype factor ranged from 7.76 to 35.92%, for year conditions 1.97–6.86, the interaction of both factors – 15.01–76.64, and random factors – 11.48–64.11% (see Table 2).

Along with this, a reliable influence of genotype on plant height and the number of grains per ear was noted – 35.92 and 14.62%, respectively, with a fairly high influence of the interaction of both factors – 40.27 and 59.20 with an insignificant manifestation of the conditions of the year – 4.43 and 4.19%. In contrast, the weight of 1000 grains was determined to a lesser extent by the genotype and environment (7.76 and 4.12%) with a significant contribution of the combined action of these factors (76.64%). The obtained pattern is explained by the variation in the indicators of varieties and hybrids, different systems of genetic control of traits and vegetation conditions.

When studying the nature of inheritance of the main selection traits in the system of reciprocal crossings, overdominance or true heterosis ($H_p > +1.00$) prevailed – 50.0–100.0%, while incomplete dominance of the trait of the best parent ($H_p = +0.5–1.00$) – 8.0–42.0, intermediate inheritance ($H_p = –0.5… + 0.5$) – 17.0–25.0, depression ($H_p < –1.00$) – 8.0% (see Table 3) were less common.

Assessment of the inheritance of the main breeding traits closely related to yield revealed a lack of reliability and inconsistency in the overall combining ability for most varieties in different years. At the same time, a number of varieties were identified that had a consistent advantage in the number of grains per ear in all years of the study. Given the greatest significance of the ear grain content in determining barley productivity [14], we further examine the results of the inheritance pattern and combining ability of this trait.

The resulting hybrids showed, on average, a wide dominance coefficient (H_p) over 2 years – from –3.2 to +24.8 (see Table 4). Thus, the inheritance pattern of the number of grains per ear var-

[6]*Omarov D.S.* On the methodology of recording and evaluating plant heterosis // Agricultural biology, 1975. vol. 10, N 1, pp. 699–702.

[7]*Griffing B.* Concept of general and specific combining ability in relation to diallel crossing systems // Australian J. Biol. Sci., 1956, vol. 9, N 4, pp. 463–493. DOI: 10.1071/BI9560463.

[8]*Aleinikov A.F., Stepochkin P.I., Grebennikova I.G.* Diallel analysis in breeding of agricultural crops. Novosibirsk: SibFTI Russian Agricultural Academy, 2011, 10 p.

Табл. 2. Результаты двухфакторного дисперсионного анализа основных количественных признаков ячменя в реципрокных скрещиваниях (2023, 2024 гг.)

Table 2. Results of two-factor analysis of variance of main quantitative features of barley in reciprocal crosses (2023, 2024)

Dispersion	Sum of squares	Degree of freedom	Proportion of variation, %	Mean-square value	$F_ф$	F_{05}
Plant height						
Total	4178	113	100,00	36,98	–	–
Genotype A	1501	18	35,92	83,38	7,82	1,85
Year B	185	1	4,43	184,94	17,35	4,03
Interaction AB	1683	18	40,27	93,48	8,77	1,85
Error	810	76	19,39	10,66	–	–
Productive tillering						
Total	44	113	100,00	0,39	–	–
Genotype A	8,3	18	18,91	0,46	1,25	1,85
Year B	0,9	1	1,97	0,86	2,33	4,03
Interaction AB	7	18	15,01	0,37	0,99	1,85
Error	28	76	64,11	0,37	–	–
Number of grains per ear						
Total	850	113	100,00	7,52	–	–
Genotype A	124	18	14,62	6,91	2,81	1,85
Year B	36	1	4,19	35,65	14,49	4,03
Interaction AB	503	18	59,20	27,97	11,37	1,85
Error	187	76	21,99	7,53	–	–
Weight of 1000 grains						
Total	10289	113	100,00	91,06	–	–
Genotype A	799	18	7,76	44,38	2,86	1,85
Year B	424	1	4,12	423,87	27,28	4,03
Interaction AB	7886	18	76,64	438,10	28,19	1,85
Error	1181	76	11,48	15,54	–	–
Weight of grain per plant						
Total	127	113	100,00	1,12	–	–
Genotype A	12	18	9,73	0,69	1,23	1,85
Year B	9	1	6,86	8,68	15,60	4,03
Interaction AB	63	18	49,95	3,51	6,30	1,85
Error	42	76	33,46	0,56	–	–

Табл. 3. Характер наследования количественных признаков у реципрокных гибридов ячменя F_1 (2023, 2024 гг.)

Table 3. Inheritance pattern of quantitative traits in reciprocal F_1 barley hybrids (2023, 2024)

Trait	Mode of inheritance				
	Depression	Intermediate	Overdominance	Incomplete parental dominance	
				best	worst
Plant height	–	17,0	58,0	25,0	–
Productive tillering	–	25,0	75,0	–	–
Number of grains per ear	8,0	–	50,0	42,0	–
Weight of 1000 grains	–	–	100,0	–	–
Weight of grain per plant	–	–	92,0	8,0	–

ied from depression to positive overdominance. Moreover, the most common inheritance of the number of grains per ear occurred according to the positive overdominance pattern – 50.0% of combinations (H_p > +1.00), indicating control of the trait by genes with dominant action. In 42.0%, incomplete dominance of the trait of the best parent was noted (H_p = +0.5…+1.00), and depression was detected in 8.0% (H_p < –1.00). Due to the greater influence of the genotype-environment interaction compared to the genotype and year conditions, the hybrids Salome × Olenek, Abalak × Salome, Salome × Abalak, Takmak × Salome, Salome × Takmak, Talan × Salome showed overdominance with a phenotypic expression of the trait (21.2–22.4 grains per ear) and a true heterosis index of 1.3–16.6%. One of the important criteria is the superiority of the hybrid over the standard variety. In our study, only the combination Buyan × Salome showed the maximum value of competitive heterosis in terms of grain content per ear – 2,9%.

The results showed reliable differences in F_1 hybrids in all years of the study both in general and specific combining ability at the 95% significance level, however, the influence of the reciprocal effect was insignificant. In 2023 and 2024, the share of GCA influence was 19.45; 13.02%, SCA - 75.42; 79.64, RE - 5.13; 7.33%, respectively. In general, in the crosses, an advantage in the inheritance of the trait of dominant or epistatic effects of genes (GCA < SCA) was noted. In the varieties Takmak, Olenek and Talan, in the inheritance of the number of grains in an ear, genes with an additive effect (GCA> SCA) play a predominant role, in the varieties Buyan, Salome, Abalak and Talan, genes of a dominant or epistatic effect were shown (GCA <SCA) (see Figs. 1, 2).

From the data presented, it is evident that the varieties Takmak, Olenek and Talan have a reliably high general combining ability (*gi* = 0.36–0.96) for ear grain content, while Buyan, Salome and Tanai have a low one, since the GCA values are lower than the LSD_{gi} = 0.31 and 0.34. The maximum GCA estimate indicates the potential of using these varieties to obtain hybrids with a high heterosis effect.

Based on the greatest number of economically valuable traits for further selection of spring barley, the hybrids Buyan × Salome, Salome × Buyan, and Olenek × Salome were selected. They had an average plant height of 65.3–67.4 cm, high productive tillering of 2.6–

Табл. 4. Типы наследования числа зерен в колосе у гибридов ячменя F_1 (2023, 2024 гг.)
Table 4. Types of grain number inheritance per ear in F_1 barley hybrids (2023, 2024,

Combination of crosses	Number of grains per ear, pcs.			$G_{ист.}$, %	$G_{конк}$, %	H_p
	P♀	F_1	P♂			
Buyan × Salome	24,4	23,3	17,4	–4,7	2,9	+0,7
Salome × Буян	17,4	22,7	24,4	–7,2	0,3	+0,5
Olenek × Salome	21,9	21,6	17,4	–1,2	–4,3	+0,9
Salome × Olenek	17,4	22,1	21,9	1,1	–2,1	+1,1
Abalak × Саломе	18,2	21,2	17,4	16,6	–6,3	+8,5
Salome × Abalak	18,0	20,5	18,2	13,1	–9,1	+24,8
Takmak × Salome	21,8	22,4	18,0	2,8	–1,0	+1,3
Salome × Takmak	18,0	22,4	21,8	2,8	–1,0	+1,3
Tanai × Salome	20,7	20,0	18,0	–3,1	–11,4	+0,5
Саломе × Tanai	21,6	19,6	20,7	–9,2	–13,1	–3,2
Talan × Salome	18,4	21,9	21,6	1,3	–3,0	+1,2
Salome × Talan	21,6	21,0	18,4	–3,0	–7,2	+0,6
LSD_{05}		1,0				

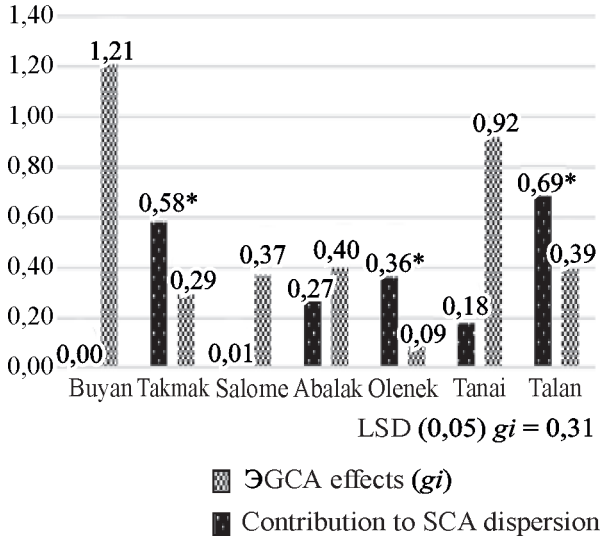

Рис.1. Комбинационная способность родительских форм ячменя по признаку «число зерен в колосе», 2023 г.

Fig. 1. Combination ability of seed parents of barley on the trait of the "number of grains per ear", 2023

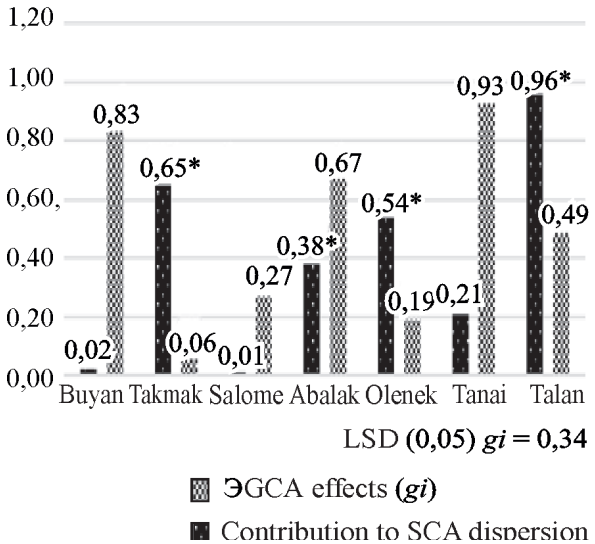

Рис. 2. Комбинационная способность родительских форм ячменя по признаку «число зерен в колосе», 2024 г.

Fig. 2. Combination ability of seed parents of barley on the trait of the "number of grains per ear", 2024

2.8 pcs., 1000-grain weight of 43.3–50.9 g, and grain weight per plant of 2.3–2.6 g. Hybrid combinations Salome × Abalak, Takmak × Salome, and Salome × Takmak, along with the number of grains per ear (20.5–22.4 pcs.), positively combined productive tillering (2.5–2.6 pcs.), 1000-grain weight (42.9–46.2 g), and grain weight per plant (2.1–2.4 g).

CONCLUSIONS

1. In the Takmak, Olenek and Talan varieties, which are involved in the crosses based on the "number of grains per ear" trait, the predominant role is played by the genes with an additive effect (GCA> SCA), while in the Buyan, Salome, Abalak and Talan varieties, the predominant role is played by the genes with a dominant or epistatic effect (GCA <SCA).

2. In the conditions of the Krasnoyarsk forest-steppe, the spring barley varieties Takmak, Olenek and Talan showed high general combining ability (*gi* = 0.36–0.96) in terms of ear grain content, as well as low to medium specific combining ability (σ = 0.06–0.49), which indicates the potential of using these varieties to obtain hybrids with a high heterosis effect.

3. In practical breeding, the most promising hybrid combinations of barley for selection are those that combine the maximum number of economically valuable traits: Buyan × Salome, Salome × Buyan, Olenek × Salome, Salome × Abalak, Takmak × Salome, Salome × Takmak.

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Влияние салициловой кислоты на всхожесть и морфологические показатели сортов яровой твердой пшеницы на фоне осмотического стресса

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Целью исследований являлось изучение посевных качеств семян, морфологических показателей проростков различных сортов яровой пшеницы при предпосевной обработке семян салициловой кислотой в условиях достаточного увлажнения и на фоне осмотического стресса. Материалом для исследований послужили семена сортов пшеницы яровой твердой (*Triticum durum* Desf.) (Безенчукская 210, Оренбургская 10, Безенчукская золотистая, Кремень), салициловая кислота, ПЭГ 6000 (полиэтиленгликоль). Обработка семян салициловой кислотой на стадии ювенильного развития не оказала существенного влияния на показатели энергии прорастания и всхожести семян, но способствовала увеличению массы корешков у сортов Кремень (на 15%), Безенчукская 210 (на 13,3%), Оренбургская 10, Безенчукская золотистая (на 1,8%). В варианте с применением полиэтиленгликоля показатели посевных качеств семян снизились на 5–10%. У сорта Оренбургская 10 снижение составило по энергии прорастания и всхожести соответственно 8 и 10%, у остальных сортов – 5–7%. Применение салициловой кислоты нивелировала негативное влияние искусственно созданной засухи на посевные качества семян и морфологию проростков. В условиях искусственно созданной засухи обработка салициловой кислотой способствовала увеличению среднего числа корешков на 2,9% (кроме сорта Оренбургская 10) и массы корешков одного проростка от 6,2 до 18,7% (исключение – сорт Кремень); средней длины и массы ростков на сорте Безенчукская золотистая на 33,5 и 42,8% соответственно и на сорте Оренбургская 10 на 18,3 и 30,7% соответственно. У остальных сортов длина ростков увеличилась на 2,0 и 8,8%.

Ключевые слова: пшеница твердая (*Triticum durum* Desf.), салициловая кислота, полиэтиленгликоль (ПЭГ), масса ростков, число корешков, масса корешков

Influence of salicylic acid on germination and morphological parameters of spring durum wheat varieties under osmotic stress

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The purpose of the research was to study the sowing qualities of seeds, morphological parameters of seedlings of various varieties of spring wheat during pre-sowing treatment of seeds with salicylic acid under conditions of sufficient moisture and against the background of osmotic stress. The materials for the research were: seeds of durum spring wheat varieties (*Triticum durum* Desf.) (Bezenchukskaya 210, Orenburgskaya 10, Bezenchukskaya zolotistaya, Kremen) salicylic acid, PEG 6000 (polyethylene glycol). Seed treatment with salicylic acid at the stage of juvenile development did not significantly affect the energy of seed sprouting and germination, but contributed to an increase in root weight in the varieties Kremen (by 15%), Bezenchukskaya 210 (by 13.3%), Orenburg 10, Bezenchukskaya zolotistaya (by 1.8%). In the variant with the use of polyethylene glycol, the indicators of seed sowing qualities decreased by 5–10%. In the Orenburg 10 variety, the decrease was 8 and 10% in sprouting energy and germination, respectively, and 5–7% in other varieties. The use of salicylic acid offset the negative impact of artificially created drought on the sowing qualities of seeds and the morphology of seedlings. Under artificially created drought conditions, treatment with salicylic acid

contributed to an increase in the average number of rootlets by 2.9% (except for the Orenburgskaya 10 variety) and the rootlet weight of 1 sprout from 6.2% to 18.7% (except for the Kremen variety); the average length and weight of sprouts on the Bezenchukskaya zolotistaya variety by 33.5 and 42.8%, respectively, and on the Orenburgskaya 10 variety by 18.3 and 30.7%, respectively. For the remaining varieties, the sprout length increased by 2.0 and 8.8%.

Keywords: *Triticum durum* Desf (durum wheat), salicylic acid, polyethylene glycol (PEG), sprout mass, number of rootlets, rootlet weight

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Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

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INTRODUCTION

The study area is located within the steppe zone of the Southern Urals on the southeastern edge of European Russia. The zone is characterized by a sharply continental climate, with dry, hot summers and unstable and insufficient moisture, as well as low freezing temperatures in winter. In addition to aridity, this area is characterized by saline soils. Excessive salts in the soil are known to reduce the morphological characteristics of seedlings. Varietal specificities in response to salinity conditions have also been established.

Thus, research by L.I. Fedoreeva et al. [1] has established a higher salt tolerance of the spring wheat variety Orenburgskaya 22 than the variety Uchitel. For agriculture in the Orenburg region, adaptation measures are being considered, including the introduction of moisture-saving technologies, expansion of drought-resistant crops, and expansion of irrigated areas. Modern agricultural cultivation technologies focus on the use of growth regulators and biologically active substances that are safe for human health and the environment. Numerous studies have shown that the exogenous application of various growth regulators, such as hormones, hormone antagonists, polyamines, nutrients, antioxidants, and others, helps improve the drought tolerance of agricultural crops [2, 3].

One of the acceptable ways to improve the vital activity of plants and increase their productivity in unfavorable environmental conditions is pre-sowing seed treatment [4, 5].

Salicylic acid (SA) is a phytohormone that is safe for humans and the environment and is particularly important for plant adaptation to stress factors [6]. SA is capable of increasing respiratory activity and resistance to cyanide by releasing heat. Its synthesis begins with the conversion of phenylalanine to trans-cinnamic acid, which is catalyzed by the enzyme phenylalanine ammonium lyase. Cinnamic acid is then converted to benzoic or orthocoumaric acid, which then forms the derivative SA. It is an adaptogen, meaning it functions as both a signaling molecule and a stress-suppressing phytohormone. It influences seed germination, vegetative growth, aging, flowering, and fruit yield.

Activation of growth processes is observed at low concentrations and inhibition at high concentrations.

According to A.V. Yakunina [7], low concentrations of salicylic acid increase seed ger-

mination, while the use of higher concentrations (0.05–0.50 mM) increases the size or weight of seedlings. Exogenous use of SA affects a wide range of physiological processes in plants, including photosynthesis and growth rate. The growth-promoting effect of low concentrations of SA has been recorded for crops such as okra, corn, wheat, tomato, and mustard [8].

The literature provides the results of experiments indicating the role of SA in the adaptive responses of plants to abiotic stresses: resistance to drought, salinity, heavy metals, and the effects of low temperatures [9].

The combined use of *Pseudomonas putida* and salicylic acid promotes stress tolerance in plants and improves plant growth. They have significant effects on germination and morphological, physiological, and biochemical parameters [10]. The use of biochar in combination with salicylic acid is recommended as an effective strategy for mitigating the harmful effects of salt stress on soybeans [11]. Pre-sowing treatment of wheat seeds with SA reduces water loss and cell membrane permeability under water stress conditions, increasing drought tolerance in wheat seedlings. Drought affects grain yield and quality. Disruptions to physiological and biochemical processes affect plant growth, anatomy, and morphology. Polyethylene glycol (PEG), a polymer preparation that virtually does not penetrate plant tissue, is widely used to simulate water stress. PEG 6000 molecules are inert, non-toxic, large enough to be absorbed by plants, and do not disrupt the water structure during the experimental period. To determine the drought tolerance of genotypes, this osmotic agent is used on various crops, such as millet, peas, wheat, sorghum, and barley [12, 13].

The purpose of the research is to study the sowing qualities of seeds, morphological indicators of seedlings of different varieties of spring durum wheat with pre-sowing treatment of seeds with salicylic acid under conditions of sufficient moisture and against the background of osmotic stress.

MATERIAL AND METHODS

The experiment examined two factors:

1. Factor A – varieties of spring hard wheat:
– Orenburgskaya 10 – control;
– Bezenchukskaya 210;
– Bezenchukskaya zolotistaya;
– Kremen.
2. Factor B – pre-sowing seed treatment:
– distilled water – control – 10 l/t of seeds;
– salicylic acid at a concentration of 0.05 mM;
– polyethyleneglycol (PEG 6000) with an osmotic pressure of 0.15 MPa;
– salicylic acid (0.05 mM) + PEG 6000 (0.15 MPa).

Wheat seeds were pre-soaked for 3 hours in a salicylic acid solution. To prepare the working solution, salicylic acid was dissolved in distilled water heated to 80°C.

Polyethylene glycol (PEG 6000) is a polymer based on ethylene glycol with a molar mass of 6000 units in the form of waxy flakes or a dense white mass. PEG 6000 - 100 g / l corresponds to 0.15 MPa.

The seeds were germinated in germination chambers between layers of filter paper in a TSO 1M thermostat at a temperature of 20 ± 2 °C in the dark, pre-treated with the studied preparations according to the experimental design, in quadruplicate, with 25 seeds in each replicate. Germination energy was calculated on the third day, and germination capacity was calculated on the seventh day (GOST 12038–84). Along with the determination of germination energy, the number of rootlets, their weight and length, and the number and weight of sprouts were counted. The reliability of sample means was assessed according to B.A. Dospekhov.

RESULTS AND DISCUSSION

Laboratory experiments revealed that treating seeds with salicylic acid at the juvenile stage had no significant effect on germination energy or viability. A slight (1–2%) increase in these parameters was noted in the Kremen and Bezenchukskaya zolotistaya varieties compared to the control samples.

In the polyethylene glycol-treated variant, seed quality indicators significantly decreased.

For the Orenburgskaya 10 variety, the reduction in germination energy and viability was 8% and 10%, respectively; for the other varieties, the reduction was between 5% and 7%.

The combined use of salicylic acid and polyethyleneglycol increased the studied seed quality parameters relative to the variant using PEG 6000. For the Orenburgskaya 10 and Bezenchukskaya zolotistaya varieties, germination energy and viability increased by 2 and 5%, respectively. For the Kremen and Bezenchukskaya 210 varieties, seed quality increased slightly. The data are presented in Table 1.

A significant increase in the average root length of seedlings under the influence of salicylic acid was obtained compared to the control in the Kremen and Bezenchukskaya 210 varieties (by 15.0 and 13.3%, respectively). In the Orenburgskaya 10 and Bezenchukskaya zolotistaya varieties, the increase in root length for this trait was significantly lower (by 1.8%). The suppressive effect of polyethylene glycol on the average root length was significantly manifested in all the studied varieties, and the decrease was, in descending order: Bezenchukskaya 210 (26.0%), Bezenchukskaya zolotistaya (18.0%), Orenburgskaya (10.8%), and Kremen (10.2%).

Treatment of spring durum wheat seeds with salicylic acid had basically no effect on the rootlet weight and the average number of rootlets per seedling. A slight increase in the rootlet weight per seedling was observed for the Bezenchukskaya 210 (9.8%) and Orenburgskaya 10 (4.0%) varieties. In the variants with the use of polyethylene glycol, the average number of rootlets per seedling for all studied varieties decreased significantly compared to the control variants. Under induced drought conditions, the use of salicylic acid contributed to an increase in the average number of rootlets by 2.9% (except for the Orenburgskaya 10 variety) and the rootlet weight per seedling from 6.2 to 18.7% (except for the Kremen variety). The data are presented in Table 2.

Treatment of durum wheat seeds with salicylic acid contributed to an increase in sprout length and weight. The greatest increase in sprout weight was obtained for the Bezenchukskaya 210 (26.1%) and Kremen (11.5%) varieties. A moderate increase in sprout weight was observed for the Orenburgskaya 10 (4.0%) and Bezenchukskaya zolotistaya (6.7%) varieties compared to the control samples. An increase in sprout length was noted for the Kremen, Bezenchukskaya 210, and Bezenchukskaya zolotistaya varieties, while the use of polyethylene glycol contributed to a decrease in average sprout length by 52.7–66.2% and sprout weight by 46.7–69.2% compared to the control.

Under artificially induced drought conditions, treatment with salicylic acid increased the average shoot length and weight by 33.5% and

Табл. 1. Всхожесть и энергия прорастания семян при использовании салициловой кислоты и ПЭГ 6000, %

Table 1. Germination and energy of seed germination when using salicylic acid and PEG 6000, %

Variety / experimental variant	Germination energy	Viability
Kremen		
Control	95	96
Salicylic acid	97	97
PEG 6000	89	90
Salicylic acid + PEG 6000	90	91
Orenburgskaya 10		
Control	93	94
Salicylic acid	94	94
PEG 6000	83	86
Salicylic acid + PEG 6000	85	91
Bezenchukskaya 210		
Control	95	97
Salicylic acid	96	97
PEG 6000	89	90
Salicylic acid + PEG 6000	91	92
Bezenchukskaya zolotistaya		
Control	93	95
Salicylic acid	94	97
PEG 6000	88	90
Salicylic acid + PEG 6000	90	95
$LSD_{0,5}$	3,88	2,39
$LSD_{0,5}$ A (variety)	2,74	1,69
$LSD_{0,5}$ B (experimental variant)	2,74	1,69
$LSD_{0,5}$ AB	2,74	1,69

42.8%, respectively, compared to the PEG 6000 treatment, and by 18.3% and 30.7%, respectively, for the Orenburgskaya 10 variety. For the remaining varieties, shoot length increased by 2.0% and 8.8%, and average weight by 5.5% and 7.1%. The data are presented in Table 3.

Calculating the influence of the studied factors on changes in seed and sprout quality indicators revealed that the "treatment option" factor makes the largest contribution, ranging from 36.57% (germination energy) to 73.40% (sprout weight). It should be noted that the "variety" factor also has a significant impact on rootlet count.

CONCLUSION

Under induced drought conditions, a decrease in sprouting energy and germination, as well as a reduction in shoot length, weight, and root length, is observed. The use of salicylic acid reduces the negative impact of artificially induced drought on seed germination quality and seedling morphology in durum wheat. Furthermore, germination energy and germination of the studied varieties increased by 1–5%, while the average shoot length and weight increased by 33.5% and 42.8%, respectively, for the Bezenchukska-

Табл. 2. Показатели корневой системы 3-дневных проростков сортов яровой твердой пшеницы
Table 2. Indicators of the root system of 3-day-old seedlings of spring durum wheat varieties

Variety / experimental variant	Average length of one rootlet, cm	Average number of roots per sprout, pcs.	Weight of roots of one sprout, g
Kremen			
Control	4,07 ± 0,15	4,3 ± 0,37	0,30 ± 0,02
Salicylic acid	4,68 ± 0,14	4,3 ± 0,19	0,30 ± 0,01
PEG 6000	3,63 ± 0,16	3,5 ± 0,28	0,20 ± 0, 04
Salicylic acid + PEG 6000	3,83 ± 0,15	3,6 ± 0,18	0,20 ± 0,01
Orenburgskaya 10			
Control	4,52 ± 0,16	4,5 ± 0,29	0,25 ± 0,02
Salicylic acid	4,60 ± 0,12	4,5 ± 0,23	0,26 ± 0,03
PEG 6000	4,06 ± 0,14	3,4 ± 0,55	0,16 ± 0,03
Salicylic acid + PEG 6000	4,26 ± 0,13	3,4 ± 0,18	0,19± 0,05
Bezenchukskaya 210			
Control	3,77 ± 0,12	4,8 ± 0,13	0,31 ± 0,04
Salicylic acid	4,27 ± 0,13	4,9 ± 0,04	0,34 ± 0,01
PEG 6000	2,79 ± 0,11	4,2 ± 0,23	0,16 ± 0,02
Salicylic acid + PEG 6000	2,92 ± 0,13	4,3 ± 0,46	0,17 ± 0,06
Bezenchukskaya zolotistaya			
Control	4,50 ± 0,15	4,8 ± 0,28	0,35 ± 0,04
Salicylic acid	4,58± 0,11	4,8 ± 0,18	0,35 ± 0,06
PEG 6000	3,69 ± 0,15	4,4 ± 0,32	0,22 ± 0,02
Salicylic acid + PEG 6000	3,84 ± 0,13	4,5 ± 0,08	0,25 ± 0,02
$LSD_{0,5}$	-	0,26	0,26
$LSD_{0,5}$ A (variety)		0,18	0,18
$LSD_{0,5}$ B (experimental variant)		0,18	0,18
$LSD_{0,5}$ AB		0,18	0,18

Табл. 3. Показатели проростков яровой твердой пшеницы на фоне контрольного и опытных вариантов

Table 3. Indicators of spring durum wheat seedlings against the background of control and experimental variants

Variety / experimental variant	Average sprout length, cm	Average sprout weight, g
	Kremen	
Control	2,40 ± 0,08	0,26 ± 0,02
Salicylic acid	2,71 ± 0,09	0,29 ± 0,04
PEG 6000	1,59 ± 0,08	0,18 ± 0,05
Salicylic acid + PEG 6000	1,73 ± 0,11	0,19 ± 0,02
	Orenburgskaya 10	
Control	2,83 ± 0,08	0,25 ± 0,01
Salicylic acid	2,83 ± 0,08	0,26 ± 0,02
PEG 6000	1,64 ± 0,10	0,13 ± 0,01
Salicylic acid + PEG 6000	1,94 ± 0,09	0,17 ± 0,03
	Bezenchukskaya 210	
Control	2,01 ± 0,04	0,23 ± 0,03
Salicylic acid	2,57 ± 0,05	0,29 ± 0,01
PEG 6000	1,47 ± 0,06	0,12 ± 0,01
Salicylic acid + PEG 6000	1,50 ± 0,08	0,15 ± 0,03
	Bezenchukskaya zolotistaya	
Control	2,79 ± 0,06	0,30 ± 0,02
Salicylic acid	2,93 ± 0,05	0,32 ± 0,04
PEG 6000	1,61 ± 0,08	0,14 ± 0,03
Salicylic acid + PEG 6000	2,15 ± 0,08	0,20 ± 0,03
$LSD_{0,5}$		0,03
$LSD_{0,5}$ A (variety)	-	0,02
$LSD_{0,5}$ B (experimental variant)		0,02
$LSD_{0,5}$ AB		0,02

ya zolotistaya variety and by 18.3% and 30.7%, respectively, for the Orenburgskaya 10 variety. In the remaining varieties, the length of sprouts increased by 2.0 and 8.8%, the average weight by 5.5 and 7.1%, the average number of roots by 2.9% (except for the Orenburgskaya 10 variety) and the weight of roots of one sprout by 6.2–18.7% (the exception is the Kremen variety).

The greatest contribution to the change in the quality indicators of seeds and their sprouts is made by the factor of seed treatment with salicylic acid, PEG 6000. The indicators ranged from 36.57% for germination energy to 73.40% for sprout weight.

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Получение мини-клубней картофеля на основе системы капельного полива

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В июне – сентябре 2024 г. с применением системы капельного полива в условиях контролируемой среды проведено исследование по выращиванию рассадным способом оздоровленных в культуре *in vitro* микрорастений шести районированных сортов картофеля разных групп спелости (Любава, Памяти Аношкиной – раннеспелые, Кемеровчанин, Невский, Танай – среднеранние, Тулеевский – среднеспелый). Растения размещали в 7-литровых сосудах, заполненных торфяным субстратом. Изучение проводили в течение 112 дней при температуре в помещении 19–22 °С, относительной влажности воздуха 70–85% и продолжительности фотопериода 16 ч. Взаимодействие созданных в лаборатории гидротермических условий и режима освещенности позволило достичь 99%-й приживаемости растений и хороших морфометрических показателей. Получены абсолютные и средние значения количественного выхода и продуктивности надземных побегов растений и мини-клубней. Установлено, что длина надземных побегов у исследуемых сортов картофеля получила наибольшее развитие до начала цветения (85–91%). Рост надземных побегов в длину заметно снижался к периоду формирования мини-клубней и составлял не более 23%. Растения с надземными побегами длиной 109–133 мм сформировали за вегетационный период 148–205 г зеленой массы. При этом ежесуточный прирост стебля у сортов составил 0,5–1,4 см. С одного растения по сортам было максимально получено от 4 до 10 мини-клубней, в среднем – от 2 до 4 шт. Из всего полученного количества мини-клубней (1113 шт.) 84,4% были морфологически сформированными для дальнейшего размножения. Средняя масса клубней с одного растения составила 56–146 г, средняя масса одного клубня – 20–69 г. Наибольшая средняя масса одного клубня зафиксирована у сортов Невский (42 г) и Любава (69 г) при диаметре клубней 49 и 61 мм. Применение капельного полива и регулируемой освещенности при выращивании мини-клубней районированных сортов картофеля позволило обеспечить выход до 71,0–89,8% стандартной фракции (9–60 мм), отвечающей требованиям ГОСТ 33996–2016.

Ключевые слова: картофель, районированные сорта, надземные побеги, мини-клубни, капельный полив, продуктивность

Production of potato minitubers using a drip irrigation system

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In June – September 2024, using a drip irrigation system in a controlled environment, a study was conducted on growing *in vitro* cultured micro plants of six released potato varieties of different maturity groups (Lyubava, Pamyati Anoshkinoi – early-maturing, Kemerovchanin, Nevsky, Tanai – middle-early, Tuleyevsky – medium-maturing) using the seedling method. The plants were placed in

7-liter vessels filled with peat substrate. The study was conducted for 112 days at a room temperature of 19–22 °C, relative air humidity of 70–85%, and a photoperiod duration of 16 hours. The interaction of hydrothermal conditions and illumination mode created in the laboratory made it possible to achieve 99% plant acclimatization and good morphometric parameters. Absolute and average values of quantitative yield and productivity of aboveground plant shoots and minitubers were obtained. It was found that the length of aboveground shoots in the studied potato varieties was developed to the greatest extent before flowering of plants (85–91%). The growth of aboveground shoots in length significantly decreased by the period of minitubers formation and was no more than 23%. The plants with aboveground shoots 109–133 mm long formed 148–205 g of green mass during the growing season. At the same time, the daily stem growth of the varieties was 0.5–1.4 cm. A maximum of 4–10 minitubers were obtained from one plant for each variety, on average – from 2 to 4 pcs. Of the total number of minitubers obtained (1113 pcs.), 84.4% were morphologically formed for further propagation. The average weight of tubers per plant was 56–146 g, the average weight of one tuber was 20–69 g. The highest average weight of one tuber was observed in the Nevsky (42 g) and Lyubava (69 g) varieties with the corresponding diameters of 49 and 61 mm. The use of drip irrigation and controlled lighting in growing minitubers of released potato varieties made it possible to ensure an output of up to 71.0–89.8% of the standard fraction (9–60 mm), which meets GOST 33996–2016.

Keywords: potato, released varieties, above-ground shoots, minitubers, drip irrigation, productivity

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INTRODUCTION

Currently, potatoes remain one of the most significant food crops in various countries and regions, with cultivated areas amounting to 19 million hectares [1, 2]. The growth of global potato production to 378 million tons [2, 3] guarantees food security for 160 countries. In Russia, this crop occupied 1,022 thousand hectares of arable land in farms of all categories[1] in 2024, providing a gross harvest of 18.02 million tons[2]. In this regard, many authors have repeatedly pointed out the need to provide potato production with high-quality seed material free from viral, viroid, bacterial, and fungal phytopathogens and obtained through *in vitro* cultivation of microplants [4–7]. At the same time, attention is focused on utilizing the potential of domestically bred varieties [8].

At the current stage of potato cultivation development, the widespread use of innovative technologies at all stages of production of original seeds of various classes is entirely justified and relevant [9]. Many researchers are devoting

[1]Cultivated area of the Russian Federation in 2024 / Federal State Statistics Service (Rosstat), Moscow, 2024.

[2]Gross harvests and yields of agricultural crops in the Russian Federation in 2024 / Federal State Statistics Service (Rosstat), Moscow, 2025.

considerable attention to various methods of producing potato minitubers, based on the use of aerohydroponic and other resource-saving systems for the accelerated propagation of new and scarce varieties in accordance with GOST 33996–2016[3-5] [6, 10–15].

Controlled lighting conditions and automated irrigation thanks to digital drip irrigation technologies, as well as the use of healthy microplants, allow for up to two crops of potato minitubers per year. This undoubtedly increases the profitability of healthy seed production[6] [9, 12, 16–18]. Therefore, optimization of potato microplant cultivation techniques on innovative installations to obtain minitubers that meet GOST requirements is relevant for seed production of the crop in the cultivation zone.

For the first time, a comprehensive study on growing micro plants and obtaining mini-tubers under controlled conditions was conducted at the Kemerovo Research Institute of Agriculture (KemNIISKh) using domestically bred potato varieties approved for use as an example.

The theoretical and practical value of this research lies in the development of techniques and methods for increasing the efficiency of potato minituber production using a drip irrigation system. Increasing plant survival and the number of minitubers while maintaining morphometric parameters will contribute to improved agronomic practices and increased crop yields.

The purpose of this work was to obtain minitubers of the regional potato varieties based on the use of a drip irrigation system in a controlled environment at the Kemerovo Research Institute of Agriculture.

MATERIAL AND METHODS

The research was conducted from June to September 2024 in the Laboratory of Potato Breeding, Biotechnology, and Agricultural Engineering at the Kemerovo Research Institute of Agriculture. The study involved 384 *in vitro* plants (Bank of Healthy Potato Varieties) of six regional varieties of different maturity groups: Lyubava and Pamyati Anoshkinoi (early maturing), Nevsky, Tanai, and Kemerovochanin (middle-early), and Tuleyevsky (medium-maturing), which were cultivated *in vivo*.

Before planting the seedlings, the samples were tested for latent viral and bacterial diseases using the ELISA method. Minitubers were grown in 25-cm-diameter, 7-liter plastic vessels filled with Agrobalt-S peat substrate (PINDSTRUP LLC). The vessels with the planted plants were placed in a modified UGSO-1 system for the all-season production of virus-free seed potatoes of the "original seed" category (developed by the Altai Center for Applied Biotechnology, Altai State University).

The study was conducted over 112 days at a room temperature of 19–22°C, a relative humidity of 70–85%, and a photoperiod of 16 hours. A Royal Clima Cassette DC Inverter air conditioner (Clima Tecnologie S.r.l., Italy; 11 kW capacity) was used to maintain the required air temperature. Lighting duration was regulated by an automatic control unit using LED-T-18-FITO LED lamps (20 W, 230 V, G13). A drip irrigation system was used to water the seedlings. It consisted of an OOS-0.25 reverse osmosis system (OOO SPA “Aquatech”; capacity 0.3 m³/h), a water intake unit with a 300-liter capacity, an Aquatech pumping

[3]*Anisimov B.V., Simakov E.A., Zhevora S.V., Oves E.V., Zebrin S.N., Mityushkin A.V., Zhuravlev A.A., Blinkov E.G., Yurlova S.M., Uskov A.I., Zeyruk V.N., Fedotova L.S.* Modern technologies for the production of seed potatoes: a practical guide / edited by. B.V. Anisimova. Cheboksary, 2018, 48 p.

[4]*Zhevora S.V., Oves E.V., Starovoytov V.I.* Innovative technology for growing potato minitubers in an aerohydroponics system: a tutorial. Moscow, 2018, 84 p.

[5]GOST 33996–2016. Seed potatoes. Specifications and methods for determining quality. Moscow: Standartinform, 2017, 32 p.

[6]*Khamidova M.A., Arzhanukhina E.V., Prokopets R.V., Nikishanov A.N.* Advantages of drip irrigation // Modern problems and prospects for the development of construction, heat and gas supply and energy supply: Proceedings of the XIII National Conf. with international participation (Saratov, April 20–21, 2023) / edited by B.V. Fisenko. Saratov, 2023, pp. 266–271.

station, and main, distribution, and irrigation pipes with drippers installed at the ends. Watering was performed twice daily at 50–70 ml per vessel for 5–8 minutes. The first fertilizing was performed with Minavit Turbo organomineral fertilizer during the growing season, and the second with Florizel complex mineral fertilizer during budding and flowering. Five days before harvesting the minitubers, the aboveground shoots were removed from the plants, and watering was suspended.

The length and weight of aboveground plant shoots were determined by measuring their length and weighing them, while the diameter and weight of minitubers were determined by measuring their length, weighing them, and counting them separately for each treatment. The number, diameter, weight, and fractional composition of minitubers per plant were determined in accordance with established methods[7-9]. Statistical processing of data was carried out using generally accepted methods and the Statistica 7.0 software package from Windows[10].

RESULTS AND DISCUSSION

Under controlled environmental conditions, data on the productivity of above-ground shoots and minitubers of the studied regionalized potato varieties of domestic selection were obtained for the first time (see Table 1).

During plant growth and development, shoot length varied across the varieties from 8–11 cm (at the planting stage) to 109–133 cm (at the time of minituber harvest). Some differences were observed during budding and the beginning of flowering. For example, the Lyubava (early-maturing), Nevsky (middle-early), and Tuleyevsky (medium-maturing) varieties had shoots reaching 85–91 cm, which is 16–25 cm longer than the shoots of the middle-early Kemerovchanin and Tanai varieties. However, by the end of the growing season, shoot lengths for the Kemerovchanin and Tanai varieties reached 128 and 133 cm, respectively, meaning no significant differences in this parameter were observed compared to the Tuleyevsky (132 cm) and Pamyati Anoshkinoi (130 cm) varieties. In contrast, under the same conditions, shoot lengths for the

Табл. 1. Продуктивность районированных сортов картофеля в контролируемых условиях среды (июнь – сентябрь 2024 г.)

Table 1. Plant productivity of the released potato varieties under controlled environmental conditions (June – September 2024)

Variety	Aboveground shoots				Mini-tubers			
	length, mm		weight, g		diameter, mm		weight, g	
	$\bar{x}$	min/max		min/max	$\bar{x}$	min/max	$\bar{x}$	min/max
Lyubava	109	70/142	148	65/345	61	10/120	69	4/258
Kemerovchanin	128	83/163	203	90/305	30	10/60	20	2/154
Nevsky	118	75/160	219	110/390	49	28/90	42	4/134
Pamyati Anoshkinoi	130	78/225	205	100/395	41	10/70	30	2/132
Tanai	133	64/182	164	55/340	36	10/70	28	2/142
Tuleyevsky	132	84/187	202	80/295	42	10/70	27	2/120
$LSD_{0,05}$	14,2		42,1		18,4		29,1	

Note. In tables 1 and 2: $\bar{x}$– arithmetic mean; min/max – minimum and maximum value by grade.

[7]Guidelines for ecological testing of potato varieties. Moscow: VASKhNIL, 1982, 14 p.

[8]*Dospekhov B.A.* Methodology of field experiment (with the basics of statistical processing of research results): textbook. Moscow: Alliance, 2011. 350 p.

[9]*Lakin G.F.* Biometrics: a textbook. Moscow: Higher School, 1990, 352 p.

[10]*Sorokin O.D.* Applied statistics on a computer. Novosibirsk, 2012, 282 p.

Lyubava and Nevsky varieties did not exceed 109 and 118 mm, respectively.

All potato varieties studied demonstrated the greatest shoot growth at the onset of budding and flowering (56–83 cm on average, 85–91%). This figure did not exceed an average of 1.4 cm per day. Daily shoot growth by variety during the second period (from flowering to harvest) ranged from 0.5 to 1.3 cm. Plants with the aboveground shoots of 109–133 mm long were found to produce 148–205 g of green mass during the growing season. The environmental conditions created during the study allowed for a 99% plant survival rate, regardless of the variety.

The quantitative yield of minitubers from one plant was 1–10 pieces, on average – 2–4 pieces (see Table 2).

Tables 1 and 2 show that the minitubers' diameter varied from 10 to 120 mm (30–61 mm on average), and their weight ranged from 2 to 258 g (20–69 g on average). The average weight of minitubers per plant was 56–146 g, with an average diameter of 77–146 mm. The highest values of the analyzed characteristics corresponded to the Lyubava (early-maturing) varieties – 61 mm and 69 g, and Nevsky (middle-early) – 49 mm and 42 g, respectively.

With such high tuber diameter and weight indicators, these varieties also produced the highest yields in the experiment: 9,313 g for the Lyubava variety and 8,006 g for the Nevsky variety. Tuber weights for the other studied varieties were 56–71% and 29–48% lower, respectively. Therefore, the yields of the Kemerovchanin, Pamyati Anoshkinoi, Tuleyevsky, and Tanai varieties were approximately half those of the most productive samples (Lyubava and Nevsky), which did not differ significantly in this indicator.

Comparison of our data with those of other authors, also obtained under controlled environmental conditions, revealed interesting results. The yield of minitubers per plant in greenhouse conditions in the Arkhangelsk region averaged 2–6 pieces [6], in the North Caucasus (Republic of North Ossetia-Alania) – 3–8 pieces [9], in the Moscow region – 8 pieces, and in the Lower Volga region – 10 pieces[11, 12].

The use of liquid chelated fertilizers on Agrobalt-N nutrient soil when growing potato microplants in tunnel shelters in the Bryansk region allowed for the stabilization of mini-tubers production to 6–11 pieces [19]. In the presented studies, from 1 to 10 minitubers (an average of 2–4 pieces) were formed on one plant. Turkish scientists obtained an average of 6–8 minitubers

Табл. 2. Количественный выход, диаметр и масса мини-клубней в контролируемых условиях среды (июнь – сентябрь 2024 г.)

Table 2. Quantitative yield, diameter and weight of minitubers under controlled environmental conditions (June – September 2024)

Variety	Quantity, pcs./plant.		Diameter, mm/plant.		Weight, g/plant.		
	$\bar{x}$	min/max	$\bar{x}$	min/max	total	$\bar{x}$	min/max
Lyubava	2	1/4	128	63/274	9313	146	14/290
Kemerovchanin	4	1/10	90	10/291	3792	60	2/174
Nevsky	3,5	1/9	146	56/234	8006	125	8/186
Pamyati Anoshkinoi	2	1/8	77	25/273	3567	56	4/168
Tanai	3	1/7	96	20/233	4805	75	4/226
Tuleyevsky	3	1/10	87	26/238	3573	56	4/158
$LSD_{0,05}$	0,6		41		3410	53	

[11] *Anisimov B.V., Chugunov V.S., Shatilova O.N.* Optimization of technological schemes and production volumes of in vitro material and minitubers in the process of original potato seed production // Potato growing: materials of the international. scientific and practical. conf. "Methods of biotechnology in potato breeding and seed production" (Moscow, July 7-9, 2014), Moscow, 2014, pp. 158–163.

[12] *Antsipovich V.V., Semenova Z.A., Khadyko O.N.* Growing potato mini-tubers under aeroponic conditions using nutrient solutions based on Murashige-Skoog medium and water-soluble fertilizer "Leafdrip" // Crop Farming and Plant Growing, 2015, N 4, pp. 21–22.

weighing 10–11 g from one plant[13], which is 2–6 times less than the results presented in our study. According to M.K. Koksharova and Sh.N. Karimova, when obtaining 9–13 minitubers from one plant, an average of 30–40 g of minitubers was obtained[14]. Iranian scientists, by adding thiourea to the soil, obtained 185 g of minitubers from one plant with an average tuber weight of 25–32 g[15].

It is important to note that, under controlled environmental conditions, regardless of the research methods, many authors have obtained fairly high yields of minitubers of the standard fraction – 75–89% (see footnotes 11, 12). The results of our studies have shown that growing minitubers using a drip irrigation system allows for a quantitative yield of the standard fraction of up to 90%, in accordance with GOST 33996–2016 (see Table 3). It was found that high indicators of the standard fraction were obtained due to minitubers of 21–40 and 41–60 mm in size, the proportion of which was 23–52 and 10–35%, respectively.

Moreover, the contribution of minitubers smaller than 9 mm in size to the formation of the fractional composition and total mass of minitubers by variety was insignificant. This fraction accounted for no more than 9% of the total number of minitubers in the Pamyati Anoshkinoi, Tanai, and Lyubava varieties. The potential for minituber formation was higher for the Nevsky, Kemerovchanin, and Tuleevsky varieties (16–27%). However, the weight of one minituber of the fraction less than 9 mm did not exceed 1 g. For this reason, when taking into account the productivity of the studied varieties, fractions of 9 mm and more with morphologically formed mini-tubers were taken into account (73–94%).

The proportion of the large fraction (over 60 mm) should also be noted. For example, in the Lyubava (early-maturing) and Nevsky (middle-early) varieties, the large fraction accounted for 35% and 16%, respectively. For other varieties, its contribution did not exceed 5%.

CONCLUSIONS

Табл. 3. Выход различных по величине фракции мини-клубней, полученных на основе применения системы капельного полива (июнь – сентябрь 2024 г.)

Table 3. Yield of minituber fractions of different sizes obtained using a drip irrigation system (June – September 2024)

Variety	Total, pcs.	Fraction, mm													
		Less than 9		9–20		21–40		41–60		More than 60		9–60 (standard)		9–60 and more (working)	
		pcs.	%	pcs.	%	pcs.	%	pcs.	%	pcs.	%	pcs.	%	pcs.	%
Lyubava	149	14	9	2	1	34	23	47	32	52	35	83	56	135	91
Kemerovchanin	241	49	20	53	22	112	47	25	10	2	0,83	190	79	192	80
Nevsky	226	37	16	0	0	74	33	78	35	37	16	152	67	189	84
Pamyati Anoshkinoi	126	7	6	3	2	66	52	44	35	6	5	113	90	119	94
Tanai	187	16	9	28	15	96	51	44	23,5	3	1,6	168	90	171	91
Tuleyevsky	184	50	27	7	4	65	35	58	32	4	2	130	71	134	73
$LSD_{0,05}$		24,9		31,5		46,3		31,5		29,7		64,1		43,3	

[13]*Özkaynak E., Samanci B.* Yield and yield components of greenhouse, field and seed bed grown potato (*Solanum tuberosum* L.) plantlets // Agriculture Faculty of Akdeniz University, 2005, vol. 18 (1), pp. 125–129.

[14]*Koksharova M.K., Karimova Sh.N.* Potato seed production in the Middle Urals // Potato growing: materials of the international. scientific and practical. conf. "Methods of biotechnology in potato breeding and seed production" (Moscow, July 7–9, 2014), Moscow, 2014, pp. 217–222.

[15]*Germchi S., Behroozi F.G., Badri S.* Effect of Thiourea on Dormancy Breaking and Yield of Potato (*Solanum tuberosum* L.) Minitubers Marfona cv. in Greenhouse // International Conference on Environmental and Agriculture Engineering IPCBEE-2011. Singapore: IACSIT Pres., 2011, vol. 15, pp. 19–24.

Based on the research conducted, the following conclusions were formulated:

1. During the vegetation period, the length of aboveground shoots in all potato varieties studied reached its greatest development by the flowering stage. The growth of aboveground shoots in length significantly decreased towards the formation of minitubers and amounted to no more than 23%. The daily growth of aboveground shoots averaged 0.5–1.4 cm. It was found that aboveground shoots in different potato varieties with an average length of 109–133 mm grew an average of 148–219 g of green mass.

2. The interaction of hydrothermal conditions and illumination created in the laboratory allowed for a 99% plant survival rate and the production of 1,113 minitubers. Of these, 940 (84.4%) were morphologically formed for further propagation.

3. The use of drip irrigation and adjustable lighting made it possible to obtain a maximum of 4–10 mini-tubers from one plant (on average 2–4 pieces), depending on the variety.

4. With a wide variation in mini-tuber weight across the experiment, the average values were 56–146 g/plant. In some cases, the weight of a single tuber in the experiment reached 42 and 69 g with a diameter of 49 and 61 mm, respectively.

5. Analysis of the fractional composition of minitubers showed a high yield of the standard fraction of up to 71.0–89.8%, which allows us to note the effectiveness of using a drip irrigation system in obtaining mini-tubers that comply with GOST 33996–2016.

Thus, the obtained results indicate that the methods used in this study, such as drip irrigation and controlled lighting, are effective in achieving high potato survival and productivity rates. They can be recommended for solving practical problems in potato seed production. Further study of the factors and methods of cultivation under controlled conditions that influence the growth and development of potato microplants, improved in an *in vitro* culture, will be aimed at increasing the number of minitubers while maintaining their morphometric characteristics.

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Новый адаптивный сорт озимой ржи Батист

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Для повышения продуктивности и качества зерна озимой ржи требуется создание новых адаптивных к различным стрессовым факторам среды сортов, отвечающих требованиям северо-восточного региона европейской части РФ. Цель исследований – создать сорт озимой ржи, обладающий высокой адаптационной способностью, устойчивостью к почвенно-климатическим стрессам, формирующий стабильно высокую урожайность. Селекционная работа по созданию нового сорта Батист проведена в 2004–2020 гг. на Фаленской селекционной станции. Изучение осуществлялось в сравнении со стандартом Фаленская 4 на почвенных фонах дерново-подзолистой почвы: обычном и естественном жестком провокационном по кислотности фоне. Агрохимические показатели почвы: обычного – pH_{KCl} – 5,0–5,2 ед., содержание подвижных ионов Al^{3+} 5,0–6,5 мг/100 г почвы, естественного провокационного – по алюмокислотности фона – pH_{KCl} – 3,7–3,9 ед., содержание подвижных ионов Al^{3+} 26,5–28,4 мг/100 г почвы. Сорт озимой ржи Батист с доминантным типом короткостебельности создан методом многократных биотипических отборов из сортов Эра и Волхова. В среднем за 2016–2020 гг. в конкурсном сортоиспытании урожайность сорта Батист составила 5,35 т/га (+0,75 т/га к стандарту) на обычном почвенном фоне, на провокационном по кислотности почвы фоне – 3,46 т/га (+0,80 т/га к стандарту). Сорт Батист характеризуется высокой зимостойкостью (4,7 балла) и регенерационной способностью после поражения снежной плесенью (86%). По хлебопекарным показателям относится к 1-му и 2-му классам качества в зависимости от условий года (число падения – 168–225 с). Проведена сравнительная оценка адаптивного потенциала по урожайности, которая показала низкую реакцию на стрессовые факторы, высокую стабильность сорта Батист в различных условиях среды. По результатам Государственного сортоиспытания (2021**,** 2022 гг.) в 2023 г. сорт Батист включен в Государственный реестр селекционных достижений РФ с допуском по Волго-Вятскому и Северному регионам.

Ключевые слова: озимая рожь (*Secale cereaele* L.), сорт, селекция, урожайность, зимостойкость, адаптивность

A new adaptive winter rye variety Batist

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To increase the productivity and quality of winter rye grain, it is necessary to create new varieties that are adaptive to various environmental stress factors and meet the requirements of the north-eastern region of the European part of the Russian Federation. The purpose of the research is to create a variety of winter rye with high adaptive capacity, resistance to soil and climatic stresses, forming a consistently high yield. Breeding work on the creation of a new variety Batist was carried out in 2004–2020 at the Falensky Breeding Station. The study was conducted in comparison with the Falenskaya 4 standard on the soil backgrounds of sod-podzolic soil: an ordinary and a natural hard, provocative background in terms of acidity. Agrochemical parameters of the soil were as follows: the usual background of pH_{KCl} was 5,0–5,2 units, mobile ion content of Al^{3+} ions was 5,0–6,5 mg/100 g of the soil, and the natural background provocative in terms of alumina acid content of pH_{KCl} was 3,7–3,9 units, while the mobile ion content of Al^{3+} ions was 26,5–28,4 mg/100 g of the soil. The variety of winter rye Batist with a dominant type of short stem was created by the method of multiple biotypic selections from the varieties Era and Volkhova. On average for 2016–2020, in a competitive variety trial on a conventional soil background, the yield of the Batist variety was 5,35 t/ha (+0,75 t/ha to the

standard), on a provocative soil acidity background, the average yield of the new variety was 3,46 t/ha (+0,80 t/ha to the standard). The Batist variety is characterized by high winter hardiness (4.7 points) and regenerative ability after snow mold damage (86%). According to baking indicators, it belongs to the 1st and 2nd quality classes, depending on the conditions of the year (falling-number – 168–225 s). A comparative assessment of the adaptive yield potential of the Batist variety was carried out, which showed a low response to stress factors, high stability of the variety in various environmental conditions. According to the results of the State Variety Trial (2021–2022) in 2023, the Batist variety was included in the State Register of Breeding Achievements of the Russian Federation, with admission to the Volga-Vyatka and Northern regions.

Keywords: winter rye (*Secale cereale* L.), variety, breeding, yield, hardiness, adaptability

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INTRODUCTION

Winter rye is a valuable food crop in Russia, standing alone among other grains in its tolerance to low temperatures and soil moisture deficits during the spring and summer growing season [1–3]. Low requirements for soil fertility, mineral fertilizer application, and the use of chemical crop protection products allow for the production of inexpensive and environmentally friendly grain, which can be used to produce healthy foods and develop organic farming, a popular trend abroad that is also becoming popular in Russia [4–6].

To produce high-quality winter rye with consistently high yields, it is necessary to develop and introduce qualitatively new varieties that are adaptable to the edaphic, climatic, and phytogenic stress factors of the cultivation zone. Varietal replacement and strain renovation provide yield increases of 10–50%. Many years of experience in breeding winter rye in many agroclimatic zones of the country have allowed us to create a large number of varieties with a wide range of economically valuable properties – the acid-resistant Kiprez, the light-grained Pamyati Bambysheva, the short-stemmed Talovskaya 45, etc. [7–10]. However, as practice shows, many problems (winter hardiness, resistance to lodging, grain quality, resistance to fungal diseases, etc.) have not been fully resolved, which are exacerbated by global and local climate change, instability of weather conditions during the growing season of winter crops [11–13].

The soil and climate conditions of the Volga-Vyatka region place strict demands on cultivated winter rye varieties, as unfavorable overwintering conditions develop annually. This is due to the increased aggressiveness of snow mold, which causes significant yield losses, sharp temperature fluctuations and the return of cold weather during the active growing season, recurring dry periods, and other factors [14, 15]. Over 70% of the region's arable land consists of low-fertility, acidic soils with elevated aluminum ion levels. Therefore, one of the priority tasks facing breeders at the Federal Agricultural Research Center of the North-East named N.V. Rudnitsky is developing high-yielding winter rye varieties that are highly resistant to low winter temperatures, have strong straws that are resistant to lodging, and are tolerant of regional stress factors.

The purpose of the research is to create a winter rye variety that is adaptable to the conditions of the north-east of the European part of Russia and capable of producing a consistently high yield of high-quality grain.

MATERIAL AND METHODS

Breeding work was conducted from 2004 to 2020 at the Falenskaya Breeding Station, a branch of the FARC of the North-East (eastern agro-soil region, central climate zone of the Kirov region). This zone is dominated by sod-podzolic medium-loamy soils formed on a clay loam mantle. Selection, population formation, establishment of paired isolation nurseries, study and propagation of the breeding material were carried out in nurseries of the parent material, breeding nurseries of varying degrees of development and competitive variety testing on soil backgrounds with different agrochemical indicators: slightly acidic and harsh provocative in terms of aluminum acidity (see Table 1).

Ecological variety testing in 2016–2023 was carried out on the experimental field of the FARC of the North-East (Kirov, central zone of the Kirov region).

The nursery establishment, observations and records were carried out in accordance with the Methodological Guidelines for Breeding and Seed Production of Winter Rye (1980) and in accordance with the methodology of the State Variety Trial of Agricultural Crops (1983). For the immunological evaluation of the breeding material for resistance to snow mold (*Microdochium nivale*), the method of V.K. Neofitova (1976) was used; for brown and stem rust − the scale of T.D. Strakhov and L.F. Rusakov (1971); the assessment of resistance to lodging was carried out on a 5-point scale using the visual assessment method; the baking qualities of grain (falling number – FN) were determined on a Hagberg-Perten device (Falling Number 1500). Statistical processing of the research results was carried out according to the method of variance analysis using the AGROS Package (version 2.07); the regression coefficient - according to the method of S.A. Eberhart, W.A. Russell (1966); the level of genetic flexibility of the variety and resistance to stressful growing conditions – according to A.A. Goncharenko (2016); homeostasis - according to the method of V.V. Khangildin (1986); the adaptability coefficient (AC) according to the method of L.A. Zhivotkov, Z.A. Morozova, L.I. A comparative assessment of the adaptive and morphobiological indicators of the promising Batist variety was carried out with the generally accepted standard – highly winter-hardy adaptive variety Falenskaya 4.

During the competitive trial of the Batist winter rye variety, the hydrothermal conditions varied significantly in terms of heat and moisture availability (Falenki, Kirov Oblast). The best conditions for achieving the highest winter rye yields were in 2018 and 2020 (HTC = 1.30 and 1.11, respectively). The spring-summer growing season of 2016 was characterized by a moisture deficit (HTC = 0.60), while 2017 and 2019 were characterized by excess moisture, which negatively impacted winter rye yields overall.

RESULTS AND DISCUSSION

The winter rye variety (*Secale cereaele* L.) Batiste (*vulgare* variety) with a dominant-monogenic type of short stems was obtained by the method of multiple biotypic selections from the varieties Volkhova and Era (Leningrad Research Institute of Agriculture "Belogorka") for the main economically valuable traits using natural provocative backgrounds for snow mold and aluminum acidity with subsequent directed in-

Табл. 1. Агрохимические характеристики почвы опытных участков
Table 1. Agrochemical characteristics of the soil of the experimental plots

Indicator	Slightly acidic soil background	Natural provocative background
pH_{KCl}, units	5,0–5,2	3,7–3,9
Content of mobile ions Al^{3+}, mg/100 g	5,0–6,5	26,5–28,4
Content of mobile phosphorus, mg/kg	272–316	72–102
Potassium content, mg/kg	150–183	66–100

tra-population cross-pollination.

The first selections of elite plants were conducted in 2004 at the Falensky Breeding Station. After studying the selected plants in 2005, a population was created, which from 2006 to 2009, was propagated in isolated plots with varying soil fertility, with repeated negative culling for winter hardiness, resistance to snow mold, leaf-stem diseases, uniformity of stem height, plant height before flowering, and overall condition before harvesting. In 2010, additional paired crosses of the Batist variety were conducted. In 2011 and 2012, the offspring from the paired crosses were studied in breeding nurseries using the half-test method. A population was created from the best pairs.

The Batist variety has an intermediate bush form, with a strong, lodging-resistant stem. The average plant height over the years of study was 127 cm; the spike is prismatic, medium in length (12.2 cm) and dense, grayish-yellow in color; the outer lemma gradually transitions into a coarse, serrated grayish-yellow awn. The grain is semi-elongated and grayish-green. The variety has high winter hardiness (4.7 points) and active regeneration capacity after snow mold damage (86%), which is the main limiting factor for yield in the unstable hydrothermal conditions of the Volga-Vyatka region of the Russian Federation (see Table 2).

The average 1,000-kernel weight is 30.5 g, exceeding the Falenskaya 4 standard by 2.6 g; vitreousness and crude protein content are within the standard. According to "GOST 16990–2017 Rye. Technical Conditions," the grain's natural content exceeds the baseline norm and is higher than the standard; in terms of baking properties, it belongs to quality classes 1 and 2, depending on the growing season (FN 168–225 s).

The variety has average field resistance to rust infections, leaf-stem diseases and root rot.

On average, during competitive variety trials on slightly acidic soils from 2016 to 2020, the Batist variety yield (5.35 t/ha) exceeded the Falenskaya 4 standard by 0.75 t/ha. The maximum yield (over 6.0 t/ha) during the study period was achieved under the most favorable conditions of 2018 and 2020 (see Table 3).

Табл. 2. Характеристика сорта озимой ржи Батист по основным хозяйственно-биологическим признакам (2016–2020 гг.)

Table 2. Characteristics of the Batist winter rye variety according to the main economic and biological characteristics (2016–2020)

Indicator	Batist	Falenskaya 4, standard	Ratio to the standard
Winter hardiness, points	4,7	4,6	+0,1
Frost resistance, points	4,6	4,4	+0,2
Regrowth after snow mold damage, %	86,0	86,0	–
Length of the growing season, days	325,0	325,0	–
Plant height, cm	127,0	127,0	–
Lodging resistance, points	4,1	3,9	+0,2
Productive tillering, pcs.	5,1	4,8	+0,3
Ear length, cm	12,2	11,2	+1,0
Number of spikelets per ear, pcs.	37,0	34,4	+2,6
Number of grains per ear, pcs.	63,0	56,0	+7
Grain weight per ear, g	2,0	1,7	+0,3
Weight of 1000 grains, g	30,5	27,9	+2,6
Grain unit, g/l	690,0	685,0	+5
Vitreousness of grain, %	33,0	32,0	+1
Crude protein content of grain, %	11,5	11,5	–

Considering that approximately 65 million hectares of arable land in Russia have a pH below 5.5 [16], and high soil acidity can reduce grain yields by up to 80% [17], new varieties must be characterized by aluminum and acid tolerance. Against a background of provocative soil acidity, the average yield of the new variety was 3.46 t/ha, which exceeds the standard by 0.80 t/ha.

The maximum yield of the new Batist variety during the competitive variety testing period against a normal background was noted in 2020 – 6.28 t/ha, against a provocative background in 2019 – 4.32 t/ha.

The new variety demonstrated a weaker response to changing environmental conditions under both soil conditions (CV = 13.5 and 20.0%) compared to the standard (CV = 21.0 and 35.5%, respectively). Consequently, the Batiste variety exhibits a smaller reduction in yield under adverse weather conditions, while remaining highly responsive to improved growing conditions. A competitive variety trial conducted a comparative assessment of the adaptive yield potential of the Batiste variety, revealing a low response to stress factors and high stability under various environmental conditions (see Table 4).

To improve the effectiveness of evaluating the Batist variety for its key economically valuable traits, an ecological trial was conducted in Kirov (central Kirov Oblast). Winter rye was sown from August 25th to 28th, which corresponds to previously established optimal dates. Given the crop's biological characteristics, the autumn growing season is particularly important for winter rye. Well-developed plants that have undergone a hardening-off phase are better able to withstand adverse overwintering conditions, consume reserve nutrients more slowly during the winter, and actively regenerate in the spring

Табл. 3. Результаты конкурсного испытания сорта Батист, п.г.т. Фаленки, т/га
Table 3. Results of the competitive trial of the Batist variety, u.t.s. Falenki village, t/ha

Variety	Year					Mean	CV, %
	2016	2017	2018	2019	2020		
Slightly acidic soil background							
Falenskaya 4, standard	4,21	3,75	5,80	5,47	3,78	4,60	21,0
Batist	4,82	4,20	6,07	5,40	6,28	5,35	13,5
± to the standard	+0,61	+0,45	+0,27	–0,07	+2,50	+0,75	–
LSD_{05}	0,53	0,43	0,40	0,49	0,81	–	–
Provocative soil background							
Falenskaya 4, standard	3,37	2,38	3,20	3,21	1,12	2,66	35,5
Batist	3,28	2,47	3,91	4,32	3,30	3,46	20,0
± to the standard	–0,09	+0,09	+0,71	+1,11	+2,18	+0,80	–
LSD_{05}	0,23	0,34	0,46	0,53	0,36	–	–

Табл. 4. Характеристика адаптивного потенциала урожайности сорта Батист (конкурсное сортоиспытание 2016–2020 гг.), п.г.т. Фаленки
Table 4. Characteristics of the adaptive yield potential of the Batist variety (competitive variety trial 2016–2020), u.t.s. Falenki village

Variety	Stress resistance, Y2 – Y1		Genetic flexibility of the variety, $\frac{Y1+Y2}{2}$		Regression coefficient, bi		Homeostaticity, Hom		Coefficient of adaptability, CA	
	1	2	1	2	1	2	1	2	1	2
Falenskaya 4, standard	–2,05	–2,25	4,78	2,25	0,55	0,58	0,22	0,07	0,92	0,94
Batist	–2,11	–1,75	5,23	3,45	0,82	0,85	0,32	0,18	1,11	1,26

Note: 1 – normal background, 2 – natural provocative acidity background.

after the snow melts. The period of intensive growth and development of winter rye in the autumn period occurs in September. September conditions have had their own characteristics depending on the year (see figures *а*, *б*).

The graphs show that in terms of moisture availability, there were years with both severe moisture deficits (September 2015 and 2019), when precipitation fell at 38% of the norm, and years with excess moisture (2016, 2017, 2021, 2022) – 120-148% of the standard indicator. Significant differences in the amount of heat were also observed by year – from very warm (with an increase of +3.2 ºC – September 2015) to cold (-2.9 ºC in 2021).

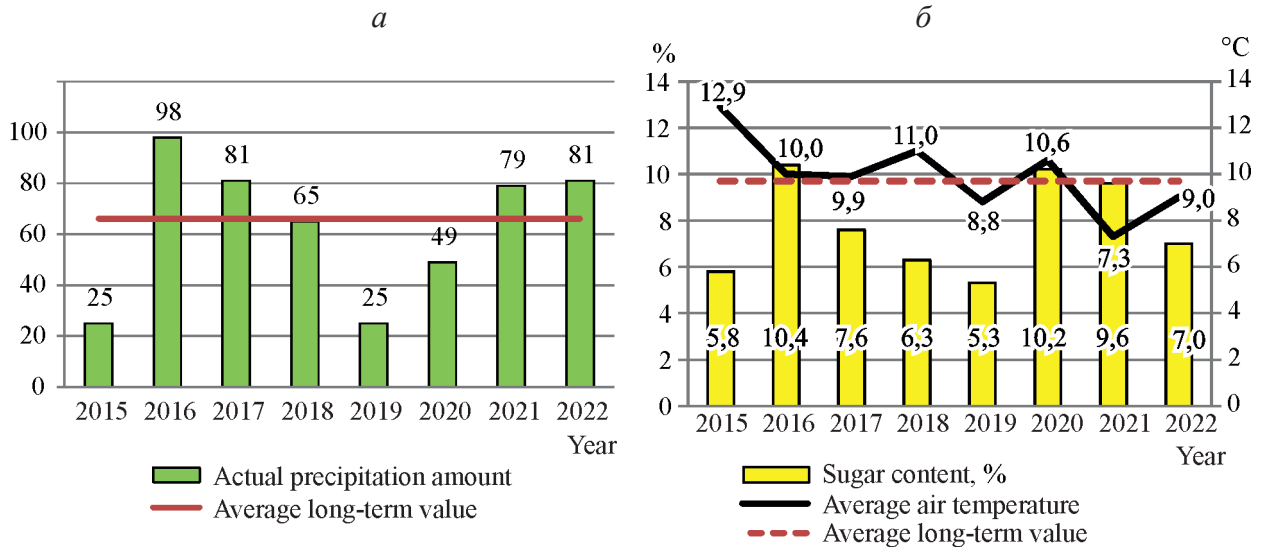
Contrasting conditions of autumn vegetation and hardening of winter rye plants during the research period led to different amounts of accumulated sugars in the tillering node – from 5,3% (2019) to 10,4% (2016).

Conditions for wintering winter crops in the Volga-Vyatka region are considered unfavorable (temperatures at the depth of the tillering node vary from -2.0 to +2.0 ºC with an optimum of -8.0 ºC, the depth of snow cover in some places reaches 90 cm), and in some places extreme (critically low temperatures in the absence of snow cover, winter thaws with the formation of a multi-layered ice crust).

Assessment of the weather conditions of the spring-summer growing season (April – July) shows that the most favorable years in terms of moisture supply were 2016 and 2019–2021 with HTC = 1.06–1.29 (see Table 5).

Contrasting heat and moisture conditions during the study years allowed us to evaluate the promising variety's response to different environmental conditions. The Batist variety's yield ranged from 3.73 (2016) to 5.73 t/ha (2019). A significant yield increase (+0.27 to +0.66 t/ha) compared to the Falenskaya 4 standard was noted in 2017, 2020, 2022, and 2023. The yield remained at the level of the highly winter-hardy standard in 2016, 2018, and 2021 (see Table 6).

The Batist variety was submitted for state variety testing in 2019 for its high winter hardiness, productivity, and tolerance to soil acidity. According to the Federal State Budgetary Institution "State Commission of the Russian Federation for Testing and Protection of Selection Achievements," in 2021-2022, Batist yields ranged from 2.88 to 4.66 t/ha on variety testing sites in the Volga-Vyatka and Northern regions. The maximum yield increase compared to the Falenskaya 4 standard was achieved on



Сумма осадков в сентябре, мм (*а*); средняя температура воздуха сентября, ºС и накопление сахаров в узле кущения, % (*б*)**,** г. Киров

The amount of precipitation in September, mm (*а*); average September air temperature, ºС and accumulation of sugars in the tillering node, % (*б*), Kirov

Табл. 5. Характеристика погодных условий весенне-летнего периода (г. Киров)
Table 5. Characteristics of the weather conditions of the spring-summer period (Kirov)

Indicator	Year of study							
	2016	2017	2018	2019	2020	2021	2022	2023
HTC	1,06	2,21	1,61	1,29	1,23	1,17	2,14	1,75
Sum of effective $t > 5$ ºC	1169	766	986	962	1023	1232	953	1056
Total precipitation, mm	205	379	306	205	319	262	364	280

variety testing sites in the Chuvash Republic (+0.93 t/ha). Furthermore, reliably high yields were achieved on variety testing sites in the Arkhangelsk Region (+0.37 t/ha), the Udmurt Republic (+0.37 t/ha), and the Komi Republic (+0.32 t/ha) (see Table 7).

Based on the results of the economic efficiency analysis of introducing the Batist variety into production under soil stress conditions (low fertility and increased soil acidity), the net income per 1 hectare will increase by 28% compared to the standard, the overall profitability will increase by 27%, and the increased straw strength and resistance to lodging will further reduce energy costs during harvesting.

CONCLUSION

As a result of many years of breeding, a new winter rye variety, Batist, has been developed, adapting to the conditions of the Volga-Vyatka region. It is characterized by high adaptive potential, winter hardiness, resistance to fusarium infection, active spring regeneration, and consistently high yields. The yield increase over the Falenskaya 4 standard is achieved through increased lodging resistance (4.1 points), greater tillering (5.1 stems), and spike productivity. The variety is suitable for cultivation in soils with low natural fertility and high soil acidity, while guaranteeing a 27% increase in profitability.

Табл. 6. Результаты экологического испытания сорта Батист, г. Киров, т/га
Table 6. Results of the environmental testing of the Batist variety, Kirov, t/ha

Variety	Yield								Mean value
	year								
	2016	2017	2018	2019	2020	2021	2022	2023	
Falenskaya 4, standard	3,77	4,05	4,72	6,50	3,33	4,49	4,47	5,01	4,54
Batist	3,73	4,32	4,68	5,73	3,99	4,48	5,12	5,53	4,70
± to the standard	–0,04	+0,27	–0,04	–0,77	+0,66	–0,01	+0,65	+0,52	+0,16
LSD_{05}	0,32	0,25	0,31	0,41	0,27	0,34	0,45	0,42	–

Табл. 7. Результаты сортоиспытания сорта озимой ржи Батист 2021–2022 гг. (данные ФГБУ «Государственной комиссии по испытанию и охране селекционных достижений»)
Table 7. Results of the variety trial of the winter rye variety Batist 2021–2022 (data from the FSBI "State Commission for Testing and Protection of Breeding Achievements")

Region	Average yield, t/ha			
	Batist	Falenskaya 4, standard	± to the standard	LSD_{05}
Chuvash Republic	4,50	3,57	+0,93	0,22
Udmurt Republic	3,60	3,23	+0,37	0,18
Arkhangelsk Region	3,65	3,28	+0,37	0,32
Komi Republic	3,36	3,04	+0,32	0,18

It has good baking qualities: FN – 168–225 (corresponding to quality classes 1 and 2), natural weight – 690 g/l, 1000-kernel weight – 30.5 g. The variety is recommended for food production. Since 2023, the promising winter rye variety Batiste has been included in the State Register of Breeding Achievements with approval for the Volga-Vyatka and Northern regions of the Russian Federation.

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Структура урожая подсолнечника при дифференцированном посеве

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В статье предложена и изучена автоматизированная методика определения структуры и урожая подсолнечника, позволяющая прогнозировать урожайность и предлагать рекомендации по оптимизации размещения сельскохозяйственных культур в зависимости от потенциала полей. Основные задачи исследования включали разработку и внедрение инновационных технологий степного земледелия, направленных на обеспечение продуктивности сельхозугодий в соответствии с их биопотенциалом. Отработку технологии дифференцированного высева семян и внесения минеральных удобрений осуществляли в течение трех лет (2022–2024) на опытно-экспериментальных полях в двух хозяйствах Алтайского края по разным системам обработки почвы (классическая плоскорезная и No-till). Хозяйства расположены в Приалейской почвенно-климатической зоне. Установлено, что одним из основных показателей, определяющих уровень пестроты почвенного плодородия, является пространственная дифференциация содержания гумуса и основных элементов питания. Алгоритмы выделения зон плодородия почвы, подлежащих дифференциации по нормам высева семян и дозам внесения минеральных удобрений, разработаны с учетом региональной специфики. В хозяйстве, работающем по системе No-till, отмечена более высокая обеспеченность опытного поля органическим веществом (4,0%). При классической плоскорезной обработке содержание гумуса составляло 3,5%. Установлено, что чем выше содержание гумуса, тем выше уровень плодородия почвы. Предложены и исследованы автоматизированные методы распознавания и подсчета количества всходов подсолнечника, а также построения карт сорной растительности по RGB-изображениям сверхвысокого пространственного разрешения, полученным с помощью беспилотного летательного аппарата. Выявлено, что при выборе рациональных соотношений нормы высева семян и доз внесения удобрений по зонам почвенного плодородия следует учитывать их совместное влияние на полевую всхожесть растений и количество полученных всходов.

Ключевые слова: точное земледелие, RGB-изображение, беспилотный летательный аппарат, сверточная нейронная сеть

Sunflower yield structure at differentiated sowing

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The article examines and proposes an automated method for determining the structure and yield of sunflower, which allows predicting yields and offering recommendations for optimizing the placement of crops depending on the potential of fields. The main objectives of the study included the development and implementation of innovative steppe agriculture aimed at ensuring the productivity of agricultural lands in accordance with their biopotential. The technology of differentiated seed sowing and mineral fertilizer application was tested for 3 years (from 2022 to 2024) on experimental fields in

two farms of the Altai Territory using different tillage systems (classical flat-cutting and No-till system). The farms are located in the Prialeiskaya soil-climatic zone. It has been established that one of the main indicators determining the level of soil fertility diversity is the spatial differentiation of the humus content and basic nutrition elements. Algorithms for the allocation of soil fertility zones subject to differentiation of seed and mineral fertilizer rates have been developed with regional specificity. In the farm working under the No-till system, there is a higher organic matter content of the experimental field (4.0%). At classical flat-cuting tillage the humus content is noted at the level of 3.5%. It has been found that the higher the humus content, the higher the level of soil fertility. Automated methods of recognizing and counting the number of sunflower sprouts, as well as building the maps of weed vegetation using RGB images of ultra-high spatial resolution obtained by an unmanned aerial vehicle have been proposed and investigated. It has been identified that when choosing rational ratios of the seeding rate and fertilizer application doses by zones of soil fertility of the field, their joint influence on the field germination of plants and the number of sprouts obtained should be taken into account.

Keywords: precision agriculture, RGB image, UAV, convolutional neural network

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INTRODUCTION

In plant cultivation, the efficiency of agricultural production depends on soil cultivation technology, moisture availability, the natural resource potential of the field, and other factors. Currently, variable-rate seeding and application of mineral fertilizers are among the most important economic and environmental aspects of precision farming. The use of this technology significantly improves the efficiency of exploiting the agroclimatic potential of fields with varying levels of natural fertility [1–7].

As part of our research, a rapidly expanding approach that involves taking into account the soil fertility zone during sowing and application of mineral fertilizers will be studied on sunflowers sown in the Altai Territory, which are a highly profitable arable crop.

Due to the significant value of sunflower, there is particular interest in the use of high-tech approaches to monitoring, assessing the struc-

ture, and yield of this crop. The use of precision farming methods, including monitoring using unmanned aerial vehicles (UAVs), is relevant and is being adopted by farmers in the region.

The development and implementation of innovative technologies in agriculture (a differentiated approach to the application of fertilizers and the determination of seeding rates) ensures the productivity of agricultural land in accordance with its biopotential, which indirectly contributes to the preservation and restoration of landscape and biological diversity in both the Altai Territory and Russia as a whole.

The use of UAVs and automated analysis of RGB images obtained with them are playing an increasingly important role in crop planning and monitoring [8–16]. High speed of real-time data analysis and the accuracy of the results allow for a timely assessment of the quality of technological operations performed in the fields.

The purpose of the study is to develop and evaluate the capabilities of an automated method for determining the structure and yield of sunflower, allowing for crop yield forecasting and recommendations for different cultivation technologies (classical subsurface tillage and no-till system).

MATERIAL AND METHODS

The study was conducted from 2022 to 2024 on agricultural land located in the Aleysky and Pospelikhinsky districts of the Altai Territory (see Fig. 1). The crop under study is grown on experimental fields of 100 hectares each.

The numbers of the allocated plots indicating the level of natural soil fertility (zones) and the implemented options for combining seeding rates and fertilizer application rates are given in Table 1.

Diammophoska (NPK 10:26:26) was applied during sowing at the following rates at the "Znamya Rodiny" agricultural production cooperative: zone 1 – 70 kg/ha, zone 2 – 50 kg/ha, zone 3 – 30 kg/ha. KAS-32 at a rate of 112 kg/ha was applied throughout the field using a liquidizer. The seeding rate was as follows: zone 1 – 50,000 seeds/ha, zone 2 – 40,000 seeds/ha, zone 3 – 30,000 seeds/ha. At the OOO "Zolotaya Osen", fertilizers were not applied, and the seeding rate was as follows: zone 1 – 55,000 seeds/ha, zone 2 – 45,000 seeds/ha, zone 3 – 35,000 seeds/ha.

Рис. 1. Карта-схема расположения опытных полей в хозяйствах Алтайского края:
1 – ООО «Золотая осень» Алейского района; *2* – СПК «Знамя Родины» Поспелихинского района

Fig. 1. Schematic map of the location of experimental fields in the farms of the Altai territory:
1 – OOO "Zolotaya Osen" Aleysky district; *2* – APC "Znamya Rodiny" Pospelikhinsky district

Табл. 1. Исследуемые факторы и уровень их изменения в опытах
Table 1. Investigated factors and levels of their changes in the experiments

Site number	Area	S_r	A_{Rf} (NPK; KAS-32)	Site number	Area	S_r	A_{Rf} (NPK; KAS-32)
APC "Znamya Rodiny"				*OOO "Zolotaya Osen"*			
1.1	1. Increased fertility	50	70; 112	1.1		55	
2.1		50	50; 112	1.2	1. Increased fertility	45	
2.2	2. Normal (moderate) fertility	40	50; 112	1.3		35	
2.3		30	50; 112	2.1		55	
3.1		50	30; 112	2.2	2. Normal (moderate) fertility	45	Not applied
3.2		40	30; 112	2.3		35	
	3. Low fertility			3.1		55	
3.3		30	30; 112	3.2	3. Low fertility	45	
				3.3		35	

Note. S_r – seeding rate, thousand pcs/ha; A_{Rf} – application rate of mineral fertilizers, kg/ha.

The establishment of the field experiments was carried out on the basis of maps of field productivity zones (see Fig. 2).

An accredited laboratory (FSBI CSA "Altaisky") conducted agrochemical soil analysis of the experimental fields by fertility zones using soil samples collected prior to spring field work. The soil samples were collected at a specified point using a hand auger from the upper horizon (0–20 cm). The soil analysis included determi-

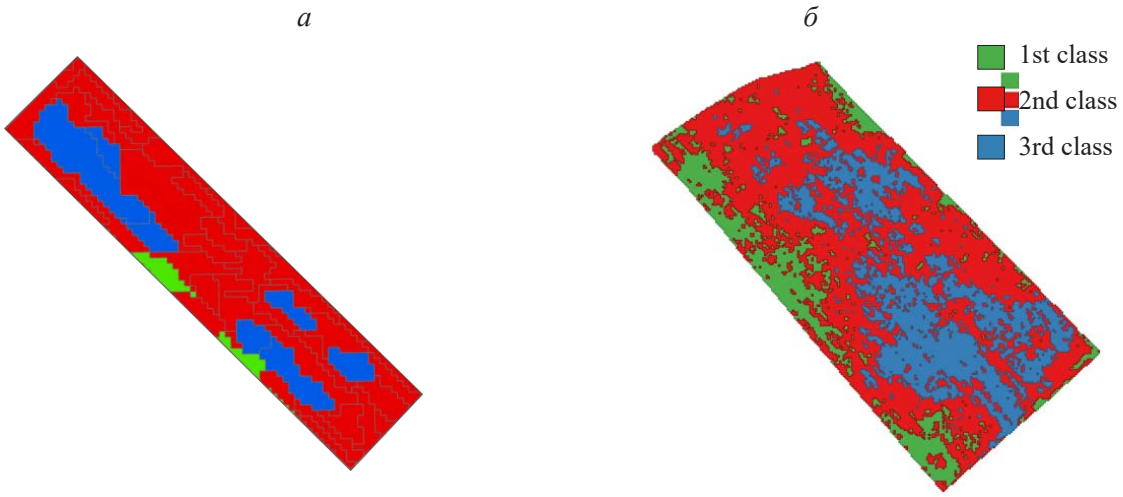


Рис. 2. Карты-задания для дифференциации норм высева семян:
а – СПК «Знамя Родины», *б* – ООО «Золотая осень»; 1-й класс – зона повышенного плодородия, 2-й класс – зона нормального (умеренного) плодородия, 3-й класс – зона пониженного плодородия

Fig. 2. Task cards for differentiation of the seeding rates:
а – APC "Znamya Rodiny", *б* – OOO "Zolotaya Osen"; 1st class – an increased fertility zone, 2nd class – normal (moderate) fertility zone, 3rd class – reduced fertility zone

nation of nitrate nitrogen content, the mass fraction of mobile phosphorus and potassium compounds, and the amount of organic matter.

The technology of sunflower cultivation was as follows in the APC "Znamya Rodiny": The forecrop was spring wheat. No autumn tillage was performed. In the spring, moisture was retained in the fields using harrowing. The LG-5462 hybrid was sown using an EDX 12000 TS direct-seeding seeder. The sowing date was May 16th. During the growing season (June 20th), chemical treatment with Global was applied (1.2 l/ha).

At the OOO "Zolotaya Osen", the forecrop was oats. In the autumn, the soil was subsurface tilled using a wide-cut cultivator to a depth of 15–17 cm. The Pioneer LE 10 hybrid was sown using a Horsch Maestro seeder. The sowing date was May 10. During the growing season (June 23), inter-row cultivation was performed using a KRM-6 cultivator. Chemical treatment of the crops was carried out in the following sequence:

1) July 7 – tank mixture of tribenuron-methyl, 50 g/ha + clethodim, 250 g/ha + haloxyfop, 250 g/ha + alpha-cypermethrin, 50 g/ha;

2) July 21 – alpha-cypermethrin insecticide, 50 g/ha.

Weather and climatic conditions during the sunflower growing season (May–August) were extremely heterogeneous during the study years. The Selyaninov's hydrothermal coefficient (HTC) values ranged from 0.54 in 2022 in the Aleysky district to 1.40 in 2024 in the Pospelikhinsky district (see Table 2).

G. T. Selyaninov identified several gradations of the HTC value that characterize the moisture and heat supply of the territory: HTC < 0.4 - very severe drought; 0.4 ≤ HTC < 0.5 - severe drought; 0.5 ≤ HTC < 0.7 - moderately dry; 0.7 ≤ HTC ≤ 1.0 - not wet enough; 1.0 < HTC ≤ 2.0 - sufficiently wet; HTC > 2.0 - waterlogged[1, 2].

Табл. 2. Значения ГТК в вегетационный период
Table 2. The HTC values of the growing season

Year	Aleysky district	Pospelikhinsky district
2022	0,54	0,70
2023	1,20	0,61
2024	1,32	1,40
2022–2024 (average)	1,02	0,90

Thus, on average, the growing season conditions in the study area changed from moderately dry in 2022 to fairly moist in 2024.

RESULTS AND DISCUSSION

This study utilizes an integrated approach to studying field potential and predicting yields based on remote sensing data. Moisture accumulation and soil organic matter content are important factors in determining the distribution of fertility zones within a single field. Agrochemical analysis results show that the most significant correlation between the spatial differentiation of fertility zones is observed in terms of humus content.

In the Pospelikhinsky district farm, characterized by a higher supply of organic matter in the experimental field (on average 4.0%), the following relationship was established between fertility zones and the dynamics of humus content in the upper soil layer (0–10 cm) – 4.3–4.2–3.9%, i.e. the higher the humus content, the higher the level of soil fertility. In the 10–20 cm soil layer, no such relationship was found, and the moderate fertility zone had an advantage: 3.6–4.1–3.9%. In the Aleysky district farm, with an average humus content in the 0–20 cm soil layer at 3.5%, similar dynamics were noted in the upper 10-cm layer – 3.8–3.3–3.1%. In the 10–20 cm layer, it was negative: 3.4–3.5–3.9% (see Table 3). This is due to the use of different

[1]*Selyaninov G.T.* On agricultural climate assessment // Works on agricultural meteorology. L.: Hydrometeoizdat, 1928, iss. 20, pp. 165–177.

[2]*Galeeva E.M., Saifullina E.N.* Analysis of changes in the values of the hydrothermal coefficient of G.T. Selyaninov on the territory of the Republic of Bashkortostan // Theoretical and applied problems of landscape geography. VII Milkovsky readings: materials of the XIV International. landscape conf. (Voronezh, May 17–21, 2023). Voronezh, 2023, vol. 2, pp. 213–215.

soil cultivation systems in these farms.

Data obtained by UAVs can detect process violations, identify areas with weeds and stunted plants, as well as crops affected by pests and diseases. This paper proposes automated methods for recognizing and counting sunflower seedlings, as well as detecting weeds using ultra-high-resolution RGB images.

The initial data for processing consisted of 3,000 RGB images measuring 5472 × 3648 pixels, obtained using a 20-megapixel digital camera mounted on a DJI Phantom 4 Pro V2.0 quadcopter. The images were captured from June 21 to 23, 2023, by specialists from the OOO "Bespilotnye Tekhnologii". The imagery was captured at a height of 10 m, and the spatial resolution was 0.3 cm/pixel.

From the original images, 19 orthophotomaps with an average size of 12,000 × 12,000 pixels were generated. Further processing was carried out using fragments of the resulting orthophotomaps.

The proposed methodology involves the following main stages of image processing:

1. Annotating the training set for semantic segmentation.

2. Formation of a sunflower seedling mask using semantic segmentation.

3. Post-processing of semantic segmentation results, search for rows and row spacings.

4. Determining the number of plants in sunflower agrocenoses using the found regression dependence.

5. Weed map creation.

A visual diagram of the stages of RGB image processing is shown in Fig. 3.

Semantic segmentation was performed into two classes ("sunflower" and "background") using the DeepLabV3+ convolutional neural network.

To obtain a representative training sample, several fragments measuring 2560 × 2560 pixels were taken from each orthophoto. Manual labeling was performed using the Supervisely web service. The labeled data was divided into training fragments measuring 256 × 256 pixels. This resulted in 3277 training, 900 validation, and 460 test fragments. To increase the size of the training sample, training data augmentation was performed, which consisted of the following operations:

1. Rotation of the images by a random angle $\alpha \in (0°, 180°)$.

2. Rescaling and random displays about the horizontal and vertical axes.

The training was performed on a cluster of the Federal Research Center for Information and Computing Technologies (HPE Apollo 6500 G10+, 2×AMD EPYC 7452 (32 Cores) 2.35 GHz, 1 TB RAM, 8×Nvidia A100 80GB SXM4) using the Tensorflow and PyTorch frameworks.

On the training set, the DeepLabV3+ model showed segmentation accuracy of 99%, on the validation set – 98%, on the test set – 97.5%.

Fig. 4 shows an example of an image with a sunflower mask applied.

Табл. 3. Агрохимическая характеристика экспериментальных полей в СПК «Знамя Родины»/ ООО «Золотая осень»

Table 3. Agrochemical characteristics of the experimental fields in the APC "Znamya Rodiny"/ OOO "Zolotaya Osen"

Area	Soil horizon (layer), cm	Content			
		nitrate nitrogen, mg/kg	P_2O_5, mg/kg	K_2O, mg/kg	humus, %
Increased fertility (1st class)	0–10	1,9/1,6	221,5/151,5	284,9/122,6	4,3/3,8
	10–20	1,7/1,8	163,3/149,4	94,0/102,2	3,6/3,4
Moderate fertility (2nd class)	0–10	2,0/2,1	175,6/128,9	236,0/114,7	4,2/3,3
	10–20	1,8/2,1	221,7/129,1	107,2/120,5	4,1/3,5
Low fertility (3rd class)	0–10	2,4/3,0	145,5/150,4	114,1/161,7	3,9/3,1
	10–20	2,0/1,9	129,4/155,8	94,2/101,3	3,9/3,9

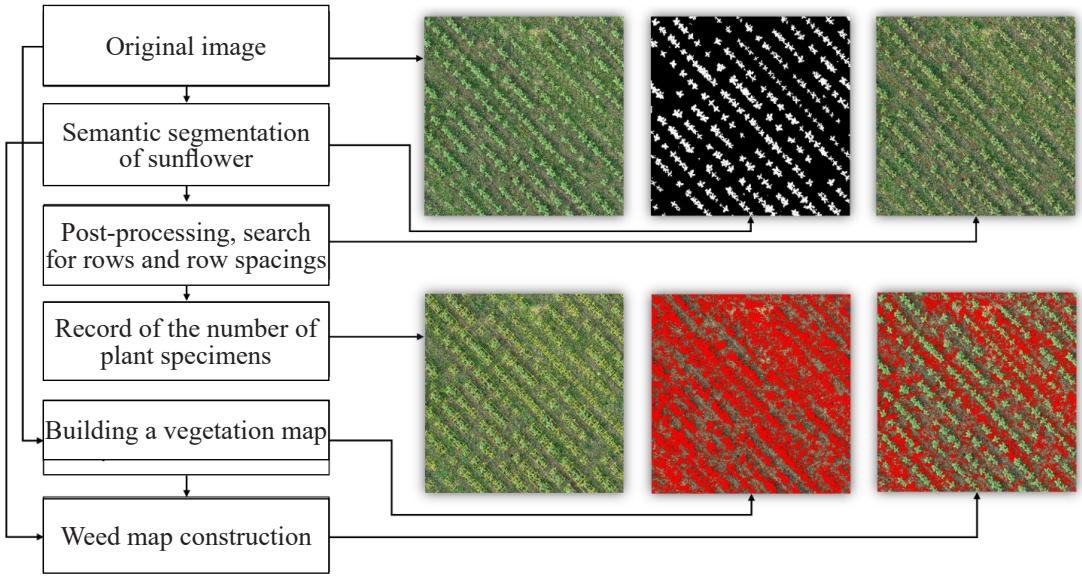


Рис. 3. Схема обработки RGB-изображений
Fig. 3. RGB image processing scheme

After performing the semantic segmentation procedure, over- or mis-segmented regions often emerge. To remove small noise objects, thresholding post-processing of the segmentation results was performed.

The search for rows and row spacings was carried out using the algorithms described in [17].

The plant quantity assessment involved several processing steps:

1. Semantic segmentation of sunflower from RGB images.

2. Finding segment contours and determining their lengths (Length).

3. Constructing minimal bounding rectangles around each segment and determining the Ratio parameter (the ratio of the rectangle's width to its height).

4. Construction of regression dependencies based on the collected statistics.

Based on the results of the experiments, it was found that linear regression models were the most optimal for determining the number of sunflower plants

$$\hat{y} = -0{,}428 + 1{,}4 \cdot \text{Ratio};$$

$$\hat{y} = 0{,}386 + 0{,}0025 \cdot \text{Length}.$$

The accuracy of sunflower plant counts in test fields using the above regression relationships ranged from 93 to 95%, depending on the quality of the plantings. The procedure for determining the number of plants is illustrated in Figure 5. The segment outlines are highlighted in red, the minimum bounding rectangles for each segment are highlighted in yellow and blue, and the numbers represent the number of plants in each segment.

To construct vegetation maps from RGB images, a simple threshold method was used based on the ExGI (Excess Green Index) vegetation

Рис. 4. Изображение с наложенной маской подсолнечника
Fig. 4. Image with a superimposed sunflower mask

index, which is often used to assess vegetation condition:

$$ExGI = 2 \times G - R - B,$$

where G, R and B – the brightness values of the image in the green, red and blue ranges of the spectrum, respectively.

To obtain a weed map, it was sufficient to obtain a vegetation mask in the image using a thresholding method based on the ExGI index and exclude the sunflower mask from it. To better highlight sunflower plants in the weed map, a morphological augmentation procedure with a 5 × 5 kernel was applied to the sunflower mask.

Examples of the images and corresponding weed maps are shown in Fig. 6 and 7.

As the analysis shows, depending on the studied factors (soil fertility zone, seeding rate, fertilizer application rate) in the APC "Znamya Rodiny", the range of changes in the average values of the calathid weight and grain weight in it across the experimental variants was 0.251–0.518 and 0.115–0.170 kg, respectively (see Fig. 8). At the OOO "Zolotaya Osen", depending on the studied factors (soil fertility zone, seeding rate), the following values were obtained: 0.057–0.180 and 0.030–0.102 kg, respectively. Moreover, while the grain weight in the heads increased linearly up to a weight of 0.410 kg, with further increases, a decrease in the growth rate was observed due to the influence of limiting factors.

The average values of the assessed indicators for the experimental variants in both farms are given in Table 4. The number of seedlings in the observation sites was determined using automated methods for recognizing and counting the number of seedlings in the ontogenetic phase of 4–6 leaves.

The average number of seedlings in sunflower crops at the APC "Znamya Rodiny" varied between 1.48 and 2.68 pcs/m^2 across the experimental variants, with a relatively low field germination rate (40.0–68.0%). At the OOO "Zolotaya Osen", field germination was significantly higher, ranging from 70.9–91.6%, with an average number of seedlings of 3.01–4.44 pcs/m^2. In our opinion, this may be due to the application of fertilizers together with seeds during sowing at the APC "Znamya Rodiny", while fertilizers were not used at the OOO "Zolotaya Osen".

а *б*

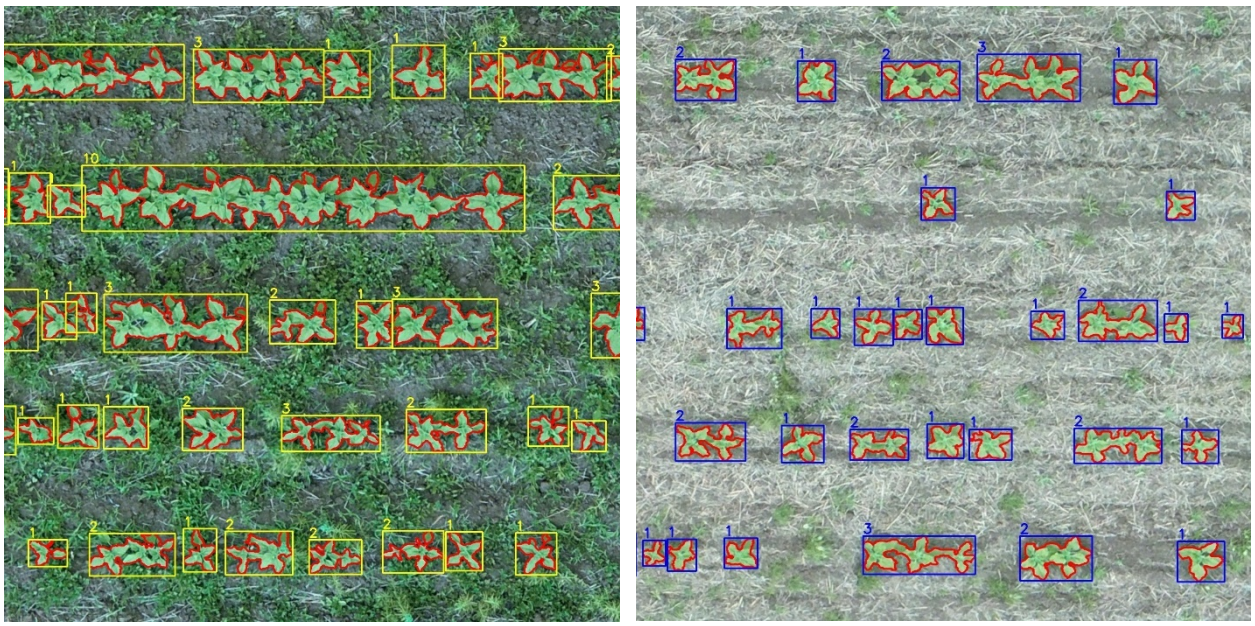


Рис. 5. Процедура определения числа растений на фрагментах изображений полей:
а – Алейский район; *б* – Поспелихинский район

Fig. 5. Procedure for determining the number of plants on the fragments of field images:
а – Aleysky district; *б* – Pospelikhinsky district

а *б*

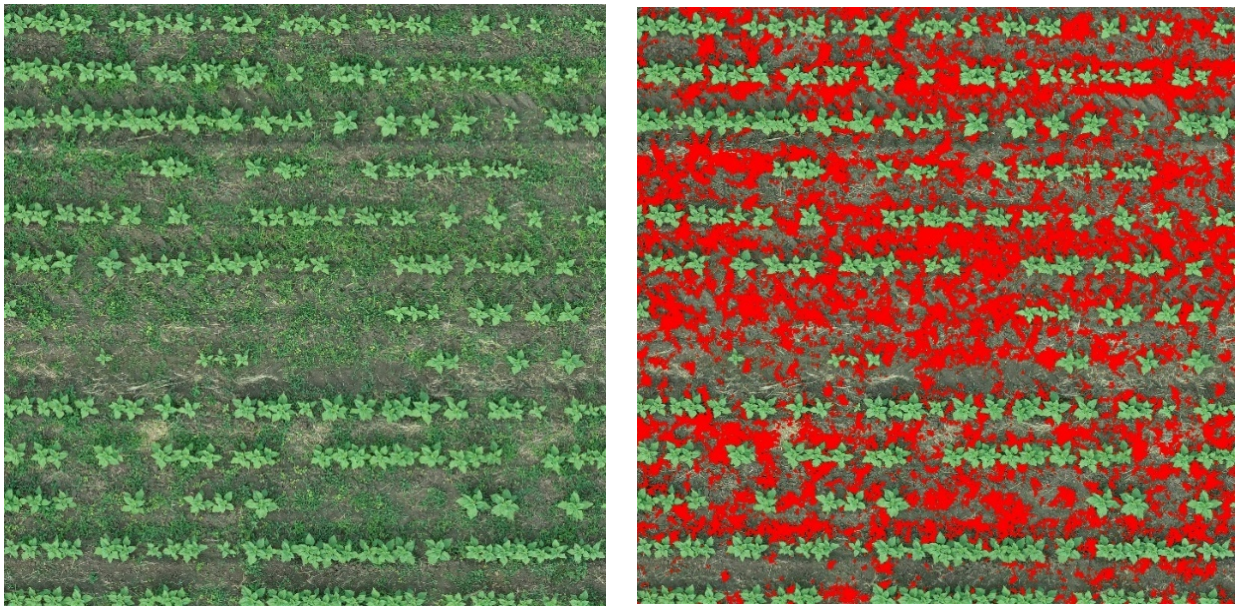


Рис. 6. Исходное изображение (*а*) и соответствующая ему карта сорной растительности (*б*) (Алейский район)

Fig. 6. Original image (*a*) and the corresponding weed vegetation map (*б*) (Aleysky district)

а *б*

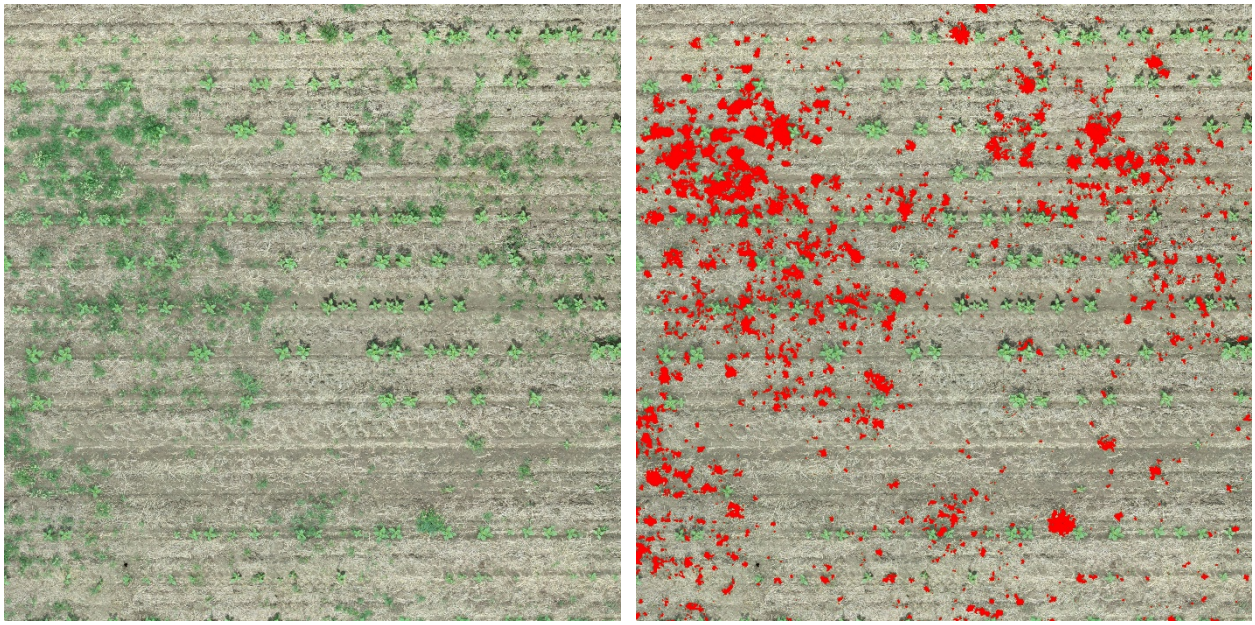
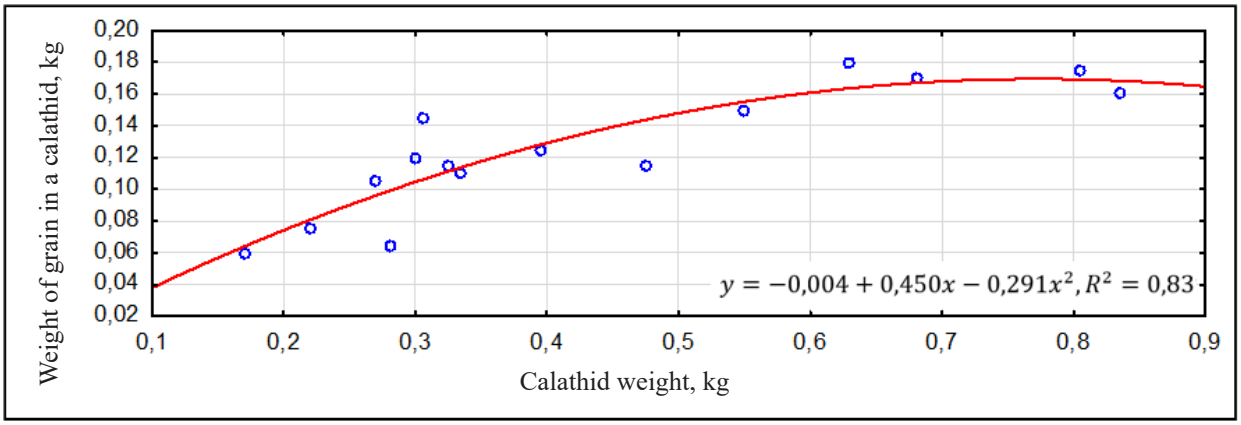


Рис. 7. Исходное изображение (*а*) и соответствующая ему карта сорной растительности (*б*) (Поспелихинский район)

Fig. 7. Original image (*a*) and the corresponding weed vegetation map (*б*) (Pospelikhinsky district)

As a result, under dry conditions (May–June), plant uptake of moisture and nutrients from the soil at higher planting densities was significantly higher, with most of these resources being spent on green mass formation. At the same time, the average weight of a single head and the grain within it decreased. This is confirmed by the significant (determination coefficient of 0.84) inverse relationship between the number of seedlings and the average grain weight (M_z) per head for all experimental variants:

а



б

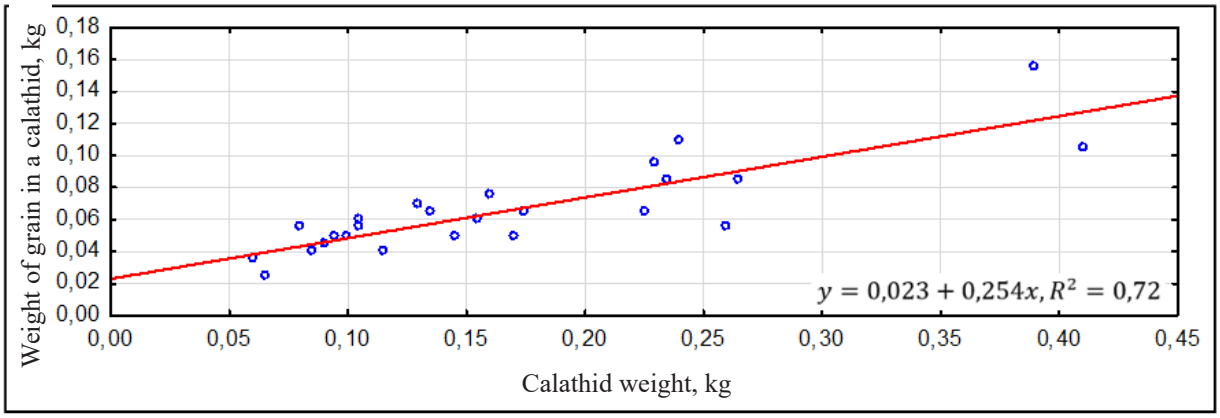


Рис. 8. Зависимость массы зерна в корзинке от массы корзинки:
а – СПК «Знамя Родины»; *б* – ООО «Золотая осень»
Fig. 8. Dependence of the grain weight in a head on sunflower head weight:
а – APC "Znamya Rodiny"; *б* – OOO "Zolotaya Osen"

$$M_з = 0{,}198 – 0{,}034\ К_{вск}.$$

Analysis of the biological yield of sunflower across the experimental variants in the APC “Znamya Rodiny”allows us to conclude that increasing the average seeding rate from 30,000 (in the low fertility zone) to 50,000 pcs/ha (in the high fertility zone) in combination with an increase in the diammophoska dose from 30 to 70 kg/ha against the background of the same dose of KAS-32 (112 kg/ha) resulted in an increase in the average yield from 22.9 to 26.1 c/ha with an average value of 24.8 c/ha across all variants. Thus, increasing the seeding rate and the fertilizer application rate in the high fertility zone allowed us to increase the yield by an average of 3.2 c/ha.

An inverse relationship was observed at OOO “Zolotaya Osen”. With an increase in the average seeding rate from 35,000 (in the low-fertility zone) to 55,000 seeds per hectare (in the high-fertility zone), without the use of fertilizers, the average yield decreased from 24.9 to 19.5 centners per hectare, or by 5.4 centners per hectare. This was primarily due to denser seedlings and low grain weight in heads. The average sunflower yield across all treatments at the OOO “Zolotaya Osen” was 22.5 centners per hectare. In our opinion, plant nutrition was the limiting factor in this case.

A mineral nutrition strategy aimed at increasing seeding rates and fertilizer application rates in a high-fertility zone should take into account limiting factors in the conditions of a particular year (the presence of moisture and nutrients in

Табл. 4. Осредненные значения оцениваемых показателей по вариантам опытов в СПК «Знамя Родины» и ООО «Золотая осень»

Table 4. Average values of the estimated indicators for the variants of experiments in the APC "Znamya Rodiny" and OOO "Zolotaya Osen"

Variant	*S*	K_s	K_{sdl}	F_g	$Y_{b.e}$
			APC "Znamya Rodiny"		
1.1	670	1664	2,48	49,6	26,6
2.1	670	1338	2,00	40,0	24,7
2.2	670	1778	2,65	66,3	26,9
2.3	670	1366	2,04	68,0	24,9
3.1	670	1796	2,68	53,6	26,9
3.2	670	1165	1,74	43,5	23,0
3.3	670	993	1,48	49,3	20,9
$LSD_{0,05}$	0	118	0,18	4,0	0,9
			OOO "Zolotaya Osen"		
1.1	563	2405	4,27	77,6	19,9
1.2	563	2308	4,10	91,1	21,5
1.3	563	1758	3,12	89,1	26,7
2.1	563	2369	4,21	76,5	20,5
2.2	563	1796	3,19	70,9	26,5
2.3	563	1697	3,01	86,0	26,9
3.1	563	2500	4,44	80,7	18,2
3.2	563	2317	4,12	91,6	21,3
3.3	563	1739	3,09	88,3	21,1
$LSD_{0,05}$	0	113	0,20	2,5	1,1

Note. S is the area of the plot for determining the number of seedlings in the plots using the remote sensing method, m^2; K_s is the number of seedlings in the observation site, pcs.; K_{sdl} is the number of seedlings per unit area, pcs./m^2; Fg is the field germination rate, %; $Y_{b.e}$ is the estimated average biological yield, c/ha.

the soil, their consumption under various tillage technologies, vegetation conditions, etc.), which will avoid a decrease in crop yields.

CONCLUSION

The developed automated method for determining the structure and yield of sunflowers allows for yield forecasting and also offers recommendations for different cultivation technologies (classical subsurface tillage and no-till systems).

When choosing rational seed application rates and fertilizer application rates according to soil fertility zones, one should take into account their combined effect on the field germination of

plants and the number of seedlings obtained, on which the mass of the basket and the grain in it depend, and, as a result, the yield of sunflower.

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Развитие болезней на *Vicia faba* L. при обработке семян энтомопатогенным грибом *Metarhizium robertsii* (Metchnikoff) Sorokin

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Кормовые бобы (*Vicia faba* L.) – ценная белковая культура, имеющая большое продовольственное значение. При возделывании в условиях Западной Сибири они поражаются целым комплексом болезней, снижающих не только качество продукции, но и приносящих значительные потери урожая. Изучено влияние энтомопатогенного гриба *Metarhizium robertsii* на развитие болезней на бобах кормовых сорта Сибирские. Полевые исследования проведены в 2019–2023 гг. на стационаре, расположенном в северной лесостепи Приобья Новосибирской области, по общепринятым методам. В качестве объекта исследований использовали штамм энтомопатогенного гриба *M. robertsii* (Р-72). Полевой эксперимент включал обработку семян кормовых бобов сорта Сибирские суспензией *M. robertsii* концентрацией 5×10^7 конидий/мл из расчета 2,5 л на 20 кг семян. Исследования показали, что обработка эндофитным энтомопатогенным грибом семян кормовых бобов *M. robertsii*, выращенных в полевых условиях, повышает устойчивость растений к комплексу заболеваний. Наиболее сильно в агроценозе бобов отмечено ежегодное проявление пятнистостей разной этиологии (виды рода *Alternaria*, *Cladosporium* и *Fusarium* и др.) – от 39,2 до 100%. При применении *M. robertsii* выявлено достоверное снижение развития болезни практически за все годы наблюдений. Растения после обработки в меньшей степени поражались корневыми гнилями, фузариозом, мозаикой, мучнистой росой и другими пятнистостями. Этот эффект отмечен во время всего периода вегетации бобов в течение 2019–2023 гг. при разных погодных условиях, что свидетельствует о положительном фитосанитарном действии и перспективе его использования в качестве агента биологического контроля в агроценозе сельскохозяйственных культур.

Ключевые слова: болезнь, кормовые бобы, *Vicia faba*, обработка семян, *Metarhizium robertsii*, развитие болезни, распространенность

Development of diseases on *Vicia faba* L. when treating seeds with the entomopathogenic fungus *Metarhizium robertsii* (Metchnikoff) Sorokin

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Broad beans (*Vicia faba* L.), as a valuable protein crop, are of great food importance. When grown in Western Siberia, they are affected by a whole range of diseases that not only reduce the quality of the product, but also cause significant crop losses. The influence of the entomopathogenic fungus *Metarhizium robertsii* on the development of diseases on broad beans of the Sibirskie variety was studied. Field studies were conducted in 2019–2023 at a station located in the northern forest-steppe of the Ob region of the Novosibirsk region, using the generally accepted methods. The strain of the entomopathogenic fungus *M. robertsii* (P-72) was used as the object of research. The field experiment included treating the seeds of the Sibirskie variety of broad beans with a suspension of *M. robertsii* at a concentration of 5×10^7 conidia/ml at a rate of 2.5 l per 20 kg of seeds. The studies

have shown that treatment of field-grown broad bean seeds with the endophytic entomopathogenic fungus *M. robertsii* increases plant resistance to a range of diseases. The most pronounced annual occurrence of spotting of various etiologies (species of the genus *Alternaria*, *Cladosporium* and *Fusarium*, etc.) in the bean agrocenosis is from 39.2 to 100%. When using *M. robertsii*, a reliable reduction in the development of the disease was revealed in almost all years of observation. After treatment, the plants were less affected by root rot, fusariosis, mosaic, powdery mildew and other spotting. This effect was observed during the entire period of bean vegetation during 2019–2023 under different weather conditions, which indicates a positive phytosanitary effect and the prospect of its use as a biological control agent in the agrocenosis of agricultural crops.

Keywords: disease, broad beans, *Vicia faba*, seed treatment, *Metarhizium robertsii*, disease development, prevalence

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The author declares no conflict of interest.

INTRODUCTION

Broad beans (*Vicia faba* L.) are a valuable protein crop of great food value. Their protection from pests is a significant concern worldwide [1–3]. When grown in Western Siberia, they are also susceptible to a range of diseases that not only reduce product quality but also cause significant yield losses[1, 2]. One of the environmentally friendly approaches and techniques that reduce the harmfulness of diseases and increase crop yields is the use of beneficial microorganisms in agricultural production, such as entomopathogenic fungi, in particular *Metarhizium robertsii* [4, 5].

Entomopathogenic fungi are capable of colonizing various plants and have a number of positive properties: they translocate nitrogen obtained by insects, stimulate plant growth and crop yields, and inhibit the development of phytophages and phytopathogens[3] [6]. A number of studies have shown the positive role of *M. robertsii* in improving plant growth and development, increasing the efficiency of nutrient use, increasing resistance to abiotic stress, and reducing the development and prevalence of diseases and pests [7, 8].

The purpose of the study is to investigate the influence of the entomopathogenic fungus *M. robertsii* on the development of diseases on fodder beans of the Sibirskie variety.

MATERIAL AND METHODS

Field studies were conducted from 2019 to 2023 at the Siberian Institute of Fodder Crops of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences, located in the northern forest-steppe region of the Ob River basin in Novosibirsk Oblast, using standard methods. The study utilized a strain of the entomopathogenic fungus *M. robertsii* (P-72), obtained from the microorganism collection of the Institute of Animal Taxonomy and Ecology of the Siberian Branch of the Russian Academy of Sciences. The field experiment involved treating the seeds of the Si-

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[3]*Ownley B.H., Gwinn K.D., Vega F.E.* Endophytic fungal entomopathogens with activity against plant pathogens: ecology and evolution // BioControl, 2010, vol. 55, pp. 113–128. DOI: 10.1007/s10526-009-9241-x.

birskie broad bean variety with a suspension of *M. robertsii* at a concentration of 5 × 107 conidia/ml at a rate of 2.5 l per 20 kg of seed. The experimental variants were systematically placed in five replicates, with a seeding rate of 400,000 viable seeds/ha, and the plot area was 39 m^2.

After treating bean seeds with the fungus *M. robertsii*, the seed samples were collected for analysis of their effectiveness against phytopathogens using standard methods. The field studies utilized natural loads of root rot pathogens in the soil, transmitted by soil and seeds. The visual records of plant infestations by various diseases were conducted using standard methods. During the stem formation phase, bean plants were sampled for mycological analysis of their infection with root rot pathogens.

The years of research varied in meteorological conditions and covered the entire spectrum of weather conditions.

RESULTS AND DISCUSSION

Research has shown that the *M. robertsii* bean seeds used for this experiment were initially significantly infected with root rot pathogens. On average, over the period 2019–2023, the control sample showed 31% *Alternaria* infestation, 16% *Cladosporium* infestation, and up to 13% *Fusarium* infestation. Analysis of seed contamination showed that treatment of bean seeds with an *M. robertsii* suspension significantly (χ-squared test significance ($p < 0.05$)) inhibited the development of seed-borne phytopathogens: *Alternaria* species (3.9 times), *Cladosporium* (16.0 times), and *Fusarium* (4.3 times) (see Table 1).

The colonization of *M. robertsii* seeds varied between 58 and 79% over the years, averaging 69%. Treatment of bean seeds with *M. robertsii* reduced the development of mold fungi: *Aspergillus* species by 3.3 times, and *Penicillium* by 2.4 times.

The positive impact of treating bean seeds with the fungus *M. robertsii* on the phytosanitary condition of plants is confirmed by the results of the root rot analysis (see Fig. 1). It was found that the disease development index was significantly reduced (2.5 times below the severity threshold) in the plants with fungus-treated seeds. A trend toward a 1.6-fold decrease in the

Табл. 1. Заселенность посевных семян кормовых бобов (2019–2023), %
Table 1. Colonization of sowing seeds of broad beans (2019–2023), %

Variant	*Alternaria*	*Aspergillus*	*Cladosporium*	*Fusarium*	*M. robertsii*	*Mucor*	*Penicillium*	*Rhyzopus*	*Trichothecium*	Other
M. robertsii	8*	4*	1*	3*	69*	3*	7*	0*	1*	0
Control	31	13	16	13	0	8	17	1	0	1

*Significance by χ-square test ($p < 0,05$).

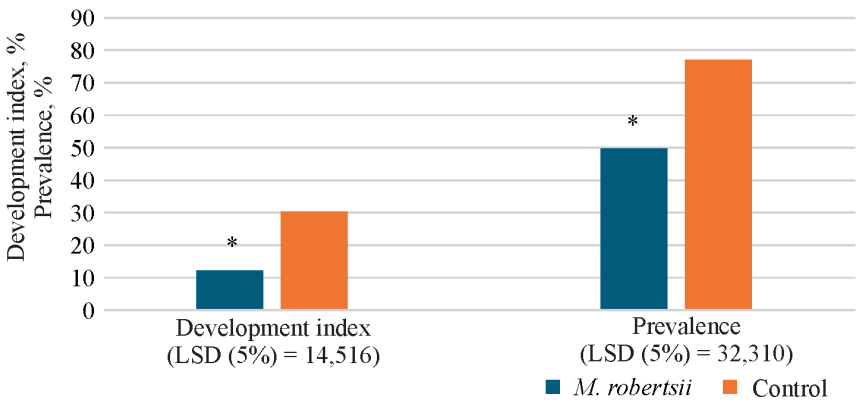

Рис. 1. Развитие корневой гнили кормовых бобов. * Значимость отличия
Fig. 1. Development of root rot of broad beans. * Significance of difference

disease prevalence was also observed.

Mycological analysis of the colonization of the bases of broad bean stems showed that both seed-borne and soil-borne pathogens, such as species of the genus *Alternaria*, *Cladosporium*, and *Fusarium*, are involved in the pathogenesis of this disease. Seed treatment significantly reduced the infection of plants with these pathogens (see Table 2).

The development of leaf and stem diseases over the years of research varied, but it was most intense towards the end of the growing season, towards the milky ripeness phase (80 days after sowing) (see Fig. 2).

The most common diseases in bean crops were powdery mildew, mosaic, fusariosis, spot diseases, and others. Weather conditions also significantly influenced the incidence and composition of diseases. The highest significant incidence of powdery mildew was observed in 2021 (47.9% of the control), which was associated with significant precipitation in June. The lowest incidence (11.6%) occurred in the dry 2022. A significant decrease in disease development was observed in 2020 and 2022. In the remaining years, although a downward trend in disease incidence was noted, no significant differences were observed. On average, over the study years, the disease development index in the control was 51.7%; seed treatment with *M. robertsii* reduced disease development by 1.6 times, improving the phytosanitary condition of the crops.

The most severe annual incidence of spotting of various etiologies (species of the genus *Alternaria*, *Cladosporium* and *Fusarium*, etc.) was observed in the bean agrocenosis – from 39.2 to 100%. When using *M. robertsii*, a significant reduction in the development of the disease was found in almost all years of observation.

In recent years, an increase in the development of a harmful disease, fusariosis, has been observed in broad bean crops, leading to complete plant death. On average, the disease incidence rate over the years of observation reached 25.9%, while in the case of fungal treatment, it decreased by 2.4 times.

Research conducted in Western Siberia showed that treating field-grown *V. faba* broad bean seeds with the fungus *M. robertsii* increases plant resistance to a range of diseases. After treatment, plants were less susceptible to root rot, mosaic, fusariosis, powdery mildew, and various

Табл. 2. Заселенность оснований стеблей кормовых бобов, %
Table 2. Colonization of the stem bases of broad beans, %

Variant	*Alternaria*	*Aspergillus*	*Cladosporium*	*Fusarium*	*Mucor*	*Penicillium*	Other
M. robertsii	23*	1	3*	47*	2*	3	3
Control	40	2	7	64	31	4	5

*Significance by χ-square test ($p < 0,05$).

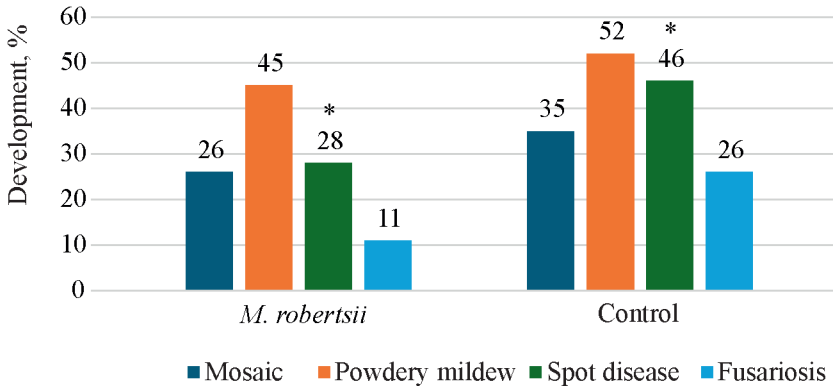

Рис. 2. Развитие болезней на кормовых бобах. * Значимость отличия
Fig. 2. Development of diseases on broad beans. * Significance of difference

spot diseases. According to published data, entomopathogenic species of the genus *Metarhizium* can colonize a wide range of plants, including legumes [4, 9].

The mechanism of action of endophytic entomopathogenic fungi of the genus *Metarhizium* against phytopathogenic fungi is not fully understood. It is believed that they enhance plant resistance to diseases through antibiosis, the release of lytic enzymes and secondary metabolites, enhanced plant resistance induction, competition with pathogens, and other mechanisms[4] [10]. The ability of *M. robertsii* to act antagonistically towards phytopathogens may be associated with various mechanisms [6]. However, they are quite complex and have not been fully elucidated[5, 6]. There are several mechanisms of antagonistic ability of endophytes: competition for niche or resources, antibiosis, parasitism and induced systemic resistance[7]. According to other authors, they can establish interspecies interactions, and protection from pathogen attack is carried out both by direct mechanisms, such as competition, parasitism and antibiosis (production of primary and secondary metabolites, enzymes or volatile compounds), and by indirect mechanisms, such as the induction of resistance.

The results we obtained and the literature data provided indicate the multifunctional effect of *M. robertsii* on the plant.

CONCLUSION

Studies have shown that treating *V. faba* broad bean seeds with the fungus *M. robertsii* increases plant resistance to a range of diseases in the field. After treatment, plants were less susceptible to root rot, fusarium, mosaic, powdery mildew, and other spotting diseases. This effect was observed throughout the entire bean growing season in all studied years, demonstrating a positive phytosanitary effect and potential for its use as a biological control agent in agricultural crops.

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ИНФОРМАЦИЯ ОБ АВТОРЕ

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Исследование биохимического состава крови осетров при использовании циклодекстринового комплекса с энтеросгелем

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Биохимическая картина крови позволяет не только определить влияние антимикробных препаратов на организм рыб, адаптацию к условиям водоемов, но и определить физиологическое состояние гидробионтов. Цель исследования заключалась в изучении влияния циклодекстринового комплекса с энтеросгелем на биохимические параметры крови молоди осетров. Для исследований сформировали подопытные группы по принципу пар-аналогов в количестве 10 экз. в каждой группе: 1-я и 2-я контрольные группы характеризовались нарушенным функциональным состоянием организма. С ними не проводили лечебных мероприятий, в комбикорм не вводили левофлоксацин с энтеросгелем. Различия заключались в том, что особям 1-й контрольной группы задавали качественный корм, 2-й контрольной – недоброкачественный. В эксперименте 1-я и 2-я опытные группы получали качественный корм, с ними проводили лечебные мероприятия, они также характеризовались нарушенным функциональным состоянием организма. Различия заключались в разной концентрации вводимого препарата – 15 и 10% соответственно. Содержание общего белка у рыб на 8-е сутки в 1-й и 2-й опытных группах составило 77,60 ± 0,80 и 84,90 ± 3,43 г/л соответственно, что на 7,87 и 0,57 г/л ниже, чем в 1-й контрольной группе. По общему содержанию белка контрольные группы между собой различий практически не имели – 86,33 и 86,63 г/л соответственно. У осетров из опытных групп показатель оказался ниже контрольных значений на 9,76 и 3,86 г/л. Анализ содержания макроэлементов показал, что их значения по группам были приблизительно на одном уровне и не выходили за пределы нормы. По полученным значениям концентрации фосфора в крови оптимальными значениями отличались осетры 2-й опытной группы, получавшие исследуемый комплекс с содержанием фторхинолона 10%.

Ключевые слова: осетры, циклодекстриновый комплекс, биохимия крови, билирубин, белок, глюкоза, креатинин, щелочная фосфатаза

Study of the biochemical composition of sturgeon blood using a cyclodextrin complex with enterosgel

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The biochemical picture of blood allows not only to determine the effect of antimicrobial drugs on the body of fish, adaptation to the conditions of water bodies, but also to determine the physiological state of aquatic organisms. The purpose of the study was to study the effect of cyclodextrin complex with enterosgel on the biochemical parameters of the blood of young sturgeons. For the studies, experimental groups were formed according to the principle of pairs-analogues in the amount of 10 specimens in each group: 1st control and 2nd control groups were characterized by an impaired functional

state of the body. No therapeutic measures were carried out with them, levofloxacin with enterosgel was not introduced into the compound feed. The differences were that individuals of the 1st control group were given high-quality feed, while the 2nd control group was given poor-quality feed. The 1st experimental and 2nd experimental groups received high-quality feed, they underwent therapeutic measures, and they were characterized by an impaired functional state of the body. The differences consisted in different concentrations of the administered drug – 15 and 10%, respectively. The total protein content of fish on the 8th day in the 1st and 2nd experimental groups was 77.60 ± 0.80 and 84.90 ± 3.43 g / l, respectively, which is 7.87 g / l and 0.57 g / l lower than in the 1st control group. In terms of total protein content, the control groups had virtually no differences between themselves with 86.33 g / l and 86.63 g / l respectively. In sturgeons from the experimental groups, the indicator was lower than the control values by 9.76 g / l and 3.86 g / l. Analysis of the content of macro elements showed that their values by groups were approximately at the same level and did not go beyond the norm. According to the obtained values of phosphorus concentration in the blood, the optimal values were observed in sturgeons of the 2nd experimental group, which received the studied complex with a fluoroquinolone content of 10%.

Keywords: sturgeons, cyclodextrin complex, blood biochemistry, bilirubin, protein, glucose, creatinine, alkaline phosphatase

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Conflict of interest
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INTRODUCTION

Industrial sturgeon farming has been rapidly developing worldwide in recent years. This is due to the fact that this technology allows for year-round fish farming under optimal conditions using modern mechanization and automation [1]. However, this technology has a significant drawback: dense stocking increases the risk of widespread aquatic organism diseases. In this regard, drugs with pronounced antimicrobial activity are used in industrial fish farming for the prevention and treatment of infections [2, 3]. A progressive approach to increasing the effectiveness of antibacterial drugs is the development of innovative dosage forms by encapsulating the drug in various types of micro- and nanoparticles made of biocompatible and biodegradable polymers, lipids, etc. [4].

This approach enhances the solubility and bioavailability of hydrophobic organic molecules, while minimizing side effects. Fluoroquinolone antibiotics exhibit pronounced activity against most microorganisms, but because they are poorly soluble in biological environments, their use is limited. Therefore, research efforts are focused on creating effective fluoroquinolone delivery systems with improved pharmacokinetic properties [5].

Among delivery substances, natural polymers (polysaccharides, cyclic oligosaccharides, and others) are of particular interest. They offer a number of advantages: biocompatibility, availability, and low cost [6–9].

To produce the complex, the cyclodextrin is selected based on the size of the internal cavity, which corresponds to the geometric dimensions of the drug molecule. Studies on dogs, rats, and

birds have shown excellent results using cyclodextrin complexes to increase the bioavailability of drugs compared to the pure drug [10].

In recent decades, various nanoparticle additives, including intestinal sorbent preparations, have been increasingly used in livestock feed to improve feed efficiency [11, 12]. The most common route of administration of medications is oral administration. The use of intestinal sorbents can shorten treatment periods and eliminate symptoms. Intestinal sorbents are gel-like or solid substances that pass through the intestines and remove toxins. High-quality intestinal sorbents are characterized by the following key properties: safety, compatibility with body tissues, and effective adsorption.

A review of scientific sources conducted over the past two decades [13] demonstrates the effectiveness of using feed additives with sorption properties in fish farming. The summarized data obtained as a result of the review allow us to consider feed additives with sorption properties as promising in terms of potential implementation in fish farming practice.

Research by Russian scientists demonstrates the positive impact of newly developed feed additives based on fish milt, glycerin, and black garlic on the reproductive performance of male sturgeon [14].

As a result of using the probiotic strain *Lactobacillus brevis* 47f in feed for juvenile sterlet, the preservation of lactobacilli in the prepared feed and the survival of the strain on the mucous surface of the intestine of fish, an increase in the concentration of lymphocytes, protein and its fractions in the blood were identified [15].

The purpose of the study is to investigate the effect of a cyclodextrin complex with enterosgel on the biochemical parameters of the blood of juvenile sturgeons.

MATERIAL AND METHODS

For the study, experimental groups were formed using the principle of analogous pairs, with 10 specimens in each group, according to the scheme (see Table 1). During the experiment, the average weight of the fish ranged from 241.1 to 243.1 g. All groups of aquatic organisms were kept in four aquariums.

During the experiment, the test fish, with the exception of the second control group, were fed a nutritionally balanced sturgeon feed. Its quality indicators are presented in Table 2.

The content of crude protein in the compound feed is 46.0%, crude fat – 17,0%.

The feed was mixed with an enterosgel-ß-cyclodextrin complex with varying amounts of levofloxacin according to the planned feeding rates and frequency. To ensure a reliable effect of the complexes, fish in the second control group were given expired feed for digestive upset 10 days before and during the experiment.

Table 3 presents the results of microbiological and chemical analysis of feed with expired shelf life, which was fed to sturgeon juveniles of the 2nd control group.

Immediately before the experiment, the fish were marked by cutting their fins and assigning

Табл. 1. Схема опыта
Table 1. Experimental scheme

Indicator	Group			
	control		experimental	
	1st	2nd	1st	2nd
Feed	Qualitative	Poor quality	Qualitative	Qualitative
Functional state of the body	Impaired	Impaired	Impaired	Impaired
Treatment measures	Not carried out	Not carried out	Not carried out	Not carried out
Levofloxacin concentration in combination with Enterosgel, %	–	–	15	10

them an individual number, and then the muscle tissue was dissected to a depth of 1 cm in the area of the dorsal fin to assess the dynamics of wound healing. The examined fish specimens did not show any pathology at the beginning of the experiment, were homogeneous and were kept in the same conditions.

The fish in the experimental groups were fed with feed containing a cyclodextrin complex for 7 days. Then, on the 8th and 14th days, the sturgeons were identified by number, and the blood was collected from the heart muscle for biochemical analysis.

The biochemical parameters analyzed included total and direct bilirubin, total protein, enzymes, creatinine, glucose, alkaline phosphatase, calcium, and phosphorus [4]. The small sample size was due to the difficulty of obtaining and processing the experimental material (n = 3). The data obtained were subjected to mathematical processing using an application software package.

During the experiment, the aquarium setup ensured flow, aeration, and water quality, meeting key hydrochemical parameters. Key parameters were regularly monitored during the study (see Table 4).

Табл. 2. Качественные показатели продукционного комбикорма для осетров

Table 2. Quality indicators of production compound feed for sturgeons

Indicator	Value
Crude protein, %	46,0
Crude fat, %	17,0
Crude fiber, %	1,9
Crude ash, %	8,0
Phosphorus, %	1,1
Total energy, MJ/kg	23,0
Vitamin A, c.u./kg	12 000,0
Vitamin D, c.u./kg	2100,0
Vitamin E, mg/kg	340,0
Vitamin C, mg/kg	525,0

Табл. 3. Результаты анализа некачественного корма для осетров

Table 3. Results of the analysis of poor-quality feed

Indicator	Value
Microbiology: Salmonella	Not detected
Toxin-producing anaerobes	The same
Enterogenic types of Escherichia coli	»
Mass fraction, %: moisture	5,8
crude protein in dry matter	41,63 ± 1,50
crude ash in dry matter	9,4 ± 0,4
crude fat per dry matter	12,3
Peroxide value, mmol $1/2O_2$/kg	24,68 ± 2,22

There were no significant fluctuations in water quality parameters during the study period.

RESULTS AND DISCUSSION

Blood is an informative indicator and reacts sensitively to the slightest changes in feeding and maintenance conditions (see Table 5). Since the experimental fish were given the feed supplemented with an enterosgel complex, it was necessary to evaluate its effect on blood parameters.

Bilirubin, aminotransferases, and alkaline phosphatase are among the indicators characterizing the condition of the liver. A study of the blood serum biochemistry on the 8th day showed that the maximum concentration of total bilirubin was detected in the 1st control group - 13.63 ± 1.75 μmol/l, in the 1st and 2nd experimental groups it was lower by 4.46 and 1.93 μmol/l, respectively. For direct bilirubin, the trend remained.

The ratio of aminotransferase enzymes on the 8th day in the 1st control group was 0.63, in the 2nd control group – 0.60, in the 1st experimental group – 0.81, in the 2nd experimental group – 0.71.

Табл. 4. Физико-химические свойства воды в аквариальной установке
Table 4. Physical and chemical properties of water in an aquarian plant

Indicator	Group			
	control		experimental	
	1st	2nd	1st	2nd
From the first to the 8th day of the experiment				
Water temperature, ºC	21,6	19,7	19,9	20,6
Oxygen content, mg/l	6,5	6,4	6,3	6,5
pH	7,34	7,53	7,83	7,48
Transparency, cm	60,0	60,0	60,0	60,0
From the 9th to the 14th day of the experiment				
Water temperature, ºC	21,5	20,8	21,0	20,9
Oxygen content, mg/l	6,6	6,7	6,6	6,5
pH	7,44	7,62	7,67	7,80
Transparency, cm	60,0	60,0	60,0	60,0

Proteins allow us to assess the functioning of the immune and hormonal systems. The total protein content of fish in the 1st and 2nd experimental groups was 77.60 ± 0.80 and 84.90 ± 3.43 g/l, respectively, which is 7.87 and 0.57 g/l lower than in the 1st control group.

Creatinine indicates the intensity of energy metabolism. The minimum amount of creatinine was noted in individuals of the 1st experimental group – 90.90 ± 0.67 μmol/l, which is 20.73 μmol/l lower than in the 1st control ($p \geq 0,95$).

Glucose levels characterize the liver's detoxification of toxic compounds and the normal functioning of the cardiovascular system. Glucose concentrations were highest in the 3rd experimental group and lowest in the 1st control group, at 2.50 mmol/l.

According to the alkaline phosphatase value, the 2nd experimental group was reliably distinguished, where its value reached 90.43 ± 2.61 units/l, which is 15.43 units/l more than in the 1st control.

Табл. 5. Биохимические показатели крови осетров на 8-е сутки
Table 5. Sturgeon blood biochemistry on the 8th day

Indicator	Group			
	control		experimental	
	1st	2nd	1st	2nd
Bilirubin, μmol/l:				
total	13,63 ± 1,75	7,80 ± 0,42*	9,17 ± 0,57	11,70 ± 1,97
direct	2,80 ± 0,15	1,57 ± 0,42	1,70 ± 0,10*	2,73 ± 0,23
AST, units/l	41,33 ± 2,20	36,33 ± 4,67	38,13 ± 2,18	38,27 ± 5,59
ALT, units/l	65,27 ± 4,65	60,50 ± 5,44	46,83 ± 4,28*	54,00 ± 3,06
Total protein, g/l	85,47 ± 2,55	83,70 ± 4,60	77,60 ± 0,80*	84,90 ± 3,43
Creatinine, μmol/l	111,63 ± 4,54	124,80 ± 0,76*	90,90 ± 0,67*	120,47 ± 0,53
Glucose, mmol/l	2,50 ± 0,31	2,80 ± 0,44	2,97 ± 0,43	3,63 ± 0,33
Alkaline phosphatase, units/l	75,00 ± 4,73	75,57 ± 4,09	78,13 ± 4,04	90,43 ± 2,61*
Calcium, mmol/l	3,47 ± 0,32	3,73 ± 0,12	3,40 ± 0,40	3,83 ± 0,03
Phosphorus, mmol/l	4,50 ± 0,56	4,43 ± 0,17	4,13 ± 0,13	4,30 ± 0,15

*$p \geq 0,95$.

The content of calcium and phosphorus varied across the groups and ranged from 3.40 to 3.83 mmol/l and from 4.13 to 4.50 mmol/l, respectively, in the experimental groups.

Information on blood biochemistry on the 14th day is presented in Table 6.

The individuals of the 1st experimental group stood out in terms of total bilirubin level, where its value was 14.43 ± 0.80 μmol/L, which is 1.37 μmol/l less than in the 1st control group. The direct bilirubin indicator was highest in the 1st control group – 3.73 μmol/l, the lowest – in the 1st experimental group – 3.07 μmol/l.

The de Ritis ratio reached the values of 0.79 in the 1st control group, 0.74 in the 2nd control group, 0.72 in the 1st experimental group, and 0.76 in the 2nd experimental group, respectively.

In terms of total protein content, the control groups had virtually no differences between themselves – 86.33 and 86.63 g/l; in sturgeons from the experimental groups, the indicator was lower than the control values by 9.76 and 3.86 g/l.

The creatinine level in the 1st experimental group was reliably the lowest – 96.83 ± 0.95 μmol/l ($p \geq 0.99$), which is 7.17 μmol/l less than in the 1st control group.

The glucose level decreased in the 1st experimental group by 0.17 mmol/l, in the 2nd experimental group it increased by 0.1 mmol/l relative to the level of the 1st control group.

The presence of alkaline phosphatase in both experimental groups was significantly lower by 26.66 units/l in the 1st experimental group, 18.76 units/l in the 2nd experimental group ($p \geq 0.99$) compared to the 1st control group.

Analysis of macronutrient levels showed that their values were approximately the same across groups and within normal limits. Based on the obtained blood phosphorus concentrations, sturgeons in the second experimental group, which received the test complex containing 10% fluoroquinolone, had the optimal values.

CONCLUSIONS

1. The introduction and mixing of the enterosgel-ß-cyclodextrin complex with varying amounts of levofloxacin with feed increased the glucose and alkaline phosphatase levels in the blood of juvenile sturgeons on the 8th day of the study, and to a greater extent in individuals with a level of introduced components of 10% compared to juveniles that were given 15%. For

Табл. 6. Биохимические показатели крови осетров на 14-е сутки
Table 6. Sturgeon blood biochemistry on the 14th day

Indicator	Group			
	control		experimental	
	1st	2nd	1st	2nd
Bilirubin, μmol/l:				
total	15,80 ± 0,15	16,30 ± 1,39	14,43 ± 0,80	15,57 ± 0,92
direct	3,73 ± 0,43	3,60 ± 0,46	3,07 ± 0,57	3,63 ± 0,20
AST, units/l	53,40 ± 5,23	45,83 ± 5,59	41,80 ± 1,60	51,07 ± 3,23
ALT, units/l	67,27 ± 2,66	62,07 ± 4,68	57,77 ± 5,83	67,23 ± 2,09
Total protein, g/l	86,33 ± 5,51	86,63 ± 4,54	76,57 ± 2,75	82,47 ± 5,72
Creatinine, μmol/l	104,00 ± 0,58	103,00 ± 1,15	96,83 ± 0,95**	100,3 ± 3,42
Glucose, mmol/l	2,97 ± 0,26	3,10 ± 0,12	2,80 ± 0,10	3,07 ± 0,22
Alkaline phosphatase, units/l	94,43 ± 1,70	92,73 ± 1,76	67,77 ± 2,77**	75,67 ± 2,60**
Calcium, mmol/l	3,63 ± 0,17	3,53 ± 00,27	3,70 ± 0,17	3,60 ± 0,21
Phosphorus, mmol/l	4,40 ± 0,29	4,73 ± 0,12	4,53 ± 0,23	5,07 ± 0,22

**$p \geq 0,99$.

other biochemical parameters of the blood, superiority was noted in the control groups of sturgeons that did not receive the additive.

2. On the 14th day, juvenile fish that received a higher dose of the administered complex had lower blood concentrations of bilirubin, creatinine, glucose, and alkaline phosphatase than other groups. Introducing 10% of the complex into the juvenile fish feed, unlike the higher dose, significantly increased all blood biochemical parameters.

3. The obtained data indicate that the introduction of a cyclodextrin complex with enterosgel at a dose of 15% into the diet along with feed did not cause significant changes in the metabolism of aquatic organisms; a 10% concentration of levofloxacin proved more effective. Despite the observed intergroup differences, the blood biochemical parameters of the entire experimental population were within the physiological norm for the species.

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Оценка коров по индексу пищевой активности в условиях роботизированного доения

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В статье представлены результаты исследования, заключающегося в апробации метода оценки коров по индексу пищевой активности. Указанный индекс определяется отношением суточного удоя ко времени, затраченному на прием корма и жевательную активность. В рамках предложенного метода проведен анализ этологических проявлений коров в условиях роботизированного доения. Сведения о поведенческих особенностях животных получены методом визуального наблюдения на одном из предприятий по разведению голштинской породы в Республике Татарстан. Установлено, что с повышением индекса пищевой активности коровы меньше находятся в положении стоя и уделяют меньше времени пассивному отдыху, больше лежат и больше времени отводят жевательной активности, что отражается на показателях их молочной продуктивности. У коров с высоким индексом пищевой активности удой за 305 дней лактации был достоверно больше, чем у коров со средним индексом, на 932,2 кг (9,0%) при $p < 0,05$, с низким индексом – на 1686,9 кг (17,5%) при $p < 0,01$. Животные с высоким индексом пищевой активности по содержанию молочного жира и белка достоверно опережали коров со средним индексом соответственно на 41,2 кг (10,3%) и 31,3 кг (9,3%) при $p < 0,05$, с низким индексом – соответственно на 71,2 кг (19,3%) и 55,4 кг (17,8%) при $p < 0,01$. Таким образом, индекс пищевой активности может использоваться как селекционный признак для совершенствования молочного стада, что позволяет комплектовать его животными активного типа поведения.

Ключевые слова: дойная корова, поведение, индекс пищевой активности, потребление корма, жевательная активность, молочная продуктивность

Evaluation of cows according to the index of nutritional activity in the conditions of robotic milking

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The article presents the results of a study on testing a method for assessing cows using the nutritional activity index. The specified index is determined by the ratio of daily milk yield to the time spent on feed intake and chewing activity. Within the framework of the proposed method, analysis of the ethological manifestations of cows under robotic milking conditions was carried out. Information on the behavioral characteristics of animals was obtained by visual observation at one of the Holstein breeding farms in the Republic of Tatarstan. It has been established that with an increase in the nutritional activity index, cows spend less time standing and devote less time to passive rest, lie down more and devote more time to chewing activity, which is reflected in their milk productivity indicators. Cows with a high nutritional activity index had significantly higher milk yield for 305 days of lactation than the cows with an average index by 932.2 kg (9.0%) at $p < 0.05$, and with a low index by 1686.9 kg (17.5%) at $p < 0.01$. Animals with a high nutritional activity index in terms of milk fat and protein content were significantly ahead of the cows with an average index by 41.2 kg (10.3%) and 31.3 kg (9.3%), respectively, at $p < 0.05$, and with a low index by 71.2 kg (19.3%) and 55.4 kg (17.8%), respectively, at $p < 0.01$. Thus, the nutritional activity index can be used as a selection feature for improving the dairy herd, which allows it to be filled with animals of an active behavior type.

Keywords: dairy cow, behavior, nutritional activity index, feed consumption, chewing activity, milk productivity

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INTRODUCTION

Currently, one of the most promising areas for the implementation of innovative technologies in the dairy industry is robotic milking technology [1]. This technology utilizes various systems and sensors to monitor data and indicators collected from animals during feeding, resting, and milking. A specialized mathematical algorithm deciphers the received data and converts it into graphs and digital values. The range of indicators obtained by an automated milking system may vary depending on its equipment and configuration [2].

In these conditions, modern methods of improving dairy cattle are based on the evaluation and selection of animals based on udder quality [3], milk production intensity [4], and stress resistance [5]. At the same time, one of the reserves for more complete realization of the genetic potential of animals is the use of their ethological manifestations in selection [6, 7]. From this point of view, the most promising are the feeding and chewing activity of animals.

We have developed a method for evaluating cows that includes ethological indicators, in particular the feeding activity[1].

The introduction of innovative approaches that take into account the behavioral characteristics of animals contributes to the further intensification of dairy farming [8]. Based on the above, it can be concluded that further study of the ethological manifestations of animals and their use in the selection of dairy cattle is a relevant area.

The purpose of the study is to test the proposed method and study the influence of the assessment parameter based on the index of food activity of cows on their economically useful traits.

MATERIAL AND METHODS

The study was conducted in 2019–2023 based on data collected at the "Mukhametshin Z.Z." farm in the Republic of Tatarstan and at the Department of Feed of the Faculty of Biotechnology and Standardization of the Kazan State Academy of Veterinary Medicine named after N.E. Bauman. The study subjects were 32 first-calf Holstein cows (98.4 ± 6.8 days of lactation, average daily milk yield of 31.0 ± 1.8 kg), serviced by Astronaut A4 robotic milkers (Lely Industries N.V., Netherlands) with free animal movement.

The cows were fed a partially mixed ration 3 times a day – at 6:00, 9:00 and 15:00, as well as concentrated feed in milking stalls during milking.

Visual observation, during which the animals' behavioral acts were recorded, was carried out over three consecutive days[2]. Afterwards, the data obtained for each cow was processed and converted into average daily indicators.

The food activity index was calculated using the formula

$$FAI = \frac{DMY}{FI + CA},$$

where FAI – food activity index, kg/h; DMY – daily milk yield, kg; FI – feed intake, h; CA – chewing activity (chewing gum), h.

[1]Pat. 2821203 Russian Federation. Method for assessing cows by food activity index / Sharipov D.R., Kayumov R.R., Yakimov O.A., Ravilov R.Kh., Galimullin I.Sh., Akhmetzyanova F.K., Zagidullin L.R., Salyakhov A.Sh., Zakirova G.M.; No. 2023132243; application 07.12.23; publ. 06/18/24, Bulletin No. 17, 7 p.

[2]*Velikzhanin V.I.* Methodological recommendations for the use of ethological traits in the selection of dairy cattle. St. Petersburg: Publishing House of VNIIGRZH, 2000, 18 p.

Based on the obtained arithmetic mean value and the standard deviation of the food activity index, a numerical criterion was determined for distributing the studied cows into groups with high, medium and low indices (see Table 1).

Certain characteristics of the milking process (duration and frequency of milking, daily milk yield) were automatically recorded and stored electronically for three consecutive days in the herd management program Time for Cows (Lely Industries N.V., the Netherlands).

All obtained digital data were processed using the variation statistics method[3]. Calculations were performed on a personal computer using Microsoft Office software using Excel (Microsoft, USA).

RESULTS AND DISCUSSION

Using the proposed method, we assessed the animals' ethological manifestations, which allowed us to classify the cows according to their food activity index. The largest number of animals were assigned to the medium food activity index group—40.6%; 28.1% were assigned to the high index group; the remaining 31.3% were assigned to the low food activity index group.

Visual observation showed that there were some differences in behavioral reactions between the groups (see Table 2).

Monitoring the time spent standing showed that cows with a high food activity index spent 748.2 minutes doing so, while animals with a medium index spent 770.7 minutes and those with a low index spent 817.9 minutes, accounting for 52.0–56.8% of their daily time. However, the differences were not significant but are consistent with data from other authors [9, 10].

When comparing the duration of feed intake, it is clear that animals with a high index spent less time on this behavioral act (243.3 min) than cows with an average (274.1 min) and low (323.3 min) indices of food activity – by 30.8 min (11.2%) and 80.0 min (24.7%), respectively ($p < 0,05$). A similar duration of the feed consumption period has been demonstrated in other studies [11]. Cows with a high food activity index made fewer approaches to feed (8.4 times) and water (8.2 times) than animals with an average (9.3 and 9.1 times, respectively) and low (9.6 and 8.9 times) indices.

Observations revealed that cows with a high food activity index enjoyed certain "privileges": they chose a place near the feed table and waterers, disturbing other animals; they calmly consumed feed and water, remaining at the feed table and waterers as long as they wanted. This suggests that cows with a high feeding activity index are dominant, high-ranking animals in the herd hierarchy. Competition and aggressive behavior among dominant cows could be the reason for the higher feed and water intake by the animals with medium and low feeding activity indices, as the latter were forced to give up space at the feed table and waterers.

The cows in the study spent between 622.1 (low index) and 691.8 minutes (high index) lying down, which is 43.2–48.0% of their daily time. Moreover, cows with a high index of food activity spent 22.5–69.7 minutes (3.4–11.2%) longer lying down than animals in other groups.

Табл. 1. Распределение коров по группам в зависимости от величины индекса пищевой активности

Table 1. Criteria for the distribution of cows by index of nutritional activity

Average value of the food activity index, kg/h (M)	Standard deviation of the food activity index (σ)		Food activity index		
	1,0	0,5	low (M – 0,5σ)	medium	high (M + 0,5σ)
2,49	0,79	0,40	< 2,08	2,09–2,89	> 2,90

[3] *Yakovenko A.M., Antonenko T.I., Selionova M.I.* Biometric methods for analyzing qualitative and quantitative characteristics in animal husbandry: a tutorial. Stavropol: Agrus, 2013, 92 p.

Табл. 2. Поведенческие реакции коров с разными индексами пищевой активности
Table 2. Behavior of cows with different indices of nutritional activity

Behavioral indicator	Food activity index		
	high	medium	low
Duration of standing, min	748,2 ± 63,1	770,7 ± 43,1	817,9 ± 50,0
Including time, min:			
feeding	243,3 ± 16,8*	274,1 ± 13,3	323,3 ± 23,6
cud	186,0 ± 41,9	165,9 ± 29,9	187,6 ± 12,9
walking	9,7 ± 0,7	11,5 ± 0,9	9,3 ± 0,8
milking	22,5 ± 1,4*	21,0 ± 1,5	17,9 ± 1,7
Duration of lying down, min	691,8 ± 63,1	669,3 ± 43,2	622,1 ± 50,0
Including chewing time, min	306,2 ± 40,8	303,8 ± 24,8	280,5 ± 28,1
Total duration of chewing, min	492,1 ± 24,7	469,7 ± 19,5	449,3 ± 27,7
Multiplicity, times:			
feed intake	8,4 ± 0,6	9,3 ± 0,7	9,6 ± 0,7
water intake	8,2 ± 0,8	9,1 ± 0,8	8,9 ± 0,6
cud	11,3 ± 0,6	11,7 ± 0,6	12,8 ± 0,7
lying	7,8 ± 1,0	7,4 ± 0,4	7,1 ± 0,8
milking	3,8 ± 0,2**	3,2 ± 0,2	2,8 ± 0,2
discharge of excrement	14,3 ± 0,9	13,5 ± 0,6	12,5 ± 0,7
urination	11,6 ± 0,9	10,2 ± 0,4	10,1 ± 0,6

*$p < 0,05$ compared to a low food activity index.
**$p < 0,01$ compared to an average food activity index.

When comparing the frequency of cows' lying down, no differences were found depending on the value of the food activity index. The animals lay down 7.1–7.8 times per day.

It is known that chewing activity is one of the most important indicators in the behavioral response of cows [12], as it is interconnected with feed consumption and the time that animals spend lying down [13].

The analysis revealed a tendency for the increasing duration of rumination with a rise in the food activity index. Animals with a high food activity index exhibited the longest rumination time: their duration of this behavioral act was 492.1 min, which is 22.4 min (4.8%) longer than animals with an average activity index (469.7 min) and 42.8 min (9.5%) longer than animals with a low index (449.3 min). The differences found were insignificant. Rumination time in the studied cows occupied 31.2–34.2% of the daily time.

Regardless of the value of the food activity index, the duration of the chewing period in cows was longer in the recumbent position (280.5–306.2 min) than in the standing position (165.9–187.6 min). This is explained by the fact that in the recumbent position, this process is less energy-consuming. Moreover, the obtained data on the duration of rumination are consistent with the results of other authors [14, 15].

It was found that cows with a high food activity index and a longer rumination period are characterized by a lower frequency of this behavior compared to the animals with medium and low indices. Thus, over the course of a day, animals with a high index ruminated 11.3 times, those with a medium index ruminated 11.7 times, and those with a low index ruminated 12.8 times.

Acts of defecation and urination, on the contrary, were more often recorded in the cows with a high index of food activity, which, in our opin-

ion, is associated with more intensive metabolic processes.

When using robotic milkers, cows are milked at any time of day, and the frequency and duration of milking are determined by the animals' physiological condition and milk production. The assessment of frequency of milking showed a significant difference ($p < 0.01$) in favor of cows with a high food activity index, which was reflected in the time spent milking. The duration of the milking process with robotic milking consists of the time spent on entering the milking parlor, identifying and positioning the animal, pre-milking udder preparation, putting on teat cups, milking, teat disinfection, and the cow's exit from the milking parlor. Thus, animals with a high food activity index, compared to heifers with medium and low indices, spent more time on this process – 1.5 minutes (7.1%) and 4.6 minutes (25.7%) longer ($p < 0.05$), respectively, while the milking process itself took 1.2–1.6% of the daily time. The frequency of milking established in our study was higher than that of other authors [16, 17].

The presented data show that with an increase in the index of food activity, cows stand less and devote less time to passive rest, lie down more and devote more time to an active state (chewing activity), which is reflected in their milk productivity (see Table 3).

When comparing milk productivity, it was found that cows with a high index yielded significantly more milk over 305 days of lactation than the cows with an average index, by 932.2 kg, or 9.0% ($p < 0.05$), while those with a low index yielded 1,686.9 kg, or 17.5% ($p < 0.01$). This had a decisive influence on the predominant amount of milk fat and protein in the milk of cows with a high nutritional activity index. Thus, they significantly exceeded animals with an average index by 41.2 kg (10.3%) and 31.3 kg (9.3%), respectively ($p < 0.05$), and those with a low index by 71.2 kg (19.3%) and 55.4 kg (17.8%) ($p < 0.01$). It should be noted that no reliable differences in the mass fraction of fat and protein in the milk of the assessed cows with different indices were found.

CONCLUSION

Based on the conducted research, it should be assumed that the proposed method for assessing cows by the index of food activity can be used for better herd management and allows the herd to be supplied with the animals of an active type of behavior, namely with a high index of food activity.

It has been established that cows with a high food activity index spend less time standing and devote less time to passive rest, spend more time lying down and devote more time to the chewing activity.

Thus, first-calf heifers with a high nutrient index proved to be the most productive. Their milk yield over 305 days of lactation, milk fat, and milk protein content were significantly higher than those of cows with medium and low nutrient indices, by 9.0–17.5, 10.3–19.3, and 9.3–17.8%, respectively.

Табл. 3. Молочная продуктивность коров с разными индексами пищевой активности
Table 3. Milk productivity of cows with different nutritional activity indices

Indicator	Food activity index		
	high ($n = 9$)	medium ($n = 13$)	low ($n = 10$)
Milk yield for 305 days of lactation, kg	11344,2 ± 345,6*	10412,0 ± 256,9	9657,3 ± 377,1
Fat mass fraction, %	3,88 ± 0,04	3,84 ± 0,03	3,83 ± 0,03
Protein mass fraction, %	3,23 ± 0,02	3,22 ± 0,02	3,22 ± 0,02
Milk fat yield, kg	441,0 ± 16,3*	399,8 ± 11,6	369,8 ± 13,5
Milk protein yield, kg	366,3 ± 12,7*	335,0 ± 8,3	310,9 ± 11,9

*$p < 0,01$ compared to a low food activity index, $p < 0,05$ compared to an average food activity index.

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ИНФОРМАЦИЯ ОБ АВТОРЕ

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Использование кормовой добавки ЭнергоЛакт-О для коров после отела

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Представлены результаты использования кормовой добавки посредством дренчевания для коров после отела. Исследования проведены в условиях молочного животноводческого комплекса Кировской области на дойных коровах черно-пестрой голштинизированной породы в лактационный период. В эксперименте исследовали две кормовые добавки для дренчевания коров – ЛактоТоп и ЭнергоЛакт-О на двух группах коров по 10 гол. в каждой. Установлено, что дренчевание коров с использованием кормовой добавки Энерго-Лакт-О в сравнении с ЛактоТоп способствует снижению уровня кетоновых тел в крови на 0,3 на 5-й день после отела. Молочная продуктивность коров 2-й группы (ЭнергоЛакт-О) начиная с первого месяца и на протяжении всей лактации достоверно превосходила молочную продуктивность коров 1-й группы (ЛактоТоп) по удою, а также массовой доле жира и белка в молоке. За 305 дней лактации данное превосходство по удою составило 10,7% ($p < 0,01$), что позволило при более высоких показателях белка и жира в молоке коров 2-й группы получить молочного жира (кг) и молочного белка (кг) от этих коров больше соответственно на 15,1 и 13,5%. Коровы, получавшие кормовую добавку ЭнергоЛакт-О, демонстрировали лучшие показатели по воспроизводству в сравнении с коровами, получавшими ЛактоТоп. Это позволило добиться от них лучшего индекса осеменения, равного 1,9 в сравнении с коровами 1-й группы с индексом в 2,1. Использование кормовой добавки ЭнергоЛакт-О позволило не только сэкономить 6000 р. при дренчевании 10 коров в первые 3 дня после отела, но и получить на 31 176 р. прибыли больше в расчете на одну корову, чем при использовании добавки ЛактоТоп. При этом рентабельность производства молока увеличилась на 9,8%.

Ключевые слова: кормление, лактирующие коровы, кормовые добавки, продуктивность, дренчевание

The use of the feed additive EnergoLact-O for cows after calving

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The results of using a feed additive by drenching for cows after calving are presented. The research was carried out in the conditions of the dairy livestock complex of the Kirov region on dairy cows of the Black-and-White Holstein breed during the lactation period. In the experiment, two feed additives for cow drenching were studied – "LactoTop" and "EnergoLact-O" on two groups of cows with 10 heads each. It was found that the drenching of cows using the feed additive "EnergoLact-O" in comparison with "LactoTop" helps to reduce the level of ketone bodies in the blood by 0.3 on the 5th day after calving. The milk productivity of cows of the second group ("EnergoLact-O") from the first month and throughout lactation significantly exceeded the milk productivity of cows of the first group ("LactoTop") in milk yield, as well as the mass fraction of fat and protein in milk. For 305 days of lactation, this milk yield superiority was 10.7% ($p < 0.01$), which allowed, with higher protein and fat levels in the milk of cows of the second group, to obtain milk fat (in kg) and milk protein (in kg) from these cows by 15.1% and 13.5%, respectively. Cows receiving the "EnergoLact-O" feed additive showed better reproduction performance compared to cows receiving "LactoTop". This allowed them to achieve a better insemination index of 1.9 compared to cows of the first group with an index of 2.1. The use of the feed additive "EnergoLact-O" allowed not only to save 6,000 rubles. when drenching 10 cows in the first 3 days after calving, but also to receive 31176 rubles more profit per cow than

when using the "LactoTop" supplement. At the same time, the profitability of milk production increased by 9.8%.

Keywords: feeding, lactating cows, feed additives, productivity, drenching

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INTRODUCTION

After calving, milk production in dairy cows increases rapidly, but the nutrients consumed in the feed cannot fully meet the cow's increased needs due to the onset of lactation, creating a negative energy balance. Dairy cows with a negative energy balance have an increased risk of developing clinical or subclinical ketosis. Ketosis in dairy cows negatively impacts milk production, dry matter intake, health, immunity, and reproductive performance [1–7].

Eliminating dehydration, providing the cow with readily available energy and calcium at the beginning of lactation, preventing the development of ketosis, increasing appetite and increasing the animal's productivity is possible through the development and use of effective feed additives through drenching [8–15].

The purpose of the study is to determine the effectiveness of using the feed additive EnergoLact-O for cows after calving.

MATERIAL AND METHODS

The study was conducted at the “Bobino-M dairy farm” in the Slobodskoy District of the Kirov Region. High-yielding Black-and-White Holstein cows were studied at the beginning of lactation. Two groups of 10 animals each were formed and treated with different supplements: LactoTop (Group 1) and EnergoLact-O (Group 2). Drenching was performed in the morning once a day for three days after calving. The feed additives to be tested were dissolved in 30 liters of warm water at 30–40°C immediately before drenching. After drenching, the cows were monitored for blood ketone levels, milk production, and reproductive performance, and the cost-effectiveness of using the additives was calculated.

Ketone body levels were measured using a portable veterinary blood glucose and ketone analyzer on the 5th day after calving (see Table 1).

According to the norm, the level of ketone bodies in the blood from 0.6 to 1.0 mmol/l indicates a slight increase in the content of beta-hydroxybutyric acid (BHA); from 1.0 to 1.5 mmol/l is a sign of subclinical ketosis; over 1.5 mmol/l is clinical ketosis.

In both groups of cows that received LactoTop and EnergoLact-O, moderate pathologies at calving were observed in 50% of cases.

Based on the results of drenching, the average level of ketone bodies was lower in the group of cows that received the EnergoLact-O supplement by 0.3 mmol/l, compared to the group of cows that received LactoTop.

Before the experiment, cows in the experimental groups showed no significant differenc-

Табл. 1. Уровень кетоновых тел в крови коров после дренчевания
Table 1. Ketone body levels in cow blood after drenching

LactoTop (1st group)			EnergoLact-O (2nd group)		
Cow inventory number	Ease of calving	Ketone body levels	Cow inventory number	Ease of calving	Ketone body levels
8162	УП	0,8	9197	MP	0,7
5643	УП	2,3	9175	MP	0,8
8141	Н	1,5	6085	N	0,8
5090	УП	1,2	6080	MP	0,9
8110	Н	1,2	2999	N	0,7
6026	Н	0,7	5628	N	0,9
7134	УП	0,9	8148	MP	0,8
4082	УП	0,6	5691	MP	0,9
7200	Н	0,9	6092	N	0,9
7178	Н	1,1	5698	N	0,6
Average amount of ketone bodies, mmol/l		1,1 ± 0,16	–		0,8 ± 0,03

Note: N – normal, MP – moderate pathology.

es in milk production or milk quality during the previous lactation. The cows' milk production during the current lactation is presented in Table 2.

Already in the first month of lactation, the milk yield of cows receiving the feed additive EnergoLact-O significantly ($p < 0.01$) exceeded that of the cows receiving LactoTop by 12.1%. Moreover, the mass fraction of fat and protein in milk was also higher in cows receiving EnergoLact-O – by 0.15 and 0.11%, respectively.

A similar trend was observed in subsequent months of lactation. Thus, according to the results of milk productivity monitoring for the first 100 days of lactation, the milk yield of cows in Group 2 was 13.1% ($p < 0.001$) higher than that

Табл. 2. Показатели молочной продуктивности в среднем по группам
Table 2. Average milk yeild indicators by groups

Indicator	LactoTop (1st group)	EnergoLact-O (2nd group)
1st month of lactation:		
Average milk yield per cow, kg	1334 ± 24,34	1496 ± 41,72**
Average FMF per cow, %	3,86 ± 0,09	4,01 ± 0,05
Average PMF per cow, %	3,24 ± 0,05	3,35 ± 0,04
2nd month of lactation:		
Average milk yield per cow, kg	1396 ± 24,50	1528 ± 57,80*
Average FMF per cow, %	3,81 ± 0,09	3,95 ± 0,05
Average PMF per cow, %	3,18 ± 0,05	3,26 ± 0,05
3rd month of lactation:		
Average milk yield per cow, kg	1245 ± 21,50	1369 ± 32,91**
Average FMF per cow, %	3,76 ± 0,09	3,89 ± 0,07
Average PMF per cow, %	3,16 ± 0,05	3,17 ± 0,06
Yield, kg:		
for 100 days	4147 ± 73,34	4692 ± 103,92***
for 200 days	7927 ± 159,39	8860 ± 195,25**
for 305 days	12 107 ± 215,71	13 406 ± 286,83**
FMF for 305 days:		
%	3,81 ± 0,09	3,96 ± 0,06
kg	461,3 ± 11,49	530,9 ± 25,25*
PMF for 305 days:		
%	3,19 ± 0,05	3,27 ± 0,06
kg	386,2 ± 7,38	438,4 ± 23,27*

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

of cows in Group 1 by 200 days of lactation, and 11.8% ($p < 0.01$).

After 305 days of lactation, milk yield per cow in Group 2 exceeded that of Group 1 cows by 10.7% ($p < 0.01$). Furthermore, the quality of milk produced was also better in the cows fed the EnergoLact-O feed additive.

In general, throughout the lactation, the amount of milk fat (kg), as well as the amount of milk protein (kg) in cows of the 2nd group significantly ($p < 0.05$) exceeded these indicators for cows of the 1st group by 15.1 and 13.5%, respectively.

The increase in milk productivity of cows after 3-fold drenching with the feed additive EnergoLact-O can be explained by the fact that at the beginning of lactation the cow experiences a sharp need for calcium, cannot compensate for this need from the feed mixture, even if the diet is complete and balanced, and only through drenching with the additive EnergoLact-O it is possible to cover the cow's need for calcium and prevent the leaching of calcium from the animal's bones. This, in turn, ensures an easier start of lactation, allows the cow to demonstrate its full genetic potential for milk production and contributes to obtaining more milk during a given lactation.

Reproductive performance was monitored in the animals that received feed additives by drenching (see Table 3).

Animals supplemented with LactoTop (3 cows) failed to be successfully inseminated during the first 6 months after calving. In this group, only 7 cows were successfully inseminated: 50% on the first attempt and 10% on the second.

All animals in Group 2, which were drenched with the EnergoLact-O feed additive, were successfully inseminated. Fertilization occurred in 30% of animals after the first insemination, 20% after the second, and the remainder after the third to fifth insemination.

Cows fed the EnergoLact-O feed additive outperformed cows fed LactoTop in terms of insemination index by 0.3. Thus, the insemination index for cows in Group 2 was 1.9, which is considered satisfactory, while the index for cows in Group 1 was 2.1, which is unsatisfactory. The low insemination index in both groups is due to the high milk productivity of the cows.

Based on the obtained data, the economic efficiency of using feed additives was calculated (see Table 4).

When using feed additives for drenching cows, one package is required per cow for one drenching. The cost of EnergoLact-O at the time of the experiment was 150 rubles, which is 57.14% lower than the cost of the LactoTop feed additive. When drenching 10 cows using the EnergoLact-O feed additive three times after calving, compared to drenching LactoTop, the savings associated with the cost of the feed additives is 6,000 rubles in favor of the first.

At a milk delivery price of 30 rubles per kilogram, the additional revenue from milk delivery from Group 2 cows per lactation amounts to 77,811.26 rubles. This, in turn, contributes to higher profits from cows fed the EnergoLact-O feed additive by 31,176 rubles per cow, and also increases milk production profitability by 9.8% to 58.7%.

Using the EnergoLact-O supplement improves cow productivity, thereby increasing marketable milk yield. Furthermore, the cost of this supplement is approximately 2.5 times lower, reducing feed additive costs.

Табл. 3. Показатели воспроизводства коров, получавших кормовые добавки

Table 3. Reproduction rates of cows that received feed additives

Indicator	Lacto-Top	Energo-Lact-O
Number of animals	10	10
Cows successfully inseminated, %	70	80
Fertilized after the first insemination, %	50	30
Fertilized after the second insemination of recovered cows, %	10	20
Insemination index	2,1	1,9
Service period, days	104,9	138,4

Табл. 4. Экономическое обоснование результатов
Table 4. Economic justification of the results

Indicator	Variant with LactoTop	Variant with EnergoLact-O
Cost of one package of feed additive for single use, rubles	350	150
Savings from purchasing the supplement for 10 cows for 3 drenchings, rubles	–	6000
Milk yield for 305 days, kg	12 107	13 406
FMF for 305 days, %	3,81	3,96
PMF for 305 days, %	3,19	3,27
Cost of 1 kg of milk with basic fat content (3.40%) and protein content (3.00%), rubles	30	
Cost of milk from 1 cow, rubles	432 786,08	510 597,34
Additional revenue received from milk delivery, rubles	–	77 811,26
Cost price of 1 kg of milk, rubles	24	
Cost of milk from one cow per lactation, rubles	290 568,00	321 744,00
Net profit from milk, rubles	142 218,08	188 853,34
Profitability of milk production, %	48,9	58,7

CONCLUSION

Drenching cows with the feed additive EnergoLact-O, compared to LactoTop, helps reducing the level of ketone bodies in the blood by 0.3 mmol/l already on the 5th day after calving.

The milk productivity of Group 2 cows (EnergoLact-O) from the first month and throughout lactation significantly exceeded that of Group 1 cows (LactoTop) in terms of milk yield, as well as the mass fraction of fat and protein in milk. Over 305 days of lactation, this superiority in milk yield amounted to 10.7% ($p < 0.01$), allowing for higher protein and fat content in milk from Group 2 cows, while yielding 15.1% and 13.5% more milk fat (kg) and 13.5% more milk protein (kg), respectively, despite higher protein and fat content in milk.

Cows fed the EnergoLact-O feed additive demonstrated superior reproductive performance compared to cows fed LactoTop. This resulted in a higher insemination rate of 1.9 compared to Group 1 cows, which had an insemination rate of 2.1.

Using the EnergoLact-O feed additive not only saved 6,000 rubles when drenching 10 cows in the first three days after calving, but also generated 31,176 rubles more profit per cow than with LactoTop. Milk production profitability also increased by 9.8%.

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Морфологические и биохимические показатели крови лактирующих коров при использовании в рационах кормовой добавки на основе шрота подсолнечника

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Представлены результаты изучения влияния скармливания различных доз кормовой добавки «Волокна подсолнечные кормовые» на морфологические и биохимические показатели крови лактирующих коров черно-пестрой породы приобского типа в условиях Алтайского края. Данная кормовая добавка является побочным продуктом при производстве пищевого и кормового белкового концентратов из шрота подсолнечника, отличается достаточно высокой питательной ценностью и обладает сорбционной активностью. Сформированы две опытные и одна контрольная группа коров по 10 гол. в каждой. Животные контрольной группы получали основной рацион, коровам 1-й опытной группы дополнительно вводили 0,5 кг, аналогам 2-й опытной группы – 1,0 кг изучаемой кормовой добавки. Продолжительность опыта составила 60 дней. Выявлено, что при скармливании кормовой добавки у коров опытных групп в конце опыта была достоверно ($p \leq 0,05$) выше по сравнению с контролем резервная щелочность сыворотки крови (на 8,2–13,1%) и отмечен достоверно ($p \leq 0,05$) более низкий уровень холестерина (на 8,8–15,2%). У коров 2-й опытной группы было достоверно ($p \leq 0,05$) более высокое, чем в контроле, содержание в крови эритроцитов (на 24,2%), а у животных 1-й опытной группы в сыворотке крови был выше уровень креатинина на 19,4% ($p \leq 0,01$) и аспартатаминотрансферазы на 22,5% ($p \leq 0,05$). Динамика изменений гематологических и биохимических показателей крови свидетельствует об оптимизации обменных процессов в организме животных под влиянием скармливания изучаемой кормовой добавки.

Ключевые слова: кормовая добавка, кормление коров, волокна подсолнечные кормовые, морфологические и биохимические показатели крови

Morphological and biochemical parameters of blood of lactating cows when using a feed additive based on sunflower meal in their diets

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The results of the study of the effect of feeding various doses of the feed additive "Sunflower feed fibers" on the morphological and biochemical parameters of the blood of lactating cows of the Black-and-White breed of the Priobsky type in the conditions of the Altai Territory are presented. This feed additive is a by-product in the production of food and feed protein concentrates from sunflower meal; it is distinguished by fairly high nutritional value and possesses sorption activity. Two experimental and one control group of cows of 10 heads each were formed. The animals of the control group re-

ceived the basic diet; the cows of the 1st experimental group received an additional 0.5 kg, and the analogues of the 2nd experimental group received 1.0 kg of the studied feed additive. The duration of the experiment was 60 days. It was revealed that by feeding the cows of the experimental groups with the feed additive, at the end of the experiment, the reserve alkalinity of the blood serum was significantly ($p \leq 0.05$) higher compared to the control (by 8.2–13 .1%) and significantly ($p \leq 0.05$) lower cholesterol levels (by 8.8–15.2%) were observed. The cows of the 2nd experimental group had a significantly ($p \leq 0.05$) higher content of erythrocytes in the blood than in the control (by 24.2%), and the animals of the 1st experimental group had a higher level of creatinine in the blood serum by 19.4% ($p \leq 0.01$) and aspartate aminotransferase by 22.5% ($p \leq 0.05$). The dynamics of the changes in hematological and biochemical blood parameters indicate the optimization of metabolic processes in the body of the animals under the influence of feeding with the studied feed additive.

Keywords: feed additive, feeding cows, sunflower feed fibers, morphological and biochemical blood parameters

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INTRODUCTION

Currently, the country's feed production levels are insufficient to produce feed with the required concentration of metabolizable energy, readily available carbohydrates, and crude protein for high-yielding lactating cows. This problem can be addressed by developing next-generation feed additives designed to enhance the digestibility of diet components, including enzyme compositions, probiotics, chelated minerals, and other ingredients [1].

Increasing the milk productivity of cows while maintaining the optimal physiological status of the body is one of the most important tasks facing scientists and practicing nutrition specialists.

To ensure high productivity of farm animals and obtain environmentally safe livestock products, it is necessary to take into account the contamination of agricultural raw materials and products with toxicants of natural origin, in particular mycotoxins [2].

Although many toxicants in feed crops and agricultural products are within the maximum permissible concentration limits, synergistic effects are possible when they are ingested in combination. Therefore, the use of adsorbent feed additives in lactating cows is relevant and has significant practical value for normalizing digestion processes and improving the productivity and quality of dairy products [3, 4].

The study of hematological and biochemical parameters of the blood of dairy cows when various feed additives are included in their diets is an urgent research task [5]. Thus, when feeding a natural mineral adsorbent to lactating cows, against the background of an increase in average daily milk yield, their blood had higher levels of glucose, total protein, calcium, and phosphorus compared to the control group, and urea was lower by 2.76% [4].

Currently, due to the development of crop production and the processing industry, a large amount of waste remains, which creates an environmental burden [6]. At the same time, waste from primary production, which contains a lot of useful nutrients (proteins, carbohydrates, vitamins, macro- and microelements, etc.), is not widely used in feeding farm animals [7].

A significant amount of secondary resources is generated during sunflower seed processing.

The oil and fat industry typically extracts only one component from them—vegetable oil—and the resulting meal is used in animal feed. The characteristics of sunflower meal, such as its high crude protein content (37–42%), low cost, and absence of toxic and anti-nutritional substances, make it feasible to develop methods for extracting protein concentrates and isolates from it to produce valuable dietary, hypoallergenic food products. Currently, the production of sunflower protein food concentrates is actively developing in the world and in Russia, and accordingly, the volume of by-products that can be used in feeding farm animals will increase to industrial scale [8, 9].

The new feed additive "Sunflower feed fibers" TU 10.41.41-317-05748654–2021 (formerly known as "Aktifibra") is produced by alkaline hydrolysis of sunflower meal and is a by-product in the production of food and feed sunflower protein concentrates. It is a dry, crumbly product with a moisture content of 9–10%.

The feed additive has a high sorption activity proven *in vitro* [10]. In addition, "Sunflower feed fibers" have a fairly good nutritional value for cattle. 1 kg of absolutely dry matter of the feed additive contains on average 13.1 MJ ME, 22–25% crude protein, 44-45% NFES, 22.0–25.0% crude fiber, 13.8 g phosphorus, 7.4 g calcium, 152.6 mg iron, 70.7 mg zinc and 39.1 mg manganese[1].

In this regard, the study of the changes in indicators characterizing metabolic processes in the body of cows when fed this feed additive is relevant and is of scientific and practical interest.

The purpose of the study is to identify the effect of using different doses of the feed additive “Sunflower feed fibers” in feeding lactating cows on the morphological and biochemical parameters of blood.

MATERIAL AND METHODS

The scientific and economic experiment was conducted at the Komsomolskoye Breeding Farm Experimental Station, a branch of the FASCA in the Pavlovsky District of the Altai Territory, using lactating Priobskaya-type Black-and-White cows in their second and third lactations. Three groups of 10 cows were formed using the analog method for the experiment: one control group and two experimental groups with a live weight of 580–600 kg and a milk yield of over 7,000 kg in the previous lactation. The control and experimental groups of animals were kept under identical conditions and were kept tethered.

At the start of the experiment, the animals were on average 100 days into lactation. The average daily milk yield at the start of the feeding trial was 32.2–32.6 kg.

During the experiment, cows in the control group were fed the main on-farm diet, balanced in all key indicators, with the following composition: corn silage (21 kg), haylage from annual grasses (21 kg), oat straw (2 kg), and compound feed “KK 60-2” (8 kg). Cows in the first experimental group were fed 0.5 kg of the studied feed supplement in addition to their main diet, and animals in the second experimental group were fed 1.0 kg of the studied feed supplement "Sunflower feed fibers" once daily with their feed. The supplement was added directly to the feed (completely mixed feed) once daily. The duration of the feeding trial was 60 days.

Blood for biochemical analysis was collected from the tail vein in the morning before feeding at the end of the experiment on day 60. Biochemical analysis of the blood serum samples was performed in the veterinary laboratory of the ARIAHVS department of the FASCA: reserve alkalinity was determined using the Nevodov's method with the Tashiro indicator; carotene was measured using the colorimetric method of G.F. Koromyslov and L.A. Kudryavtseva. Total protein, albumin, bilirubin, creatinine, cholesterol, triglycerides, calcium, phosphorus, chlorides, alkaline phosphatase, GGT, ALT, and AST were determined using a ChemWellCombi 2910

[1]*Zaborskikh E. Yu.* Effect of a new feed additive based on sunflower meal on milk productivity of cows // Agrarian science for agriculture: collection of papers from the XVII International scientific and practical conference in 2 books. Barnaul: ASAU, 2022, Ch. 2. pp. 122–124.

automated biochemical and ELISA analyzer using Vector-Best reagent kits. Blood morphology was performed at the Veterinary Laboratory in Barnaul. Hemoglobin was determined using the hemoglobin-cyanide method, and red blood cell and white blood cell counts and differential were determined using a Mikromed-2 microscope.

The digital material obtained in the experiments was processed using the variation statistics method according to N.A. Plokhinsky (1969) using biometric processing methods using the Microsoft Excel 2016 software package.

RESULTS AND DISCUSSION

As a result of feeding lactating cows the studied feed additive, almost all the main biochemical parameters of blood serum, characterizing the level of metabolism and health status, were within the normal range (see Table 1).

Analysis of the data presented in Table 1 reveals significant differences between the groups in alkalinity, cholesterol, and creatinine levels. Cholesterol performs structural and hormone-producing functions, participates in the absorption of vitamin D, improves digestion, and is involved in the functioning of the serotonin receptor system [11]. In cows in the control group, cholesterol levels at the end of the experiment were slightly higher than normal, while in animals in the experimental groups, they were significantly ($p \leq 0.05$) lower (by 15.2% and 8.8%, respectively) and within normal limits. Elevated blood cholesterol levels in cows can occur with impaired liver function and often accompany ketosis. As a rule, this is accompanied by a decrease in the alkaline reserve of the blood [12].

Although the reserve alkalinity of the blood serum in all experimental animals was within the physiological norm, in cows of the experimental groups this indicator was significantly higher ($p \leq 0.05$) compared to the control group in cows of the 1st experimental group by 13.1% (552.0 mg%), in the 2nd group by 8.2% (528.0 mg%).

The source of muscle energy is creatine phosphate, which is formed from creatinine. Since creatinine is one of the components of residual nitrogen, its level in the blood serum allows us to evaluate the excretory function of the kidneys and the intensity of metabolism in the muscle tissue of animals [11]. In cows of the 1st experimental group, the level of creatinine in the blood serum was 19.4% higher than in the control ($p \leq 0.01$), in animals of the 2nd experimental

Табл. 1. Основные биохимические показатели сыворотки крови коров
Table 1. Main biochemical parameters of cow blood serum

Indicator	Unit of measurement	Norm	Group		
			control	1st experimental	2nd experimental
Total protein	g/l	72,0–86,0	82,0 ± 2,10	78,7 ± 0,90	82,0 ± 3,04
Albumin	mmol/l	27,0–43,0	35,1 ± 1,50	36,3 ± 0,97	32,9 ± 1,48
Carotene	mg%	0,4–1,0	0,62 ± 0,040	0,47 ± 0,030	0,57 ± 0,070
Bilirubin	μmol/l	0,2–5,1	2,31 ± 0,320	1,71 ± 0,36	2,17 ± 0,300
Cholesterol	mmol/l	2,3–6,6	7,0 ± 0,40	5,9 ± 0,54*	6,4 ± 0,86*
Triglycerides	mmol/l	0,22–0,55	0,44 ± 0,020	0,47 ± 0,020	0,47 ± 0,030
Reserve alkalinity	mg%	360–580	488 ± 18,4	552 ± 18,4*	528 ± 17,5*
Creatinine	μmol/l	55,8–162,4	69,7 ± 5,96	83,3 ± 4,22**	78,1 ± 3,70
Calcium	mmol/l	2,3–3,2	2,45 ± 0,070	2,47 ± 0,050	2,43 ± 0,040
Phosphorus	mmol/l	1,5–2,9	2,32 ± 0,130	2,35 ± 0,110	2,13 ± 0,180
Chlorides	mmol/l	94,0–104,0	98,1 ± 0,55	97,0 ± 0,71	97,2 ± 0,96

Here and in tables 2, 3:
*$p \leq 0,05$.
**$p \leq 0,01$.

group this indicator was also higher than in the control (by 12.0%) with an insignificant difference.

The increase in the level of creatinine in the blood serum of experimental animals occurred within the physiological norm and, obviously, this is associated with increased synthesis of milk protein and with an increase in the average daily milk yield of cows in the experimental groups at the end of the experiment compared to the control by 13.8 and 17.0%, respectively.

Of the liver enzymes, aspartate aminotransferase (AST) and gamma-glutamyl transferase (GGT) have high diagnostic value, while alanine aminotransferase (ALT) and alkaline phosphatase reflect metabolic processes to a somewhat lesser extent [13]. Table 2 shows the results of analyses of cow blood serum for the content of the main liver enzymes.

From the analysis of the data presented in Table 2, it follows that the cows of the 1st experimental group, compared to the control group, had a significantly ($p \leq 0.05$) higher AST level by 22.5%. In animals of the 2nd experimental group, this indicator was higher than in the control group by 14.5%, with an insignificant difference.

In cows of the experimental groups, a tendency towards an increase in ALT activity was noted compared to the control by 21.5 and 13.9%, respectively, as well as alkaline phosphatase by 8.0–10.1% with an insignificant difference.

The higher level of AST and ALT activity in the serum of cows in the experimental groups compared to the control group may be associated with increased milk synthesis, which is confirmed by the data of our studies.

Animals in all groups showed elevated gamma-glutamyl transferase activity relative to normal, with a slight tendency toward normalization in cows in the first experimental group. A slight increase in GGT levels is typical in cows during intensive lactation, which results in increased liver stress due to metabolic factors.

Table 3 shows the data from the analysis of the morphological composition of the blood of experimental animals.

From the analysis of the data presented in Table 3, it is evident that the hemoglobin level in cows of all three groups was slightly below normal, while the red blood cell content was within the reference values.

During the period of milking, as a rule, the highest daily milk yields are obtained from cows; in addition, after the body has recovered, fruitful insemination should occur. These factors significantly affect hematopoiesis. Thus, according to M.L. Kochneva et al. [14], the maximum hemoglobin content in the blood of Holstein cows was 20–25 days before calving and on the 5th day after it, and on the 80th day of lactation, the hemoglobin content below the reference limit was in 27% of the experimental animals. In an experiment conducted by S.B. Kim et al. [15], at the peak of lactation in highly productive cows, a decrease in hemoglobin and hematocrit, as well as an increase in total cholesterol and an increase in alanine aminotransferase activity were observed.

In our experiment, in cows fed the feed additive "Sunflower feed fibers" at a dose of

Табл. 2. Активность ферментов печени коров, ед./л
Table 2. Activity of cow liver enzymes, u/l

Indicator	Norm	Group		
		control	1st experimental	2nd experimental
AST	48–110	64,8 ± 2,96	79,4 ± 2,13*	74,2 ± 3,85
ALT	17–37	28,8 ± 3,41	35,0 ± 1,60	32,8 ± 1,34
GGT	5–25	31,4 ± 4,37	27,6 ± 3,11	31,2 ± 4,56
Alkaline phosphatase	29–153	114,8 ± 12,31	124,0 ± 10,46	126,4 ± 6,99

Табл. 3. Морфологические показатели крови коров
Table 3. Morphological indices of cow blood

Indicator	Ед. изм.	Norm	Group		
			контрольная	1-я опытная	2-я опытная
Hemoglobin	г/л	99–129	77,6 ± 3,61	73,8 ± 1,20	77,6 ± 6,32
Erythrocytes	10^{12}/л	5,0–7,5	5,7 ± 0,15	5,9 ± 0,21	7,1 ± 0,34*
Leukocytes	10^{9}/л	4,5–12,0	5,5 ± 0,44	6,5 ± 0,62	7,5 ± 0,36*
Lymphocytes	10^{9}/л	40–75	61,4 ± 4,41	60,4 ± 3,72	48,4 ± 9,71

1.0 kg/head per day (2nd experimental group), the level of erythrocytes in the blood was significantly higher compared to the control group by 24.2% ($p \leq 0.05$), in animals of the 1st experimental group (dose 0.5 kg/head) the difference with the control was insignificant (higher by 3.5%).

In animals of the 2nd experimental group, a significant difference ($p \leq 0.05$) was found between the control group and the leukocyte content in the blood of 37.2%, while in cows of the 1st experimental group, this indicator was higher than in the control group by 18.2%, with an insignificant difference. The increase in the number of the formed elements in the blood of animals of the experimental groups within the physiological norm probably indicates more intensive hematopoiesis.

CONCLUSION

Feeding the feed additive "Sunflower feed fibers" at a dosage of 0.5 and 1 kg/head per day for 60 days to lactating cows had a significant positive effect on metabolic parameters.

At the end of the experimental feeding period, animals in the first experimental group had lower serum cholesterol levels than the control group, higher levels of reserve alkalinity and aspartate aminotransferase, and a tendency toward a decrease (normalization) in gamma-glutamyl transferase activity. Cows in the second experimental group had significantly higher levels of red blood cells and white blood cells in the blood compared to the control group, higher reserve alkalinity and creatinine levels in the blood serum, and lower cholesterol levels.

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Система усовершенствованных методов прогнозирования технического состояния автомобилей

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Представлены результаты выполненных исследований по совершенствованию системы прогнозирования параметров технического состояния узлов и агрегатов автомобилей сельхозтоваропроизводителя на примере грузовых автомобилей, реализуемой в среде электронных таблиц офисного пакета программ персонального компьютера. В качестве программ офисного пакета можно использовать приложения LibreOffice Calc или MS Excel и др. Цель данного исследования – разработка системы программно-алгоритмических и информационных средств прогнозирования параметров технического состояния узлов и агрегатов грузовых автомобилей за счет усовершенствования методов прогнозирования. Данные методы в совокупности способны уточнить статистическую оценку прогнозируемых параметров и дадут возможность специалисту принять обоснованные решения по дальнейшей эксплуатации грузового автомобиля. Для повышения оперативности работы система программно-алгоритмических и информационных средств может быть использована на планшетах и мобильных смартфонах. Обосновано усовершенствование методов прогнозирования в информационной модели системы программно-алгоритмических и информационных средств прогнозирования. Выстроенный алгоритм информационной модели имеет понятный и доступный для пользователя интерфейс с доступом к корневой директории папок с систематизированными файлами, имеющими расширения .doc и .xlsx. Прогнозные расчеты выполняются после ввода результатов диагностики рассматриваемого автомобиля и после обработки системой в выданной информации указывается спрогнозированный и предельный параметр критического состояния узлов и агрегатов автомобиля. При этом обеспечивается своевременное и качественное выполнение технической диагностики в установленном порядке и объеме, снижение вероятности отказов автомобиля на линии, повышение эффективности работы парка сельхозтоваропроизводителя.

Ключевые слова: совершенствование прогнозирования, электронные таблицы EXCEL, LibreOffice Calc, техническая диагностика, система ПАИС

The system of improved methods for predicting the technical condition of vehicles

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The results of the performed research on the improvement of the system of forecasting parameters of the technical condition of the units and assemblies of agricultural vehicles on the example of trucks, implemented in the spreadsheet environment of the office program package of the personal computer are presented. LibreOffice Calc or MS Excel applications among other can be used as the office package programs. The purpose of this research is to develop a system of software-algorithmic

and information tools of predicting the parameters of the technical condition of units and assemblies of trucks by improving the methods of prediction. These methods in aggregate are able to clarify the statistical evaluation of the predicted parameters and will enable the specialist to make informed decisions on further operation of the truck. The system of software -algorithmic and information tools can be used on tablets and mobile smartphones to increase the efficiency of work. The improvement of forecasting methods in the information model of the system of software-algorithmic and information tools of forecasting is substantiated. The established algorithm of the information model has a clear and accessible interface for the user with access to the root directory of folders with systematized files having extensions .doc and .xlsx. Predictive calculations are performed after entering the diagnostic results of the vehicle in question and after processing by the system, the predicted and maximum parameters of the critical state of the vehicle's units and assemblies are indicated in the information provided. This ensures timely and quality performance of technical diagnostics in the prescribed order and volume, reduces the probability of vehicle failures on the line, and increases the efficiency of the farming company's fleet.

Keywords: prediction development, EXCEL, LibreOffice Calc, technical diagnostics, SAIT system

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INTRODUCTION

High-quality implementation of the maintenance service plan (MS) ensures the maintenance of the technical readiness factor of the vehicles of agricultural producers (AP). One method for improving technical service when servicing trucks is predicting the remaining life of the technical condition parameters of components and assemblies, based on the results of technical diagnostics (TD). TD can be performed in two ways: first, directly at the MS station by a specialist using the necessary tools; second, predictive, which allows, based on the collected statistical information on a specific vehicle, to predict the remaining life of a vehicle component or unit, which can significantly speed up the decision-making process for implementing the necessary intervention on the object of technical diagnostics. Software implementation for this method is possible within the spreadsheet environment of a personal computer's Office suite. Applications such as LibreOffice Calc or MS Excel[1], among others, can be used as Office suite programs.

The implementation of such a forecasting methodology in the process of MS of tractors has demonstrated their practical significance and the potential for the application of information technologies in this area [1]. This article examines approaches to improving forecasting using methodological techniques that allow for refining the statistical assessment of the predicted diagnostic parameter for making decisions on the further operation of agricultural producers' trucks [2].

[1]*Sidorenko M.N., Krikov A.M*. Application of computer technologies to improve the forecasting of the residual life of the parameters of units and assemblies of trucks of the agro-industrial complex // Agrarian science - for agriculture: Proc. XVIII international. scientific and practical. conf. In 2 books. Barnaul: Altai State Agrarian University,2023, Ch. 1, pp. 164–166.

The purpose of the study is to increase the efficiency of using the software-algorithmic and information tools (SAIT) system for forecasting the parameters of the technical condition of units and assemblies of trucks by improving the forecasting methods used.

To achieve the research objective, it is necessary to solve the following tasks:

1. Analysis of the values of the current rate of change of the technical condition parameters of the units and assemblies of trucks based on the consideration of all similar parameters, including individual parameters of other samples of the model under consideration.

2. Adjustment of the indicator of the typical curvature coefficients α taking into account the nominal parameters of the technical condition and the dynamics of the transformation of the predicted coefficient based on real data obtained during the current technical diagnostics.

3. Development of the control action options, including the formation of a list of technical diagnostic operations for earlier diagnosis of individualized parameters of the technical condition of truck components and assemblies, moving away from the canons of the existing list of operations.

4. Formulation of the control action options when constructing a list of parameters of the technical condition of units and components, taking into account information on its technical condition, close to the maximum permissible, indicating the names, forecast and limit values.

The solution to these tasks will collectively improve the accuracy of statistical assessments of predicted parameters and enable relevant specialists to make informed decisions on the implementation of necessary interventions on specific vehicles during their operation.

To implement the SAIT system, the agricultural producer's engineering team must have a personal computer with minimum performance requirements. For increased operational efficiency, the SAIT system can be used on tablets and mobile phones. The system can be used remotely with the use of the Internet[2].

MATERIAL AND METHODS

The improved SAIT system was the subject of the study. The following data analysis methods were primarily used: statistical (grouping, determining average scores, tabulation), multivariate (factor analysis), simulation (expert assessments, intuition, experience), and deterministic (programming).

When solving the first problem for the parameter under consideration, the number of identical parameters (NIP) is first determined on the analyzed sample of trucks [3]. If the NIP for the sample under consideration $j = 1$ (i.e. there is no other NIP), it is taken into account as the number of trucks of a given model in the fleet of the agricultural producer itself (AP). For example, if the CO content in the exhaust gases of trucks is a single parameter for one vehicle, then the NIP will be taken into account for their other samples. For example, on an eight-cylinder engine there will definitely be a diagnostic parameter for which the NIP will be $j = 8$, in which case, when assessing the NIP, eight speeds will be taken into account to assess the change in the analyzed parameter – v_{c1}, v_{c2}, …, v_{c8}, which corresponds to the improvement of the forecasting method in the SAIT system. The determination of the average rate of change of the analyzed diagnostic parameter is estimated using the expression

$$V_{\text{cp}} \frac{(v_{c1} + v_{c1} + v_{c2} + ... + v_{ci})}{(j + 1)}, \qquad (1)$$

W here V_{av} – average rate of change of the analyzed diagnostic parameter, units of parameter/unit of operation α (α – the exponent of the function of change in the parameter (wear

[2]*Kontrobaeva Zh.D., Salykov B.R.* Improving the efficiency of road transport for the transportation of agricultural goods based on innovative digital technologies // 3i: Intellect, Idea, Innovation, 2023, N 1, pp. 143–151. DOI: 10.52269/22266070_2023_1_143.

of the mating part)); v_{c1}, v_{c2}, ..., v_{cj} – rate of change of the analyzed diagnostic parameter, units of parameter/unit of operation α; j – number of diagnostic parameters.

Here the value of the speed under consideration v_{c1} appears twice, which is done to increase its weight during averaging. [4].

According to expression (1), all predicted diagnostic parameters of the technical condition of the truck in question are recalculated, replacing the actual rates of their change with the obtained values V_{av}, respectively.

To solve the second problem, it is necessary to adjust the tabulated standardized coefficients α, which is carried out using the least squares method. Taking into account the actual data of the analyzed parameter P_1, P_2, …, P_r, where r – the number of measurements of the parameter under consideration, including its nominal and limit values. The specified standardized coefficient α can be considered in a single-type AP, therefore, when improving the SAIT system, it is necessary to adjust this coefficient during a production check. To make the adjustment, it is necessary to ensure that the sum of the deviations of the set of actual values of the parameter being diagnosed from their calculated values is minimal. In this regard, to meet this condition for solving the problem under consideration, the method for determining the necessary diagnostic parameters based on the least squares method is best suited [5]. To achieve optimal forecasting quality using this method, the minimum number of similar parameters being diagnosed should be no less than three, i.e., the first is its nominal value from the regulatory reference data (RRD), the second is located in the memory of the personal computer and is the parameter obtained during the last diagnostic, the third value of the diagnostic parameter is obtained directly during the technical diagnostic process [6].

According to the least-squares method, the change curve must be specified through at least three points. The more parameters stored in a personal computer, the more accurate the process of predicting the technical condition of truck components and assemblies will be.

Such data for previous diagnostic and forecasting techniques, as well as the nominal and limit values for the predicted parameter are compared with the calculated series R_1, R_2, …, R_r (index 1, 2, ..., r – serial number of the measurement), formed in relation to the selected coefficient α_0, representing the exponent of the change function at the nominal value of the parameter, respectively, the R_1, R_2, …, R_r range is formed for a sequence of values α_0 taken from the range ((0.7...1.3) × α) with a step of 0.1. The sum of squared deviations itself is calculated using the expression

$$S = (P_1 - P_1)^2 + (P_2 - P_2)^2 + \ldots + (P_r - R_r)^2, \quad (2)$$

where P_1, P_2, ..., P_r – actual data of the analyzed parameter; R_1, R_2, ..., R_r – change of the analyzed parameter until the limit value is reached.

For further forecasting operations, the coefficient α_0 used is chosen to be its value from the range specified above, which allows obtaining the minimum sum of squared deviations S of the actual data from those calculated using the expression (2).

As can be seen from the above, in order to improve this forecasting method, it is necessary to store information about its diagnostics for all previous assessment/checking procedures for each truck in the computer memory.

Based on the solution of the two problems mentioned above, all the predicted parameters of the technical condition of the truck in question are calculated (G_{ir}), where i – predicted parameter of the technical condition of its unit or assembly.

When solving the third problem, a comparison is made between the difference L of the predicted values of G_{ir} and the identical limit parameters of the technical condition (R_{id}) available in the RRD, where d is the limit value of the predicted parameter of the technical condition of a unit or assembly of an auto truck (hereinafter – AT).

The value L is estimated as $G_{ir} - R_{id}$, if $(0,1 \times U) \geq L \leq (0,9 \times U)$, where U – the mileage of a given truck until its next regular TD, then the unit/assembly corresponding to the parameter is included in the list for earlier diagnostics. The information provided indicates the name, as well as the predicted (G_{ir}) and maximum (R_{id}) values of the critical parameter. Logically, the unit/assembly in question may have several such parameters, and all of them are presented in the specified information group.

When solving the fourth problem, the same difference L is compared. If $L \leq (0.1 \times U)$, then the unit/assembly corresponding to the parameter is included in the repair list. As above, the information provided for it indicates its name, as well as the predicted (G_{ir}) and limit (R_{id}) dimensions of the parameter being repaired. All other unit/assembly parameters with identical estimates are also presented in the specified information group.

RESULTS AND DISCUSSION

The enhanced SAIT system is located on storage media in a folder named "SSAIT 2.0." This directory consists of four folders ("Block 1," "Block 2," "Block 3," and "E-books for the AT models in question"), the "SAIT 2.0 User's Guide" file, and the "book_xlsx" file from the "START" main menu. The "START" menu contains hyperlinked blocks that allow you to view the contents of the "book_xlsx" files:

1. Computer input and adjusting RRD/ information on the models considered in the system [6] AT AP TS-1.

2. Computer input of the results of the latest diagnostic test of a separate AT AP sample and combining them with the data from previous diagnostic tests TS-2.

3. Formation and computer input of the information on the basic methods of improved forecasting of the sample under consideration AT AP TS-3.

4. E-books on the models of the AT APs TS-4 under consideration.

The developed PAIS system at the stage of development and implementation to the manufacturers had an information shell of MS Excel software, was later integrated into LibreOffice Calc spreadsheets and demonstrated stable operation on the Astra Linux operating system installed on a laptop with the following parameters: processor Intel(R) Core(TM) i5-2410M CPU @ 2.30GHz 2.30 GHz; RAM 8.00 GB; video adapter Intel(R) HD Graphics 3000; SCSI drive Apacer&Prod AS350 512GB; optical drive DVD+-RW TS-L633J [7].

The components of the information model are presented in the form of electronic spreadsheets "electronic books" (hereinafter referred to as books_xlsx) [8], containing all the information necessary for forecasting on the considered truck models, respectively. Also provided here is a general book_xlsx of the SAIT system, containing a list of the considered GA models and the first-level menu "Start".

Each of the attached menus contains a sheet titled "List of AT Models." It lists the model names of the ATs in question, indicating their quantity and hyperlinks to the corresponding .xlsx file. Below the table, the user is provided with an explanatory text explaining their possible actions: delete information for a specific AT brand from the table; correct the table information for a specific AT brand; add information for a new AT brand to the table [9].

In the xlsx workbook, the following sheets are formed for each AT model: sheet 1 with the name "RRD of the AT model", containing the RRD for the AT model under consideration; sheet 2 with the name "Record of individual AT units of the model under consideration" (shortly as "Record of AT units of the model"), containing the considered list of AT of this model in the AP fleet; sheet 3 with the name "VRP1", formed using the symbols of the actual state registration plate of the first AT unit under consideration as "VRP1" (see Fig. 1).

Predictive calculations are performed after entering the diagnostic results for the vehicle

in question, taking into account the selected forecasting enhancement method specified in the input data. To perform the calculations, a table is created that includes the names of the vehicle components and assemblies, the condition parameter, the unit of measurement, the parameter value, the parameter value from the previous diagnostic, and the parameter value from the current diagnostic (see Fig. 2).

A similar function is also created for cases of accounting for similar AT values for a specific model. In the direct-action mode in the xlsx workbook, the user, operating on sheet 2 – "Summary of AT units of the model" with the following functions: delete information on the AT of a specific unit from the sheet, thereby deleting the information on the model itself; adjust information on a specific AT unit without affecting the information on the model itself; supplement the sheet with information on a new AT unit [10].

The operational calculation, input/output information is processed in the book_xlsx on the sheet "auto_working", the table cells contain links to the next sheet with formulas for the mathematical calculation of the improved forecasting of the residual diagnostic parameter of the resource of units and assemblies, reflecting formulas (1) and (2), linking hyperlinks to the readings of the parameters of the current diagnostics and the calculation of the residual parameter of the resource of units and assemblies using all forecasting methods (see Fig. 3).

Data from previous diagnostics are linked to the AT unit in question. To achieve this, the results of previous technical diagnostics are entered into the personal computer's memory, and the technical condition parameter values are recorded in the table, shifting the previously recorded data to the right. The number of TDs performed is also taken into account to calculate the desired curvature coefficient using the formula for subtracting the average value, taking into account the estimated change in the parameter in question [11]. Each cell of the specified columns from the sheet form contains algorithmic formulas and consists of multiple interconnected hyperlinks to the required sheets

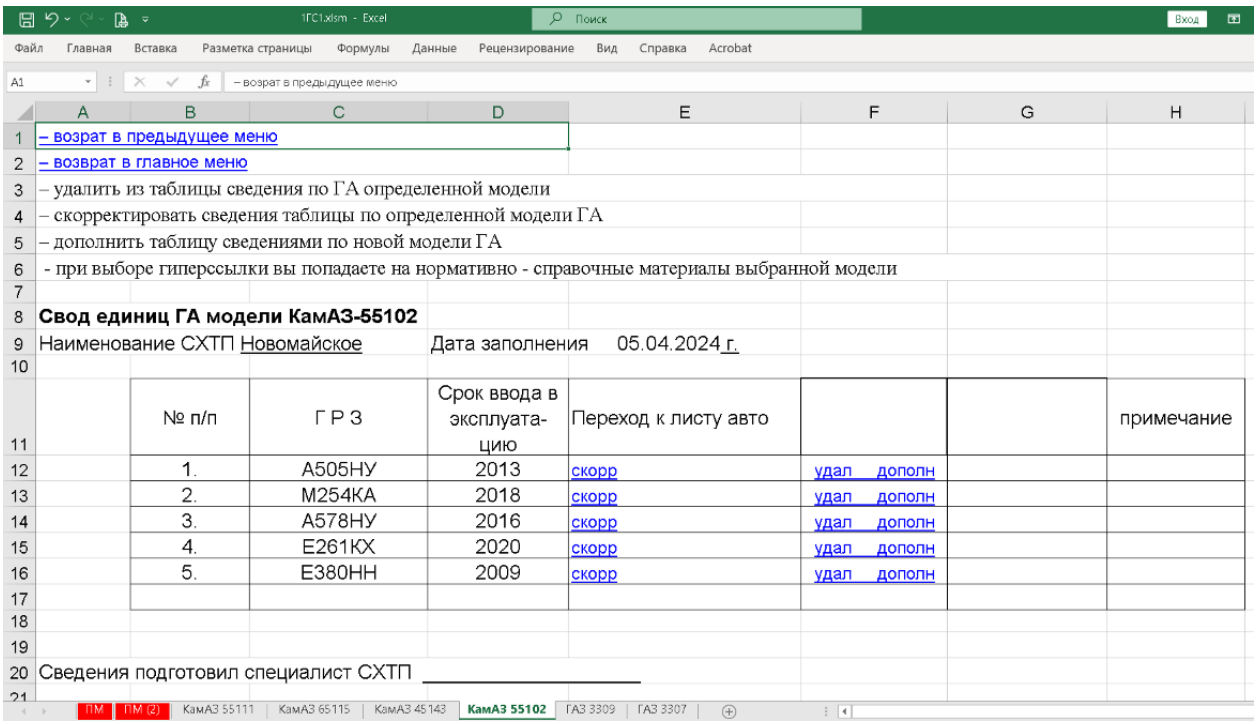
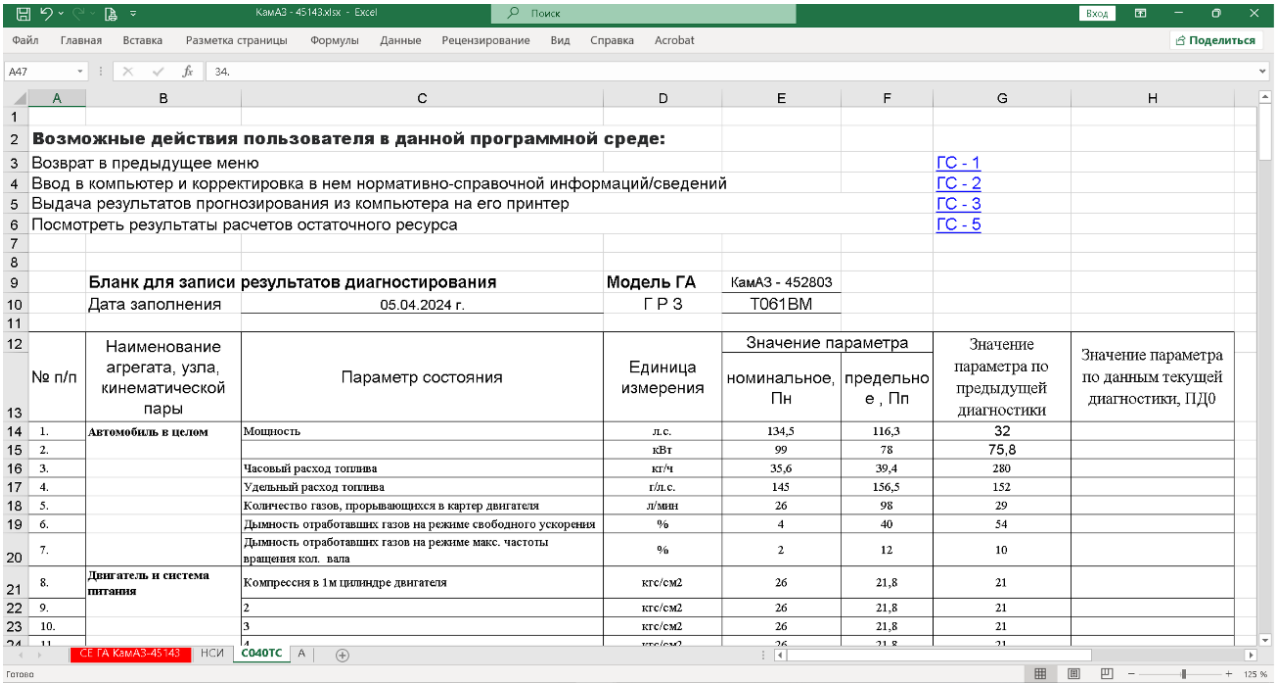


Рис. 1. Фрагмент листа «Свод единиц ГА модели»

Fig. 1. Fragment of the sheet "Summary of the AT model units"



Возможные действия пользователя в данной программной среде:

Возврат в предыдущее меню	ГС - 1
Ввод в компьютер и корректировка в нем нормативно-справочной информаций/сведений	ГС - 2
Выдача результатов прогнозирования из компьютера на его принтер	ГС - 3
Посмотреть результаты расчетов остаточного ресурса	ГС - 5

Бланк для записи результатов диагностирования — **Модель ГА**: КамАЗ - 452803

Дата заполнения: 05.04.2024 г. — ГРЗ: Т061ВМ

№ п/п	Наименование агрегата, узла, кинематической пары	Параметр состояния	Единица измерения	Значение параметра: номинальное, Пн	Значение параметра: предельное, Пп	Значение параметра по предыдущей диагностики	Значение параметра по данным текущей диагностики, ПД0
1.	**Автомобиль в целом**	Мощность	л.с.	134,5	116,3	32	
2.			кВт	99	78	75,8	
3.		Часовый расход топлива	кг/ч	35,6	39,4	280	
4.		Удельный расход топлива	г/л.с.	145	156,5	152	
5.		Количество газов, прорывающихся в картер двигателя	л/мин	26	98	29	
6.		Дымность отработавших газов на режиме свободного ускорения	%	4	40	54	
7.		Дымность отработавших газов на режиме макс. частоты вращения кол. вала	%	2	12	10	
8.	**Двигатель и система питания**	Компрессия в 1м цилиндре двигателя	кгс/см2	26	21,8	21	
9.		2	кгс/см2	26	21,8	21	
10.		3	кгс/см2	26	21,8	21	

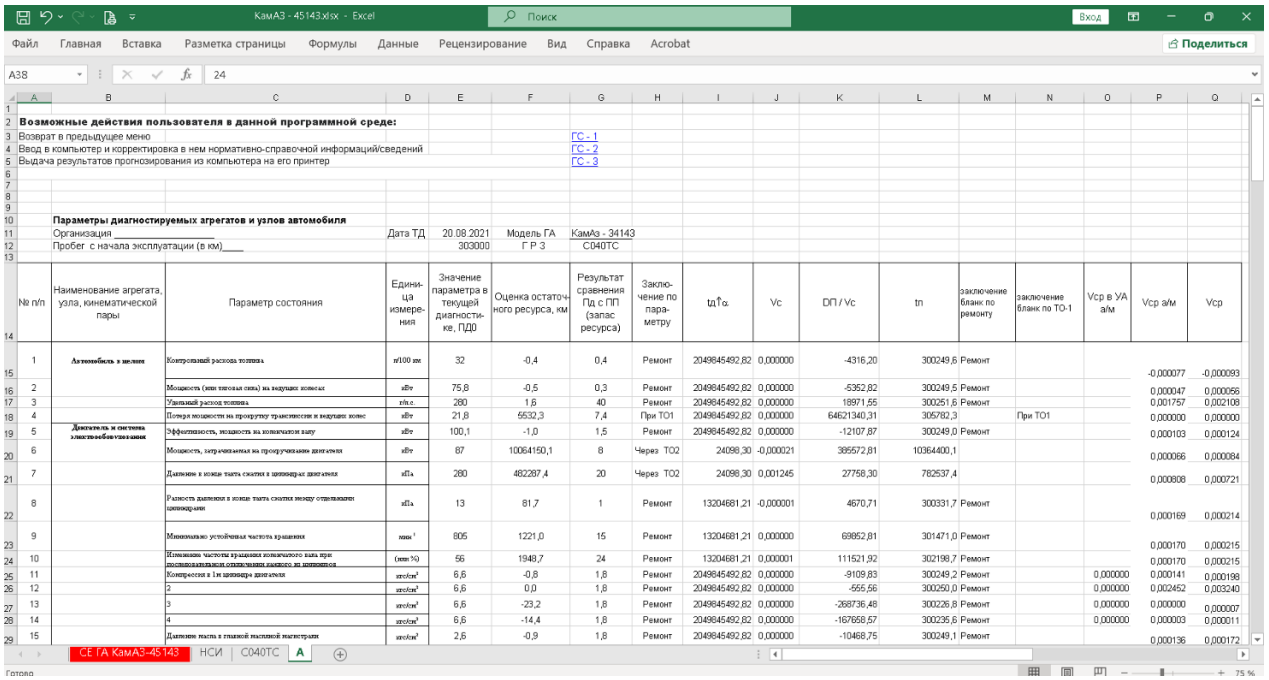
Рис. 2. Фрагмент листа «Бланк для записи результатов диагностирования»
Fig. 2. Fragment of the sheet “The form for recording diagnostic results”

of the improved SAIT system [12].

The implementation of advanced forecasting methods in the SAIT system will improve the efficiency of technical diagnostics of vehicles during scheduled and unscheduled maintenance, as well as the level of competence of service specialists.

CONCLUSIONS

1. The changes made to the SAIT system made it possible to recalculate all predicted



Возможные действия пользователя в данной программной среде:

Возврат в предыдущее меню	ГС - 1
Ввод в компьютер и корректировка в нем нормативно-справочной информаций/сведений	ГС - 2
Выдача результатов прогнозирования из компьютера на его принтер	ГС - 3

Параметры диагностируемых агрегатов и узлов автомобиля

Организация _____ — Дата ТД: 20.08.2021 — Модель ГА: КамАз - 34143

Пробег с начала эксплуатации (в км)____ — 303000 — ГРЗ — С040ТС

№ п/п	Наименование агрегата, узла, кинематической пары	Параметр состояния	Единица измерения	Значение параметра в текущей диагностике, ПД0	Оценка остаточного ресурса, км	Результат сравнения Пд с ПП (запас ресурса)	Заключение по параметру	tn1*α	Vc	ДП / Vc	tn	заключение бланк по ремонту	заключение бланк по ТО-1	Vcp в УА а/м	Vcp а/м	Vcp
1	**Автомобиль в целом**	Контрольный расход топлива	л/100 км	32	-0,4	0,4	Ремонт	2049845492,82	0,000000	-4316,20	300249,6	Ремонт			-0,000077	-0,000093
2		Мощность (или тяговая сила) на ведущих колесах	кВт	75,8	-0,5	0,3	Ремонт	2049845492,82	0,000000	-5362,82	300249,5	Ремонт			0,000047	0,000056
3		Удельный расход топлива	г/л.с.	280	1,6	40	Ремонт	2049845492,82	0,000000	18971,55	300251,6	Ремонт			0,001757	0,002108
4		Потеря мощности на прокрутку трансмиссии и ведущих колес	кВт	21,8	5532,3	7,4	При ТО1	2049845492,82	0,000000	64621340,31	305782,3		При ТО1		0,000000	0,000000
5	**Двигатель и система электрооборудования**	Эффективность, исходность на коленчатом валу	кВт	100,1	-1,0	1,5	Ремонт	2049845492,82	0,000000	-12107,87	300249,0	Ремонт			0,000103	0,000124
6		Мощность, затрачиваемая на прокручивание двигателя	кВт	87	10064150,1	8	Через ТО2	24098,30	-0,000021	385572,81	10364400,1				0,000066	0,000084
7		Давление в конце такта сжатия в цилиндрах двигателя	кПа	280	482287,4	20	Через ТО2	24098,30	0,001245	27758,30	782537,4				0,000808	0,000721
8		Разность давления в конце такта сжатия между отдельными цилиндрами	кПа	13	81,7	1	Ремонт	13204681,21	-0,000001	4670,71	300331,7	Ремонт			0,000169	0,000214
9		Минимально устойчивая частота вращения	мин$^{-1}$	805	1221,0	15	Ремонт	13204681,21	0,000000	69852,81	301471,0	Ремонт			0,000170	0,000215
10		Изменение частоты вращения коленчатого вала при последовательном отключении каждого из цилиндров	(мин-1)/Ц	56	1948,7	24	Ремонт	13204681,21	0,000001	111521,92	302198,7	Ремонт			0,000170	0,000215
11		Компрессия в 1м цилиндра двигателя	кгс/см^2	6,6	-0,8	1,8	Ремонт	2049845492,82	0,000000	-9109,83	300249,2	Ремонт		0,000000	0,000141	0,000198
12		2	кгс/см^2	6,6	0,0	1,8	Ремонт	2049845492,82	0,000000	-555,56	300250,0	Ремонт		0,000000	0,002452	0,003240
13		3	кгс/см^2	6,6	-23,2	1,8	Ремонт	2049845492,82	0,000000	-268736,48	300226,8	Ремонт		0,000000	0,000000	0,000007
14		4	кгс/см^2	6,6	-14,4	1,8	Ремонт	2049845492,82	0,000000	-167658,57	300235,6	Ремонт		0,000000	0,000003	0,000011
15		Давление масла в главной масляной магистрали	кгс/см^2	2,6	-0,9	1,8	Ремонт	2049845492,82	0,000000	-10468,75	300249,1	Ремонт			0,000136	0,000172

Рис. 3. Фрагмент листа «Расчеты совокупности методов прогнозирования»
Fig. 3. Fragment of the sheet “Calculations of the aggregate forecasting methods”

diagnostic parameters, replacing the actual rates of their change with the obtained values of the average rate of the analyzed diagnostic parameter, thereby increasing the accuracy of prediction.

2. The adjustment of the typical curvature coefficients indicator is carried out taking into account the nominal parameters of the technical condition and the dynamics of the transformation of the predicted coefficient based on real data obtained during the current technical diagnostics.

3. Based on the forecasting results, the user is presented with a list of possible control actions, and units and assemblies with forecast values close to the limit are automatically included in the list for repair.

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Состояние животноводства в Сибирском казачьем войске в конце XIX в.

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В конце XIX в. развитие животноводства на территории Сибирского казачьего войска находилось на достаточно высоком уровне. Как по площади посевов, так и по численности скота казаки сравнялись с сибирскими крестьянами. Животноводством и хлебопашеством занималось войсковое население на Иртышской, Бийской, Бухтарминской и Ишимской оборонительных линиях, а также в Киргизской степи. Животноводство не требовало таких трудозатрат, как работа на пашне, и не было жестко связано с циклами сельскохозяйственных работ. Именно поэтому в казачьих хозяйствах нередко насчитывалось по 20 гол. и более крупного рогатого скота. В 90-е годы XIX в. жизнь казаков заметно изменилась в результате строительства Великого Сибирского пути. Получили развитие скотоводство, коневодство и овцеводство. Размеры стад определялись достаточным количеством пахотной земли, пастбищ и сенокосных угодий. Из домашней птицы разводили кур, уток, гусей, индеек. В указанный период произошел переход казачьего хозяйства от скотоводческо-промыслового и полунатурального к земледельческо-скотоводческому и мелкотоварному. Казаки разводили лошадей, крупный и мелкий рогатый скот, реже – свиней и домашнюю птицу не только для внутреннего потребления, но и с целью продажи. В статье на основе имеющихся статистических данных рассмотрен ряд вопросов, отражающих состояние животноводства на территории Сибирского казачьего войска: общее количество сельскохозяйственных животных в подсобных хозяйствах войскового населения (1898 г.); соотношение поголовья сельскохозяйственных животных и численности населения (1899 г.); сравнительно-аналитические данные по инфекционным болезням животных (1894–1898 гг.); убыль сельскохозяйственных животных по военным отделам Сибирского казачьего войска (1898 г.).

Ключевые слова: животноводство, инфекционная заболеваемость, Сибирское казачье войско

The state of animal husbandry in the Siberian Cossack army at the end of the XIX century

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At the end of the XIX century, the development of livestock farming in the territory of the Siberian Cossack army was at a fairly high level. In terms of both the number of crops and the number of livestock, the Cossacks equaled the Siberian peasants. The military population on the Irtysh, Biysk, Bukhtarma and Ishim defensive lines, as well as in the Kyrgyz steppe, were engaged in livestock breeding and arable farming. Animal husbandry did not require such labor costs as working on arable land, and was not rigidly connected with the cycles of agricultural work. Therefore, Cossack farms often had 20 or more heads of cattle. With the construction of the Great Siberian Railway in the nineties of the XIX century, the life of the Cossacks changed markedly. Cattle breeding, horse

breeding, and sheep breeding started to develop. Animal husbandry played a secondary role in the economy of the Siberian Cossack army at the end of the XIX century. The size of the herds was determined by a sufficient amount of arable land, pastures and hayfields. Among the poultry they bred were chickens, ducks, geese, and turkeys. During this period, the Cossack economy transitioned from livestock-breeding and semi-subsistence to agricultural-livestock-breeding and small-scale commodity production. The Cossacks bred horses, cattle, small cattle, and, less frequently, pigs and poultry, not only for domestic consumption but also for sale. The article, based on available statistical data, examines a number of issues reflecting the state of animal husbandry in the territory of the Siberian Cossack army: the total number of farm animals in the subsidiary farms of the military population (1898); the ratio of the number of farm animals to the population (1899); comparative analytical data on infectious diseases of animals (1894–1898); the loss of farm animals in the military departments of the Siberian Cossack army (1898).

Keywords: animal husbandry, infectious diseases, Siberian Cossack army

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The Siberian Cossack Host was an irregular army in the Russian Empire from the 17th to the 20th centuries, operating in Siberia, including northern and eastern Kazakhstan. Officially, it dates back to 1582. It is the third-oldest Cossack host in Russia (after the Don and Terek hosts) [1–3].

In terms of military, administrative, and economic management, the Siberian Cossack Host was located in two regions of the Steppe Governorate-General—Akmola and Semipalatinsk—as well as in the Biysk District of the Tomsk Governorate, and consisted of three military divisions. The center of the 1st Military Division was Kokchetav, the 2nd was Omsk, and the 3rd was Ust-Kamenogorsk. The division into divisions was necessary for ease of military command. Each military division consisted of several stanitsas (councils), and each stanitsa consisted of several villages. Furthermore, Cossack lands were scattered in patches across the Kazakh steppe. The entire military territory at the end of the 19th century amounted to just under 5 million dessiatines. From 1869, the executive bodies were: for military matters, the Omsk Military District Headquarters; for administrative and economic matters, the Military Economic Board (a collegial body consisting of a chairman, two advisers, and a treasurer). The chairman of the board was appointed by the military ataman from among the military staff officers [4–6].

Information on the administrative-territorial division of the Siberian Cossack army at the end of the 19th century is presented in Table 1.

Table 1 shows that the 3rd Military Division had the largest number of settlements – 85, which constituted 48.6% of the total number of settlements in the Siberian Cossack Host. The 1st Military Division had the smallest number of settlements – 33 (18.8%).

In terms of the ratio of stanitsas to settlements, the settlement-type residential areas had the advantage. In total, the Siberian Cossack Host had 138 settlements and 37 stanitsas, which constituted 78.8% and 21.2% of the total number of settlements (175), respectively. Of these, 12 stanitsas were located in the 1st Military Division, 7 in the 2nd, and 18 in the 3rd. The 1st through 3rd Military Divisions had 21, 50, and 67 settlements, respectively.

Табл. 1. Административно-территориальное деление Сибирского казачьего войска (1898 г.) [7]
Table 1. Administrative-territorial division of the Siberian Cossack army (1898) [7]

Military department	Geographical position	Control center	Stanitsas, number/%	Settlements, number /%	Total settlements, number/%
1st	Petropavlovsk and Kokchetav districts of the Akmola region	Kokchetav	12/32,4	21/15,2	33/18,8
2nd	Omsk and Petropavlovsk districts of the Akmola region	Omsk	7/18,9	50/36,2	57/32,6
3rd	Pavlodar, Semipalatinsk, Ust-Kamenogorsk, Karkalinsk and Zaisan districts of the Semipalatinsk region, Biysk district of the Tomsk province	Ust-Kamenogorsk	18/48,6	67/48,5	85/48,6
Total for the Siberian Cossack Army			37/21,2	138/78,8	175/100,0

Data on the quantitative composition of the livestock population in the territory of the Siberian Cossack Host are presented on the basis of reports from village administrations [7] (see Table 2).

From Table 2 it follows that the total number of farm animals in the Siberian Cossack Host was 393,110 heads. The largest number was cattle – 145,579 heads (37.0%). There were 137,558 heads of small cattle (34.9%), of which 130,231 heads of sheep (94.7%), and 7,327 heads of goats (5.3%). The number of horses was 104,052 heads (26.4%), and 5,876 heads of pigs (1.5%). The 1st and 2nd military departments also had camels (45 heads in total, 0.01%).

The following statistics are available for the military departments. The 3rd Military Department had the largest number of horses – 54,075 heads (51.9%). The number of horses in the 1st and 2nd Military Departments was 22,515 heads (21.6%) and 27,462 heads (26.4%), respectively. The number of cattle in the military departments varied slightly: 1st – 46,754 heads (32.1%), 2nd – 51,579 heads (35.4%), 3rd – 47,246 heads (32.4%). In terms of the number of small cattle, the 2nd military department prevailed over the 1st and 3rd military departments. In terms of the number of pigs, the 1st military department occupied first place – 2,672 heads (45.5%). In the 3rd military department there were 889 pigs, in the 2nd – 2,305.

The military sergeant major, colonel, ataman of the 1st military department of the Siberian Cossack Host, and writer F.N. Usov noted: "At present, horse breeding and cattle breeding are equally developed among the Siberian Cossacks; the former is even preferred because horses are less susceptible to disease than cattle, and

Табл. 2. Общее количество сельскохозяйственных животных в подсобных хозяйствах на территории Сибирского казачьего войска (1898 г.), гол./%
Table 2. The total number of farm animals in subsidiary farms on the territory of the Siberian Cossack army (1898), heads/%

Military department	Horses	Cattle	Small cattle		Pigs	Camels	Total animals
			sheep	goats			
1st	22 515/21,6	46 754/32,1	43 489/33,4	1601/21,8	2672/45,5	35/77,7	117 066/29,7
2nd	27 462/26,4	51 579/35,4	51 276/39,4	1789/34,4	2305/39,2	10/22,2	134 421/34,2
3rd	54 075/51,9	47 246/32,4	35 466/27,2	3937/53,7	899/15,3	–	141 623/36,1
Total	104 052/26,4	145 579/37,0	137 558/34,9		5876/1,5	45/0,01	393 110/100,0

also because of the development of the transport industry in the military territory." [6].

According to military veterinarian P.S. Popov: "Animal husbandry should form the basis of the well-being of the military population, since livestock farming, and especially horse breeding, are of absolute economic importance in agricultural terms, and the well-being of the entire army, as well as of individual Cossack households, is closely dependent on them. The primary measure of the prosperity of a given Cossack household is the number of horses it possesses, and therefore horse breeding is the primary factor in increasing or decreasing the well-being of an individual Cossack household, and, in general, of the entire Cossack population." [7].

Data on the number of horses in relation to other types of farm animals in the Siberian Cossack Army are presented in the figure.

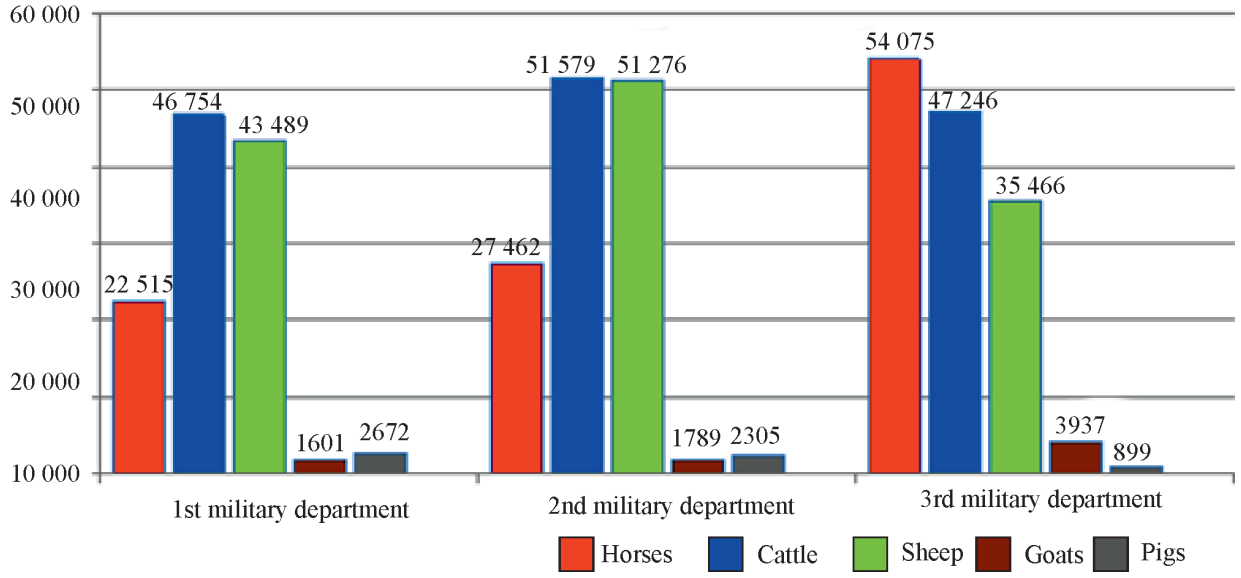
The diagram shows that the 3rd Military Division had the largest number of horses – 54,075. The 1st Military Division had the smallest number of horses – 22,515. The 2nd Military Division had the horse population of 27,462 horses.

Analyzing the ratio of the number of farm animals, we can conclude that the priority in the 3rd military department was horse breeding, in the 1st and 2nd departments – cattle and sheep breeding (see the figure).

According to available information, goat breeding accounted for a small share of overall livestock farming among the Cossacks. Pigs were also kept in small numbers, primarily by Cossacks from among the resettled peasants living in the Petropavlovsk and Kokchetav districts. In most of the Siberian Cossack Host, pigs were not raised; in this area, they were replaced by sheep. Camels were kept in very small numbers. Poultry farming was not developed [6].

The ratio of the number of livestock and the population in the Siberian Cossack Host is presented in Table 3. This indicator clearly demonstrates the degree of provision with livestock (meat) products and is the main indicator characterizing the well-being of the population of the Siberian Cossack Host in the specified historical period.

The data in Table 3 show that as of 01.01.1899, there were 393,065 heads of farm animals for 137,145 people in the Siberian Cossack Host. In this structure of the livestock, the first place was occupied by cattle (145,579 heads, 37.0%), the second place by small cattle (137,558 heads, 34.9%), the third place by horses (104,052 heads, 26.5%), and a smaller number of pigs (5876 heads, 1.5%).



Соотношение численности лошадей и других видов сельскохозяйственных животных по Сибирскому казачьему войску (1898 г.), гол. [7]

The ratio of the number of horses and other types of farm animals in the Siberian Cossack army (1898), heads [7]

Табл. 3. Соотношение поголовья сельскохозяйственных животных и численности населения на территории Сибирского казачьего войска на 01.01.1899 г. [7]

Table 3. The ratio of livestock to population in the territory of the Siberian Cossack army as of 01.01.1899 [7]

Military department	Population size, people	Horses		Cattle		Small cattle		Pigs	
		heads	heads/ people	heads	heads/ people	heads	heads / people	heads	heads / people
1st	48 567	22 515	0,463	46 754	0,963	45 090	0,928	2672	0,055
2nd	44 649	27 462	0,615	51 579	0,152	53 065	1,188	2305	0,052
3rd	43 929	54 075	1,231	47 246	1,075	39 403	0,896	899	0,021
Total	137 145	104 052 (26,5 %)	0,758	145 579 (37,0%)	1,061	137 558 (34,9%)	1,003	5876 (1,5%)	0,043
Total number of farm animals in the Siberian Cossack Army, heads.		393 065							
Number of animals per capita		2,866							

In total, there were 2,866 heads of farm animals per capita. Among meat products, the highest figure was for cattle (1,061), and the lowest for pigs (0,043).

In 1898, 62 fairs were established in Cossack villages, of which 32 were in the 1st military department, 13 in the 2nd, and 17 in the 3rd. The items traded at these fairs were mainly: butter, lard, sheep wool, horse hair, leather, as well as herds of horses, droves of cattle and sheep [7].

By the end of the 19th century, livestock farming in the Siberian Cossack army had acquired a commercial character, which was reflected in the development of trade in livestock products.

P.S. Popov, in his "Brief Essay on the Veterinary and Sanitary Condition of the Siberian Cossack Host," noted: "Even worse in terms of the paucity of statistical material is the information on the incidence and mortality of domestic animals of the military population, noted in the report on the state of the Siberian Cossack Host for 1898. This report contains data only on epizootics of domestic animals, delivered to the Military Economic Administration by regional veterinarians of the Akmola and Semipalatinsk regions, excluding information on epizootics in Cossack villages located within the Tomsk province. How high the incidence and mortality of domestic animals from various kinds of non-infectious diseases are, and also in what figures the loss of domestic animals from various accidents that are not dependent on their suffering from various kinds of diseases is expressed, is completely unknown, since the registration of the total loss of domestic animals in the army has not been established to date." [7].

The reason for the incompleteness of statistical data is the lack of any proper organization of work in collecting information on the incidence and mortality of domestic animals from various diseases, which is explained by the lack of veterinary and medical personnel in the Tomsk province, Akmola and Semipalatinsk regions [7].

Nevertheless, using the presented figures, we will try to generally characterize the epizootic situation in the territory of the Siberian Cossack army in 1894–1898 (Tables 4, 5).

From the data in Table 4 it follows that plague, pneumonia, scabies, anthrax, foot-and-mouth disease, and rabies were registered among cattle; anthrax, equinia, influenza, strangles, and scabies were registered among horses; and rabies was registered among dogs.

Табл. 4. Сравнительно-аналитические данные по инфекционным болезням животных на территории Сибирского казачьего войска [7]
Table 4. Comparative analytical data on infectious diseases of animals in the territory of the Siberian Cossack army [7]

Disease name	1894			1895			1896			1897			1898		
	got sick, heads	died, heads	%	got sick, heads	died, heads.	%	got sick, heads	died, heads	%	got sick, heads.	died, heads	%	got sick, heads	died, heads	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1st military department															
Cattle															
Cattle-plague	–	–	–	214	52	24,3	–	–	–	–	–	–	–	–	–
Contagious bovine pleuropneumonia	45	21	46,6	121	42	34,7	–	–	–	124	53	42,7	48	30	62,5
Scabies itch	–	–	–	–	–	–	–	–	–	–	–	–	105	6	5,7
Anthrax	–	–	–	18	18	100,0	14	14	100,0	–	–	–	3	3	100,0
Foot-and-mouth disease	–	–	–	16	–	–	–	–	–	220	1	0,4	328	–	–
Horses															
Anthrax	4	4	100,0	–	–	–	12	11	91,6	8	8	100,0	24	21	87,5
Glanders	–	–	–	–	–	–	8	1	12,5	2	–	–	11	3	27,2
Influenza virus infection	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Strangles	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scabies itch	–	–	–	–	–	–	–	–	–	–	–	–	15	–	–
2nd military department															
Cattle															
Cattle-plague	–	–	–	2	7 (slaughtered)	–	–	–	–	–	–	–	–	–	–
Contagious bovine pleuropneumonia	85	53	62,3	579	257	44,3	–	–	–	282	194	68,8	154	78	50,6
Scabies itch	–	–	–	–	–	–	–	–	–	–	–	–	35	–	–
Foot-and-mouth disease	–	–	–	–	–	–	–	–	–	2693	–	–	576	–	–
Anthrax	18	18	100,0	22	22	100,0	36	31	86,1	18	18	100,0	23	19	82,6

Окончание табл. 4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Horses															
Anthrax	43	41	95,3	7	6	85,7	1	1	100,0	5	2	40,0	19	11	57,9
Glanders	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Influenza virus infection	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Strangles	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scabies itch	–	–	–	–	–	–	56	–	–	–	–	–	241	8	3,3
3rd military department															
Cattle															
Cattle-plague	218	170	77,9	–	–	–	–	–	–	115	22	19,1	–	–	–
Contagious bovine pleuropneumonia	–	–	–	–	–	–	11	1	9,1	–	–	–	–	–	–
Scabies itch	–	–	–	94	3	3,2	78	2	2,5	145	–	–	–	–	–
Foot-and-mouth disease	238	8	3,3	–	–	–	924	8	0,8	307	1	0,3	–	–	–
Anthrax	–	–	–	49	44	89,8	9	7	77,7	2	2	100,0	13	13	100,0
Rabies	2	2	100,0	–	–	–	–	–	–	–	–	–	–	–	–
Horses															
Anthrax	15	12	80,0	47	26	55,3	21	21	100,0	6	6	100,0	31	28	90,3
Glanders	2	1	50,0	83	45	54,2	37	5	13,5	34	3	8,8	39	12	30,7
Influenza virus infection	5	1	20,0	–	–	–	–	–	–	–	–	–	–	–	–
Strangles	3	–	–	5	2	40,0	–	–	–	–	–	–	–	–	–
Scabies itch	92	8	8,7	4	1	25,0	71	–	–	160	–	–	–	–	–
Dogs															
Rabies	–	–	–	–	–	–	2	2	100,0	6	6	100,0	–	–	–
Total	770	339	44,0	1261	525	41,6	1280	104	8,1	4127	316	7,6	1665	232	13,9

Табл. 5. Убыль лошадей и крупного рогатого скота по Сибирскому казачьему войску (1898 г.) [7]
Table 5. Loss of horses and cattle in the Siberian Cossack army (1898) [7]

Military department	Horses					Cattle				
	total number, heads	got sick		died		total number, heads	got sick		died	
		heads	%	heads	%		heads	%	heads	%
1st	22 515	50	0,2	24	48,0	46 754	484	1,1	39	8,1
2nd	27 462	260	0,9	19	7,3	51 579	788	1,5	97	12,3
3rd	54 075	70	0,1	40	57,1	47 246	13	0,03	13	100,0
Total for the Siberian Cossack Army	104 052	380	0,4	83	21,8	145 579	1285	0,8	149	11,6

The highest incidence of disease in animals in the Siberian Cossack Host was recorded in 1897 – 4,127 animals, of which 316 died (mortality rate of 7.6%). The lowest incidence was recorded in 1894 – 770 animals fell ill, 339 died (mortality rate of 44.0%). In 1895, 1896 and 1898, animal mortality rates were 41.6; 8.1 and 13.9%, respectively.

Cattle plague was characterized by the highest mortality rate (77.9%) in the 3rd military division of the Siberian Cossack army in 1894, where 170 of 218 sick animals died. A high incidence of cattle with contagious pneumonia was noted in 1897 in the 2nd military division, where 194 of 282 sick animals died, the mortality rate was 68.8%.

High mortality rates among animals were observed due to anthrax. Thus, in 1895, 1896, and 1898, the mortality rate among cattle in the 1st Military Division was 100.0%. In the 2nd Military Division, the mortality rate among cattle due to anthrax in 1894–1898 was 100.0; 100.0; 86.1; 100.0; 82.6%, respectively. High mortality rates were also observed among cattle in the 3rd Military Division.

Cases of rabies were recorded among dogs in the 3rd military department in 1896 and 1897, as well as among cattle in 1894 with a mortality rate of 100.0%.

Low mortality rates for foot-and-mouth disease and scabies were observed in cattle. For example, in 1897, mortality rates for foot-and-mouth disease in the 1st and 2nd Military Divisions were 0.4% and 0.3%, respectively (220 and 307 sick animals). In the 3rd Military Division, an increase in foot-and-mouth disease incidence was noted between 1894 and 1896. While 238 cattle were infected in 1894, with a mortality rate of 3.3%, in 1896 the number increased to 924, with a mortality rate of only 0.8%. The lowest mortality rate was recorded in 1897, when, with an incidence of 307 heads, the mortality rate was only 0.3%. For example, the mortality rate from scabies (common scab) in cattle in 1898 in the 1st and 2nd military divisions varied from 100.0 to 3.3%, in the 3rd military division in 1894 and 1895 it ranged from 8.7 to 25.0%, respectively.

Among the horses in the Siberian Cossack Host, anthrax, and to a lesser extent, glanders, strangles, and scabies, were characterized by high rates of morbidity and mortality. The mortality rate of horses due to anthrax in military units for 1894–1898 ranged from 40% to 100% (see Table 4).

P.S. Popov wrote in his "Brief Essay on the Veterinary and Sanitary Conditions of the Siberian Cossack Host": "This essay lists the widespread contagious diseases that civilian veterinary personnel, responsible for the protection of the domestic animals of the military population, have to observe and which are not so significant as to be able to promptly direct their efforts to the suppression of this, as well as other diseases." [7].

The statistical data in Table 5 show that in the Siberian Cossack Host, the incidence of horses in 1898 was 380 heads (0.4%), and the mortality rate was 83 heads (21.8%). Among cattle, 1,285 out of 145,579 heads were affected (incidence 0.8%, mortality 11.6%).

Among the military departments, a lower incidence rate was observed among cattle in the territory of the 3rd Military Department – 13 heads (0.03%), while the mortality rate was 100.0%. The highest incidence rate among farm animals in 1898 was recorded among cattle in the 2nd Military Department – 788 heads, while the mortality rate was 97 heads (12.3%).

Among horses, the highest mortality rate was observed in the 3rd military department – 57.1%. The 2nd military department had a low mortality rate – 7.3%. At the same time, the incidence of horses in the 1st–3rd military departments was 0.2; 0.9; 0.1%, respectively.

The Siberian Cossack Host's reports for 1897 state: "In the more distant future, it may be possible to establish livestock insurance against losses. One of the atamans of the military departments recently raised the issue of insuring horses in the host, which would undoubtedly provide a very important service to the Cossack population." Apparently, the Military Economic Administration and departmental administrations are already beginning to recognize the need to take various measures to provide the Cossacks with horses, which are a "powerful engine" and an expression of the entire agricultural well-being of the Cossacks. Of course, all these issues are time-sensitive, and to ensure their proper resolution, veterinary and medical personnel will have to actively participate and facilitate their speedy implementation." [7].

The above confirms the fact that due attention was paid to the issues of preserving the livestock of farm animals in the Siberian Cossack army.

CONCLUSIONS

1. At the end of the 19th century, the Siberian Cossack army was a militarized structure that had, in addition to military tasks, economic and business ones.

2. Livestock farming in the Siberian Cossack Host at the end of the 19th century was commercial in nature. Cossacks bred horses, cattle, sheep, and, less commonly, pigs, chickens, ducks, geese, and turkeys, not only for domestic consumption but also for sale.

3. At the end of the 19th century, animal husbandry in the Siberian Cossack army was one of the leading branches of economic activity.

4. The high mortality rate of farm animals in the Siberian Cossack Host at the end of the 19th century was due to the insufficient number of veterinarians and their inadequate professional training. This was due to the fact that permanent veterinary paramedic schools in Siberia only opened in the second half of the 19th century: in Tobolsk and Tomsk in 1878, and in Omsk in 1879.

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ИНФОРМАЦИЯ ОБ АВТОРАХ

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Periodical publication

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

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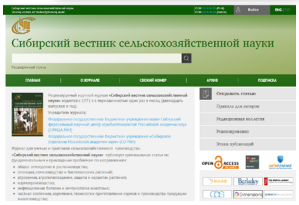

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