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SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

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ВЛИЯНИЕ ОБРАБОТКИ ПОЧВЫ И УДОБРЕНИЙ НА ФАУНУ ДЕРНОВО-ПОДЗОЛИСТОЙ ГЛЕЕВАТОЙ ПОЧВЫ И УРОЖАЙНОСТЬ ПОЛЕВЫХ КУЛЬТУР

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Представлены результаты изучения систем отвальной, поверхностно-отвальной и поверхностной обработки почвы, а также систем удобрения на основе соломы, используемой как отдельно, так и в сочетании с полным минеральным удобрением. Приведены данные за 2019–2021 гг. по численности почвенной фауны, урожайности многолетних трав 1-го и 2-го годов пользования и яровой пшеницы. Исследования проводили на дерново-подзолистых глееватых среднесуглинистых почвах (опытное поле Ярославской государственной сельскохозяйственной академии). За рассматриваемый период самая высокая численность полезной почвенной фауны (дождевые черви (*Lumbricina*), божьи коровки (Coccinellidae) и жужелицы (Carabidae)) наблюдалась при поверхностно-отвальной обработке, что свидетельствует о наличии в данной системе благоприятных условий для питания указанных организмов. Количество нематод (*Nematoda*) в этом варианте уменьшилось, причем существенные изменения зафиксированы по разным слоям почвы в зависимости от года, что может быть связано с более сильным ростом растений и повышением их способности противостоять гельминтам. Установлено, что наибольшее влияние на полезную фауну оказало совместное применение соломы и полного минерального удобрения: отмечены увеличение полезной фауны почвы и снижение популяции нематод, что можно объяснить сокращением бактерио- и микотрофов. За все годы исследований поверхностно-отвальная обработка почвы обеспечивала урожайность полевых культур на уровне отвальной обработки или несколько ниже. Внесение соломы вместе с полной нормой минеральных удобрений обусловило наиболее высокие значения указанного выше показателя.

Ключевые слова: фауна почвы, дождевые черви, жужелицы, нематоды, многолетние травы, яровая пшеница, урожайность

INFLUENCE OF TILLAGE AND FERTILIZERS ON THE FAUNA OF SOD-PODZOLIC GLEYIC SOIL AND THE YIELD OF FIELD CROPS

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The results of the study of the mouldboard, surface-mouldboard and surface soil treatment systems, as well as straw-based fertilizer systems used both separately and in combination with full mineral fertilizer are presented. Data for 2019-2021 on soil fauna, yield of perennial grasses of the 1st and 2nd years of use and spring wheat are given. The studies were conducted on sod-podzolic gleyic middle-loamy soils (experimental field of the Yaroslavl State Agricultural Academy). During the period under study, the highest abundance of beneficial soil fauna (earthworms (*Lumbricina*),

ladybugs (Coccinellidae) and carabid beetles (Carabidae) was observed during surface-mouldboard treatment which indicates that this system has favorable feeding conditions for these organisms. The number of nematodes (*Nematoda*) in this variant decreased with significant changes recorded in different soil layers depending on the year, which may be associated with stronger plant growth and an increase in their ability to resist helminths. It was found that the greatest impact on the beneficial fauna had a combined application of straw and total mineral fertilizer: an increase in the beneficial soil fauna and a decrease in the population of nematodes were observed, which can be explained by the reduction of bacterio- and mycotrophs. In all the years of research the surface-mouldboard treatment provided the yield of field crops at the level of the mouldboard tillage or slightly lower. Application of straw together with full norm of mineral fertilizers caused the highest values of the above-mentioned indicator.

Keywords: soil fauna, earthworms, ground beetles, nematodes, perennial grasses, spring wheat, productivity

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INTRODUCTION

Soil fauna plays an important role in humus formation and ecological balance of agrolandscapes. Understanding the factors affecting soil biological organisms is critical to improving the sustainability of agricultural systems, especially given the emergence of new farming systems based on bioeconomics. Soil fauna regulates a number of ecological processes, including decomposition of organic matter, nutrient cycling and energy transfer[1] [1].

Earthworms (*Lumbricina*) increase soil macroporosity, improve water inflow, increase nutrient availability and aeration[2] [2], and participate in the degradation of soil organic matter [3]. Therefore, they are traditionally considered as indicators of soil fertility [4].

Ground beetles (Carabidae) are useful insects necessary for the destruction of pests and weeds[3,4] [5]. At the same time, some species of ground beetles, being phyto- and myxophagous, are markedly harmful to agricultural crops and sometimes to pastures and sown seeds of forest species [6].

Ants (Formicidae) are of great value in the ecosystem. They destroy plant wastes and use some harmful insects as food. In the presence of ants, the soil is enriched with minerals, organic matter, and oxygen [7]. In addition, there are many studies on ants eating the seeds of weeds[5, 6] [8].

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Ladybugs (Coccinellidae) play one of the most important roles in the control of plant pests [9]. This beetle is capable of destroying 150-200 different insects per day. And most importantly, the ladybug finds pests even in twisted leaves where no insecticides reach. It eats insects at all stages of their development (egg, caterpillar, pupa) [10].

Soil nematodes (*Nematoda*) are of great importance for the trophic tissues of soil and underground ecosystems [11]. Numerous data indicate that soil nematodes directly or indirectly participate in various soil-ecological processes, such as decomposition of organic matter and mineralization of nutrients7 [12, 13]. The most widespread hemisaprobionts in soil feed on bacteria, fungi, yeasts, and small protozoa. As a consequence, the soil is enriched in nitrogen due to the excretions of nematodes [14].

Soil treatment, which causes a direct natural impact, also destroys the habitat of pedobionts, significantly reducing their populations[8, 9] [15]. Fertilizers have an effect on soil macrofauna[10] [16], but a clear picture is not yet observed. There are not enough studies on the impact of various agricultural technologies on the number of soil fauna. This problem is particularly relevant for sod-podzolic gleyic soils, since, according to some data, excessive overwatering contributes to the depletion of soil fauna [17]. In the non-chernozem zone sod-podzolic soils mainly prevail, and temporary overwatering is sometimes quite widespread. Therefore, it is extremely important to identify the effect of different in intensity tillage and fertilizer systems on the number of pedobionts.

MATERIAL AND METHODS

The studies were conducted in 2019-2021 on sod-podzolic gleyic medium-loamy soil in a multi-year field 2 factor experiment laid on the experimental field of the Yaroslavl State Agricultural Academy.

On average, during the study period, the soil tilled horizon contained: organic matter - 2.72%, P_2O_5 - 153.60 mg / kg soil, K_2O - 80.20 mg / kg soil, the total of exchangeable bases was 21.50 mg eq / 100 g soil, hydrolytic acidity - 1.41 mg eq / 100 g soil, pH_{salt} - 5.60.

Field experiment scheme:

I. *Factor A. Primary soil tillage system:* 1) mouldboard (MP); 2) surface tillage with loosening (STL); 3) surface-mouldboard (SP); 4) surface (ST).

II. *Factor B. Fertilizer system:* 1) no fertilizer (F_0); 2) N_{30} (N); 3) straw (S); 4) straw + N_{30} (SN); 5) straw + NPK (SNPK); 6) NPK (NPK).

In 2019 and 2020, the studies were conducted in crops of clover-grass mixture of the 1st and 2nd years of use, respectively, and in 2021 - in crops of spring wheat.

The number of nematodes in the soil was measured by the Baermann funnel method, and soil invertebrates by sampling by soil excavation. Yield was determined by the continuous plot method, taking into account moisture and weediness.

Studies were conducted on the treatment variants MP, SP and ST on the nutrition background of F0, S, SNPK and NPK. Examination of crops, soil sampling was carried out at the beginning and the end of the vegetation period. It is known that this soil is characterized by temporary excess moisture. The average soil moisture during the growing season was 20-22%.

On average in April 2019 air temperature was 4-6 °C, which is 1-2 °C above the climatic norm. In May the weather was warm and hot on some days. The amount of precipitation in

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April and May was below the norm. The summer of 2019 was predominantly cool and wet. A total of 370 mm of precipitation fell during the growing season, which was in line with the average annual data. The sum of active average daily air temperatures above 10 °C was 1910°, which was 210° greater than the long-term average.

In 2020, on average in April and May air temperatures were 1 °C below the long-term average. Precipitation in April reached half of the norm, in May - exceeded it 1.5-2.0 times. The period of active vegetation was 139-143 days, while the average long-term duration was 120-131 days. The total amount of precipitation during the growing season of 2020 was 405 mm, i.e. 110% of the average multiyear amount. The sum of active air temperatures above 10°C was 1980°C, which is 135°C more than the long-term average.

In 2021 the average April air temperature exceeded the climatic norm by 2-3 °C, reaching 5-7 °C. In May it was also higher than the norm by 2.0-2.5 °C. The summer was warm and unevenly humid. Mean daily active air temperatures above 10°C during the growing season were 2000°C, 280°C above the long-term average. During the growing season 2021 there was 400 mm of precipitation (the level of the climatic norm). Thus, despite some deviations in precipitation and temperature from the long-term average, climatic conditions for growth and development of field crops were favorable.

RESULTS AND DISCUSSION

In 2019, the following representatives of soil fauna were found in the crops of perennial grasses of the 1st year of use: ant (Formicidae), earthworm (*Lumbricina*), ground beetle (Carabidae), millipede (*Myriapoda*), ladybug larva (Coccinellidae), cutworm (*Agrotis segetum*).

Rainworms were mainly represented by such species as *Aporrectodea caligniosa*, one of the most common on agricultural lands. Various species of beetles, such as *Pterostichus melanarius, Poecilus cupreus, Broscus cephalotes*, and *Harpalus latus*, were found on sod-podzolic gleyic soil. All of them are predators, feeding on insects, crustaceans, and other invertebrates. In the variant with the system of surface-mouldboard tillage (SP), when straw was applied together with NPK, it seems that more favorable conditions for plants were formed, and food sources for these beetle species were in sufficient quantity. Polypods were found among millipedes which eat plant remains and serve as food sources for the same beetles. Of ladybugs (Coccinellidae), the most common predator species, *Coccinella septempunctata* was registered.

On average by factors, the use of the studied tillage systems did not cause any significant changes in the number of fauna in the crop of perennial grasses of the 1st year of use in the soil layer 0-10 cm (see Table 1).

Application of surface-mouldboard tillage (SP) caused a significant increase in the number of ground beetles by 2.61 individuals/m^2. The application of straw as an organic fertilizer together with the full rate of mineral fertilizers contributed to a significant increase in ants, earthworms and ground beetles in the layer 0-10 cm by 8.59; 10.16 and 4.69 individuals/ m^2, respectively.

The use of an organic-mineral fertilizer system (SNPK) caused a statistically significant increase in the number of ladybug larvae in the 10-20 cm layer - 2 times more than the control.

In 2020, the following representatives of soil fauna were found in the upper part of the arable horizon of perennial grasses: ant, earthworm, beetle, and nematode (see Table 2).

Application of the studied tillage systems did not cause any noticeable changes in the number of ants and earthworms with the highest values in the case of surface-mouldboard tillage (SP) - 30.56 and 41.52 individuals/m^2, respectively. On average by factors, the use of the SP variant led to an increase in the number of ground beetles in the soil layer 0-10 cm from 29.33 ex/m^2 on the control to 36.78 ex/m^2. On average for the fertilizer systems with surface-mouldboard tillage (SP) there was a statistically significant decrease in the number of nematodes in the upper part of the arable horizon - by 3.89 ind./100 g of soil.

Application of all fertilizer systems under consideration led to a statistically significant increase in the number of nematodes with the lowest value in the variant with straw and total mineral fertilizer (SNPK) - 33.33 ind. /100 g of soil in the upper part of the arable horizon.

Earthworms and nematodes were found in the 10-20 cm layer. Application of the system of surface-mouldboard tillage (SP) on average by factors contributed to a significant increase in the number of earthworms.

The opposite trend was observed in the study of nematode abundance: the same variant of treatment showed the lowest value - 35 ind. /100 g of soil.

On average by factors, the use of straw and a complete norm of mineral fertilizers (SNPK) led to a significant increase in the population of earthworms from 29.60 ind/m^2 on the control to 40.45 ind/m^2.

Application of NPK fertilizers caused a statistically significant increase in the number of nematodes in the lower part of the arable horizon by 20 specimens/100 g of soil.

In 2021, the following representatives of soil fauna were found in spring wheat crops: ground beetle (Carabidae), leaf beetle (*Oulema*), ladybug larva (Coccinellidae), earthworm (*Lumbricina*), and nematode (*Nematoda*). Leef beetles were represented by one species, *Oulema melanopus*. Application of the studied tillage systems did not cause any noticeable changes in the number of the above insects with the highest values for the system of surface-mouldboard tillage (SP) on both layers of the arable horizon (see Table 3).

Табл. 1. Численность фауны почвы в посеве многолетних трав 1-го года пользования, экз./м^2
Table 1. The number of soil fauna in the crops of perennial grasses of the 1st year of use, ind./m^2

Option	Soil layer, cm	Ant (Formicidae)	Earthworm (*Lumbricina*)	Ground beetle (Carabidae)	Millipede (*Myriapoda*)	Ladybug larva (Coccinellidae)	Cutworm (*Agrotis segetum*)
Factor A. Basic soil tillage system							
MP	0–10	25,00	26,04	25,00	32,29	27,08	29,17
	10–20	25,00	26,04	25,52	30,73	26,04	30,21
SP	0–10	29,17	27,60	28,13	26,56	27,08	26,56
	10–20	29,69	31,25	28,13	26,04	33,85	25,00
ST	0–10	25,00	27,08	25,00	30,73	25,00	29,17
	10–20	26,56	28,65	25,00	32,29	25,00	31,25
LSD_{05}	0–10	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$
	10–20	$F_ф < F_{05}$	$F_ф < F_{05}$	2,22	$F_ф < F_{05}$	5,28	$F_ф < F_{05}$
Factor B. Fertilizer system							
F_0	0–10	25,00	25,78	25,00	26,56	25,00	31,25
	10–20	25,00	25,00	25,00	29,69	25,00	31,25
S	0–10	25,00	25,78	25,00	34,38	26,56	28,91
	10–20	26,56	25,00	26,56	30,47	25,00	31,25
SNPK	0–10	33,59	35,94	29,69	25,00	28,13	28,13
	10–20	33,59	41,41	29,69	26,56	50,00	25,00
NPK	0–10	25,00	25,00	25,00	32,03	25,00	27,34
	10–20	25,00	25,00	25,00	35,16	25,00	31,25
LSD_{05}	0–10	4,48	6,00	3,43	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$

Табл. 2. Численность фауны почвы в посеве многолетних трав 2-го года пользования
Table 2. The number of soil fauna in the crops of perennial grasses of the 2nd year of use

Option	Soil layer, cm	Ant (Formicidae), ind./ m^2	Earthworm (*Lumbricina*), ind./m^2	Ground beetle (Carabidae), ind./m^2	Nematode (*Nematoda*), ind. / 100 g of soil
Factor A. Basic soil tillage system					
MP	0–10	26,15	33,09	29,33	40,56
	10–20	–	30,04	–	41,67
SP	0–10	30,56	41,52	36,78	36,67
	10–20	–	38,55	–	35,00
ST	0–10	28,22	36,94	29,71	40,56
	10–20	–	31,16	–	48,33
LSD_{05}	0–10	$F_ф < F_{05}$	$F_ф < F_{05}$	3,51	3,33
	10–20	–	5,27	–	$F_ф < F_{05}$
Factor B. Fertilizer system					
F_0	0–10	25,00	29,60	31,64	53,33
	10–20	–	29,60	–	38,89
S	0–10	26,15	35,70	28,45	34,44
	10–20	–	33,40	–	38,89
SNPK	0–10	26,15	41,91	39,63	33,33
	10–20	–	40,45	–	32,22
NPK	0–10	33,33	39,46	29,60	40,00
	10–20	–	31,64	–	58,89
LSD_{05}	0–10	$F_ф < F_{05}$	7,40	5,52	9,75
	10–20	–	6,96	–	13,84

On average for the fertilizer systems the SP variant treatment caused statistically significant decrease in the number of nematodes in the 10-20 cm layer by 2.96 nematodes/100 g of soil. In the upper part of the arable horizon similar dynamics was traced, but the differences were insignificant. The minimum value was observed at surface-mouldboard tillage (SP) in the layer 10-20 cm - 10,21 ind./100 g of soil.

On average by factors, the use of straw together with full norm of mineral fertilizers (SNPK) provided a significant increase in the soil layer 0-10 cm of ground beetles and earthworms - by 15.28 and 7.32 individuals/m^2, respectively. A similar trend was observed when analyzing the number of ladybug larvae. But here reliable changes were observed in both layers of the arable horizon.

On average by factors, the use of all the studied fertilizer systems led to a decrease in the number of nematodes in both soil layers. In the upper part of the arable horizon there was a significant decrease in the above indicator when using as a fertilizer full rate of NPK, both alone and together with straw, with a minimum value for the background "Straw + NPK" 10.36 ex./100 g of soil. In the layer 10-20 cm, the same trends persisted, but the differences were not significant.

On average by fertilizer systems, the application of annual surface tillage (ST) caused a significant reduction in grain yield of spring wheat by 3.96 c/ha (see Table 4).

In 2019, the use of straw together with the full rate of mineral fertilizers increased the yield of perennial grasses of the 1st year of use

Табл. 3. Численность фауны почвы в посеве яровой пшеницы
Table 3. The number of soil fauna in spring wheat crops

Option	Soil layer, cm	Ground beetle (Carabidae), ind./m²	Leaf beetle (*Oulema*), ind./m²	Ladybug larva (Coccinellidae), ind./m²	Earthworm (*Lumbricina*), ind./m²	Nematode (*Nematoda*), ind. / 100 g of soil
Factor A. Basic soil tillage system						
MP	0–10	30,21	35,24	36,46	34,38	12,06
	10–20	28,13	37,50	36,46	38,54	13,17
SP	0–10	34,38	35,85	38,54	41,67	11,51
	10–20	33,33	38,36	39,58	43,75	10,21
ST	0–10	29,17	35,42	37,50	35,57	12,50
	10–20	30,21	35,42	35,42	37,65	11,50
LSD_{05}	0–10	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$
	10–20	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$	$F_ф < F_{05}$	1,00
Factor B. Fertilizer system						
F_0	0–10	27,78	34,72	33,33	34,35	13,31
	10–20	27,78	36,69	36,11	36,69	13,05
S	0–10	27,78	34,72	33,33	39,46	12,58
	10–20	26,39	36,69	33,33	39,91	11,67
SNPK	0–10	43,06	38,08	50,00	41,67	10,36
	10–20	43,06	40,28	47,22	43,06	10,72
NPK	0–10	26,39	34,48	33,33	33,33	11,72
	10–20	25,00	34,72	31,94	40,28	11,08
LSD_{05}	0–10	7,29	$F_ф < F_{05}$	4,61	4,12	1,31
	10–20	$F_ф < F_{05}$	$F_ф < F_{05}$	11,48	$F_ф < F_{05}$	$F_ф < F_{05}$

by 63.06 c/ha. In 2020, the same picture was observed on the grasses of the 2nd year of use, but the differences were insignificant. In 2021 application of all the studied systems of fertilizers contributed to statistically significant increase in the yield of spring wheat with the maximum value for the background "Straw + NPK" 23.64 c/ha.

The following representatives of geobionts were found in the soil of the experimental field during the whole period of research: earthworm, millipede, nematode; geophiles: cutworm caterpillar, ladybug; geoxenes: ground beetle, ant, leef beetle.

It is established that the reduction of mechanical impact on the soil favors the development of soil fauna. An increase in the amount of organic matter in the soil contributes to an increase in the number of useful pedofauna.

Табл. 4. Влияние различных систем обработки почвы и удобрений на урожайность полевых культур, ц/га
Table 4. Influence of various tillage and fertilizer systems on the yield of field crops, c/ha

Option	Perennial grasses of the 1st year of use (2019)	Perennial grasses of the 2nd year of use (2020)	Spring wheat (2021)
Factor A. Basic soil tillage system			
MP	366,68	197,50	22,37
SP	365,93	176,53	21,87
ST	329,78	217,25	18,41
LSD_{05}	$F_ф < F_{05}$	$F_ф < F_{05}$	2,96
Factor B. Fertilizer system			
F_0	332,37	192,10	17,10
S	331,70	169,00	21,56
SNPK	395,43	213,77	23,64
NPK	357,00	213,50	21,22
LSD_{05}	30,10	$F_ф < F_{05}$	3,18

CONCLUSION

On sod-podzolic gleyic medium-loam soil it is recommended to use the system of surface-mouldboard tillage (SP) with the application of straw together with full norm of mineral fertilizers (SNPK) as the basic one. These agricultural practices help to increase the number of earthworms, ladybugs and ground beetles, reduce the number of nematodes, as well as obtain high yields of crops.

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ПРИЕМЫ ВОЗДЕЛЫВАНИЯ ЯЧМЕНЯ В УСЛОВИЯХ ЛЕСОСТЕПИ СРЕДНЕГО ПОВОЛЖЬЯ

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Представлены результаты изучения влияния различных предшественников и минеральных удобрений на урожайность ячменя в условиях черноземных почв Ульяновской области. Исследования проводили в рамках стационарного полевого опыта в 2017–2019 гг. Почвенный участок представлен выщелоченным среднемощным черноземом, имеющим следующие характеристики: содержание гумуса – 6,22%, подвижного фосфора и калия – 198,0 и 121,0 мг/кг соответственно, $pH_{сол}$ – 6,4, сумма оснований – 46,4 мг-экв./100 г. Схема опыта предусматривала анализ влияния предшествующих культур при выращивании ячменя на фоне комплексного минерального удобрения (NPK). Установлено, что запасы продуктивной влаги в метровом слое почвы выше на удобренных вариантах (155,4–166,0 мм). Концентрация нитратного азота была выше по предшественнику горох и при использовании NPK – 53,0 мг/кг почвы. Наибольшая биологическая активность почвы наблюдалась по предшественнику горох на фоне NPK – 33,3%. Наименьшее количество сорняков в посевах отмечалось по предшественнику гречиха как на фоне удобрений, так и без них (20,7–25,7 шт./м^2). Урожайность ячменя с наилучшими качественными показателями была выше по предшественнику горох на фоне NPK – 3,55 т/га. Наибольший чистый доход получен на удобренных вариантах: 7174–7212 р./га, рентабельность 40,2–40,5%.

Ключевые слова: продуктивная влага, нитратный азот, предшественник, урожайность, эффективность

BARLEY CULTIVATION PRACTICES IN THE FOREST-STEPPE CONDITIONS OF THE MIDDLE VOLGA REGION

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The results of studying the effect of different forecrops and mineral fertilizers on the yield of barley in the conditions of chernozem soils of the Ulyanovsk region are presented. The research was carried out as part of a stationary field experiment in 2017-2019. The soil area is represented by leached medium-sized chernozem with the following characteristics: humus content - 6.22%, mobile phosphorus and potassium - 198.0 and 121.0 mg/kg, respectively, pH_{sol} - 6.4, the sum of bases - 46.4 mg-eq./100 g. The scheme of the experiment provided for the analysis of the influence of previous crops when growing barley against the background of complex mineral fertilizer (NPK). It was found that the reserves of productive moisture in the meter layer of soil are higher on fertilized variants (155.4-166.0 mm). The concentration of nitrate nitrogen was higher in the pea forecrop and when using NPK - 53.0 mg/kg of soil. The greatest biological activity of the soil was observed for the forecrop peas against the background of NPK - 33.3%. The smallest number of weeds in crops was noted for the forecrop buckwheat both on the background of fertilizers and without them (20.7-25.7 pcs/m^2). The yield of barley with the best quality indicators was higher than the forecrop peas against the background of NPK - 3.55 t/ha. The largest net income was received on fertilized variants: 7174-7212 rubles/ha, profitability 40.2-40.5%.

Keywords: productive moisture, nitrate nitrogen, forecrop, yield, efficiency

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The author declares no conflict of interest.

INTRODUCTION

One of the main spring crops in our country is barley. It is grown as a food, fodder and industrial crop. In 2021 barley took 8189,0 thou. ha (10,2%) of all sown area of cereals and leguminous plants in Russia (79 935,9 thous. ha). Of the total sown area of cereal crops in the Ulyanovsk region (1073.0 thous. ha) barley is grown on 151.8 thousand ha (14.1%). In the Middle Volga region, characterized by favorable climatic conditions, it is possible to obtain quality barley up to 6-7 t/ha. But grain production in the region does not fully meet the existing requirements in terms of both volume and quality. At the same time the potential of soils and plants is poorly used. For modern farming systems it is important to develop and implement measures to restore soil fertility and increase the productivity of crop rotations from 1 hectare, which do not require large financial investments. It is, first of all, increase of biodiversity of crops in crop rotations and application of optimal doses of mineral fertilizers [1, 2] [1, 2].

In this regard, there is a need to determine the degree of influence of the forecrops and different doses of mineral fertilizers on the productivity of crops in crop rotations with the prospect of reducing energy and resource costs in agriculture.

The purpose of the study was to analyze the effect of the forecrops and fertilizers on the main parameters of soil fertility and barley yields in the forest-steppe zone of the Middle Volga region.

Objectives:

1) determine the effect of the forecrops and fertilizers on agrophysical, agrochemical and biological properties of the arable layer and yields;

2) determine the degree of influence of the forecrops and fertilizers on the phytosanitary status of crops;

3) calculate the economic efficiency of cultivation depending on the forecrops and fertilizers.

MATERIAL AND METHODS

The works were carried out in the experimental fields of the department of agriculture of the Ulyanovsk Research Institute of Agriculture n.a. N.S. Nemtsev in 2017-2019.

The object of research was barley (*Hordeum sativa* L.) of the Odessa 100 variety with seeding of 4.5 million pcs/ha. Potatoes, peas and buckwheat were used as the forecrops. Crop rotations were deployed in time and space (see Table 1).

The area of the experimental plot was 9.2 ha, one field - 9456 m^2 (236.4 × 40.0 m), working plot - 1200 m^2 (40.0 × 30.0 m), registration plot -120 m^2 (4.0 × 30.0 m). Repeatability was three times. Plot placement is systematic.

Табл. 1. Схема опыта
Table 1. Scheme of the experiment

Option	Forecrop		
No fertilizer	Potato	Peas	Buckwheat
$N_{56}P_{16}K_{16}$	»	»	»

[1] URL: https://uln.gks.ru/storage/mediabank/Посевные%20площади%20под%20урожай%202021%20года.pdf.
[2] URL: https://www.nsss-russia.ru/wp-content/uploads/2022/01/1.-Nekrasov-Minselhoz-VAS_27.01.2022.pdf.

The soil plot is leached medium medium-loamy chernozem with the following agrochemical characteristics: pH_{salt} - 6.4; total absorbed bases - 46.4 mg equivalent/100 g; humus content - 6.22% (by Tyurin); labile P_2O_5 - 198 mg/kg, labile K_2O - 121 mg/kg (by Chirikov).

NPK was applied in parts: under straw and crop residues - ammonium nitrate at a compensatory dose of 10 kg p.n./ha; under cultivation - N_{30}; during sowing - $N_{16}P_{16}K_{16}$. For fertilizer application, AMAZONE spreader and SZ-3,6 seeder were used.

After stubble cleaning at optimal time, plowing was carried out with plough PN-4,35 to a depth of 23-25 cm. Harrowing was carried out with heavy harrow BZTS-1,0 in two tracks, pre-sowing cultivation - with a cultivator KPS-4,0 to a depth of 5-6 cm. Sowing was carried out in the first ten-day period of May.

In the tests Balerina herbicide was used at a dose of 0.5 l/ha together with Mortira at a concentration of 15.0 g/l, Kolosal Pro fungicide at a dose of 0.3 l/ha, and Borey insecticide at a concentration of 0.1 l/ha. All preparations were applied in the tillering phase in a tank mixture by MTZ-82 + OP-1200. Harvesting was carried out by direct harvester Yenisey 950.

Grain was cleaned to 100% purity and 14% moisture content (GOST 27548-97). Statistical evaluation was performed according to B.A. Dospekhov[3].

To determine the intensity of biological processes occurring in the soil the method of linen decomposition was used, because it is very clear and it can be used to judge the activity of bacteria, under the action of which the decomposition of organic matter takes place.

Direct costs (wages with accruals for tractor drivers, fuel cost, current repairs, depreciation charges, herbicides, NPK) were calculated according to the accepted normative documents of the Institute. Yield indicators were used as an average for 2017-2019. Calculations were made on the basis of flow charts.

Weather conditions in the years of the study were different. The most favorable in the growing season was 2017: HTC = 1.4, exceeding the norm in precipitation in April - September by 29.0%. Conditions in 2018 were unfavorable: HTC = 0.5, May and June drought and overwatering in August. Conditions in 2019 were close to average annual norms, HTC = 1.1.

RESULTS AND DISCUSSION

The increase in the density in the arable layer of soil compared with the optimum can lead to a decrease in the yield of grain crops. If it is within the optimal values, it has no significant effect on their productivity [3].

Analysis of the density of the soil on barley forecrops in the period of reaching the equilibrium state showed that it was in the optimal range for the growth and development of plants. Thus, during the experiments the density was at the level of 1.10- 1.15 g/cm^3 (see Table 2).

The loosest soil structure was observed in buckwheat and pea (1.10-1.11 g/cm^3), the densest (1.15 g/cm^3) - in row crops. Nevertheless, soil density remained favorable for growth and development of barley.

The provision of agricultural crops with moisture depends on their rotation in crop rotations, cultivation technology, amount and distribution of precipitation, mechanical and physical composition of the soil [4].

Our research showed that spring moisture reserves were accumulated mainly due to winter precipitation, where there was no significant difference between the forecrops on the background of natural fertility (145.5-150.7 mm with LSD = 6.4). Good moisture supply was noted after application of $N_{56}P_{16}K_{16}$ and the use of buckwheat as a forecrop - 166,0 mm, which was 15,3 mm higher than for the nonfertilized background; for the forecrop potatoes and peas this difference was 12,2 and 7,7 mm respectively.

By the period of harvesting the reserves of productive moisture on all the studied crops on the variants without fertilizers decreased by

[3]*Dospekhov B.A.* Methodology of field experience (with the basics of statistical processing of research results). Moscow: Book on Demand, 2012. 352 p.

Табл. 2. Влияние предшественников и удобрений на агрофизические свойства почвы (в среднем за 2017–2019 гг.)

Table 2. The effect of the forecrops and fertilizers on the agrophysical properties of the soil (on average for 2017-2019)

Forecrop	Soil density (0-30 cm layer), g/cm^3	Productive moisture reserves (0-10 cm layer), mm			
		Tillering		Full ripeness	
		No fertilizer	$N_{56}P_{16}K_{16}$	No fertilizer	$N_{56}P_{16}K_{16}$
Potato	1,15	145,50	157,70	65,00	46,10
Peas	1,11	147,70	155,40	69,30	51,60
Buckwheat	1,10	150,70	166,00	71,20	45,30
LSD_{05}	0,03	6,40	10,80	9,60	9,20

52,8-55,3%, on the background of $N_{56}P_{16}K_{16}$ - by 66,8-72,7%. This is due to the fact that by the phase of full ripeness barley plants growing on the fertilized plots became more powerful compared to the variants without fertilizers, so they took more moisture from the soil to form the harvest.

To harvest high yields of good quality grain it is necessary to obtain and maintain complete sprouts. The conducted studies showed that field germination in the phase of full sprouts for all the forecrops on the variants without fertilizers was not high and was in the range of 77,578,0%, or 349-351 pcs./m^2 (see Table 3).

This indicator was higher on fertilized plots and amounted to 83.3-84.8% (375-382 pcs/m^2).

Different forecrops had no significant effect on the safety of barley plants. This indicator was almost the same in all the variants - 68,8-70,9% (240-248 pcs/m^2). As a result of the application of fertilizers the density of plants before harvesting was higher and varied from 310 to 322 pcs/m^2. Preservation of barley plants by the time of harvest was 82.6-84.3% with some increase for peas.

The provision of available nutrients is one of the basic principles of effective fertility, and the systematic process of their formation and accumulation is an important criterion for sustainable yields [4, 5] [5].

The study found that the content of nitrate nitrogen in the soil was in the range of 36.4-53.0 mg/kg, with most of the pea field both on the background of natural fertility and after fertilization (see Table 4).

The content of mobile phosphorus on the plots without fertilizers on all the forecrops reached 185-198 mg/kg of soil, on the variants

Табл. 3. Полевая всхожесть, сохранность и густота стояния растений (в среднем за 2017–2019 гг.)

Table 3. Field germination and preservation of plants (on average for 2017-2019)

Forecrop	Density of crop (full sprouting phase), pcs./m^2		Field germination, %		Density of crop before harvesting, pcs./m^2		Viability %	
	No fertilizer	$N_{56}P_{16}K_{16}$	No fertilizer	$N_{56}P_{16}K_{16}$	No fertilizer	$N_{56}P_{16}K_{16}$	No fertilizer	$N_{56}P_{16}K_{16}$
Potato	349,0	375,0	77,5	83,3	240,0	310,0	68,8	82,6
Peas	350,0	382,0	77,7	84,8	248,0	322,0	70,9	84,3
Buckwheat	351,0	380,0	78,0	84,4	243,0	315,0	69,2	82,9
LSD_{05}	8,2	9,4			12,1	$F_ф < F_{05}$		

[4] *Tikhonov N.I.* Effect of the forecrop, sowing date and variety on the yield and brewing quality of spring barley grain // Izvestia of the Lower Volga Agro-University Complex: science and higher professional education. 2007. N 4 (8). pp. 13-19.

[5] *Kulikova A.Kh., Nikitin S.N., Toigildin A.L.* Biopreparations in the Spring Wheat Fertilization System // Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2017. Vol. 8. N 1. pp. 1796–1800.

with fertilizers it was higher and amounted to 194-204 mg/kg, but there was no significant difference between the variants.

The proportion of potassium in the variants without fertilizers ranged from 64 to 91 mg/kg of soil, with the greatest amount noted for the forecrop buckwheat. As a result of fertilization its concentration in the soil increased to 78-97 mg/kg. The largest increase compared to the variant without fertilizer was 22 mg/kg of soil for the forecrop pea.

Nitrogen content in the phase of barley full maturity in the variants without fertilizers decreased by 13.5-42.8% and reached 27.1-31.5 mg/kg of soil. Its preservation was higher in buckwheat, on fertilized variants - in pea (32.2-37.6 mg/kg soil).

The concentration of phosphorus decreased by 20,1-34,8%, potassium - by 9,4-29,7% and was 129-155 and 58-77 mg/kg respectively. At the same time, conservation was higher on the fertilized variants for the pea forecrop, although there were no significant differences between the variants.

Soil is a complex multi-component system, it cannot be considered in isolation from the vital activity of living organisms, so the energy of decomposition of fiber is used to judge its quality and abundance of microflora[6] [6].

Analysis of soil biological activity showed that it was unequal for all the forecrops on the background without fertilizers (from 28.2 to 32.0%), and significantly higher - for peas (see Table 5).

On fertilized plots, soil biological activity increased by 1.3-3.7% and amounted to 31.5-33.3%, where the highest activity was recorded for peas. At sowing on potatoes and buckwheat the biological activity of soil decreased by 1,4 and 1,8% respectively, and mathematical processing showed reliable differences between them.

In the case of permanent cultivation of cereals or improper alternation of crops in the rotation there is an increase in weed infestation by almost all types of weeds. Weed control is one of the most important tasks affecting the yield and economic efficiency[7] [7].

It was found that in the structure of barley agrophytocenosis both minor and perennial weeds prevailed. On average for the 3 years of research the lowest infestation was noted in the variants without fertilizers for buckwheat forecrop (20,7 pcs./m^2), after fertilizing it increased by 24,1% and amounted to 25,7 pcs./m^2 (see Table 6).

Табл. 4. Содержание основных питательных элементов в пахотном слое почвы под ячменем (2017–2019 гг.), мг/кг почвы

Table 4. The content of the main nutrients in the arable soil layer under barley (2017-2019), mg/kg of soil

Forecrop	Tillering			Full ripeness		
	$N\text{-}NO_3$	P_2O_5	K_2O	$N\text{-}NO_3$	P_2O_5	K_2O
Potato	44,9 / 45,7	198,0 / 201,0	64,0 / 78,0	27,1 / 32,2	129,0 / 153,0	58,0 / 66,0
Peas	51,6 / 53,0	185,0 / 194,0	75,0 / 97,0	29,5 / 37,6	129,0 / 155,0	62,0 / 77,0
Buckwheat	36,4 / 38,7	197,0 / 204,0	91,0 / 93,0	31,5 / 32,5	132,0 / 154,0	64,0 / 75,0
LSD_{05}	5,2 / 6,7	$F_ф < F_{05}$ / $F_ф < F_{05}$	$F_ф < F_{05}$ / $F_ф < F_{05}$	5,4 / 6,4	4,5 / 3,6	$F_ф < F_{05}$ / $F_ф < F_{05}$

Note. Numerator - variants without fertilizer, denominator - after fertilizer application $N_{56}P_{16}K_{16}$.

[6] *Irmulatov B.R., Sarbasov A.K., Mustafayev B.A.* Influence of the forecrops and technology in the regulation of the mode of application of nutrients // Agrarian Science. 2017. N 4. pp. 2-5.

[7] *Evdokimova M.A.* Influence of the forecrops and mineral fertilizers on the yield of spring barley // Vestnik of Ulyanovsk state agricultural academy. 2015. N 1 (29). pp. 11-14.

Табл. 5. Влияние предшественников и удобрений на биологическую активность почвы (2017–2019 гг.), %

Table 5. The effect of the forecrops and fertilizers on the biological activity of the soil (2017-2019), %

Forecrop	No fertilizer	$N_{56}P_{16}K_{16}$
Potato	28,2	31,9
Peas	32,0	33,3
Buckwheat	29,7	31,5
LSD_{05}	2,1	1,2

In the variants without fertilizers and with fertilizers weed infestation by minor and perennial weeds in the forecrops potatoes and peas increased by 1.5-1.8 times compared with buckwheat. The considered indicators exceeded the economic threshold of harmfulness, especially for perennial suckering weeds (4-8 times and more). Therefore, it became necessary to control the weeds by chemical means.

In 30 days after the use of herbicides the number of annual and perennial weeds in the forecrops decreased in the variants without fertilizers by 86-91 and 65-84%, respectively, and in the variants with fertilizers - by 88-89 and 74-88% respectively.

A large number of studies have established that the rational placement of spring crops on favorable forecrops in crop rotations with the use of optimal doses of mineral fertilizers can increase crop productivity and maintain soil fertility[8] [8].

The highest barley yield in the average for 3 years was obtained for the forecrop peas on the background of $N_{56}P_{16}K_{16}$ - 3,55 t/ha; the increase was 0,40 t/ha (112,7%) compared with the variant without fertilizers (see Table 7). This variant had the highest payback of 1 kg of fertilizer with an increase of 4.54 kg of grain.

The barley yield in the variants without fertilizers and with buckwheat forecrop was 3,12 t/ha, the yield increased by 0,31 t/ha (109,9%) after application of the fertilizer with the dose of $N_{56}P_{16}K_{16}$. Recoupment of 1 kg of fertilizer by grain gain was 3.52 kg.

At barley cultivation on potatoes the yield on the background of natural fertility was fixed within 3,10 t/ha, in the variant with fertilizers - 3,38 t/ha. In this case the gain was 0,28 t/ha (109,0%), there was no significant difference between the forecrop buckwheat and peas. Fractional application of 1 kg of fertilizers gave an increase of barley grain on the forecrop potato by 3.18 kg.

Табл. 6. Засоренность посевов ячменя (2017–2019 гг.), шт./м^2

Table 6. Infestation of barley crops (2017-2019), pcs/m^2

Forecrop	Before herbicide treatment			30 days after the treatment			Biological effectiveness of herbicides, %		
	Biennials	Perennials	Total	Biennials	Perennials	Total	Biennials	Perennials	Total
No fertilizer									
Potato	22,3	16,5	38,8	3,0	4,5	3,5	86,0	72,0	91,0
Peas	11,3	11,0	22,3	1,0	3,8	6,8	91,0	65,0	69,0
Buckwheat	11,5	9,2	20,7	1,3	1,5	2,8	88,0	84,0	86,0
LSD_{05}	2,5	4,7		0,8	0,7				
$N_{56}P_{16}K_{16}$									
Potato	22,5	17,2	39,7	2,7	2,5	5,2	88,0	85,0	85,0
Peas	20,2	14,8	35,0	2,3	3,8	6,1	89,0	74,0	83,0
Buckwheat	15,2	10,5	25,7	1,8	1,2	3,0	88,0	88,0	87,0
LSD_{05}	2,0	2,1		$F_ф < F_{05}$	$F_ф < F_{05}$				

[8] *Ermakov V.V., Dubovik D.V.* Effect of mineral fertilizers and predecessors on grain quality of winter wheat depending on the exposure of the slope // Agricultural Chemistry. 2005. N 4. pp. 16-21.

Barley occupies a significant place in the grain balance of the Ulyanovsk region, accounting for about 14% of the total volume. It accounts for about 20% of the produced grain. It is used to produce peeled barley and pearl barley groats; it is used for baking in mixture with wheat and rye. Barley grain contains a sufficient amount of protein and is an excellent concentrated feed[9] [9].

As a result of the studies, it was found that the use of mineral fertilizers increased the raw protein content by 2,0-2,3%, the weight of 1 thousand grains increased by 2,1-3,0 g (5,0-7,0%) compared with the unfertilized variant (see Table 8).

The highest quality indicators of barley grain were obtained for the forecrop peas on the background of mineral fertilizers.

Cultivation of crops on the best forecrops in different crop rotations with the use of fertilizers is an important reserve for increasing yields at the lowest cost[10] [10, 11].

Economic analysis showed that production costs for all the studied forecrops were the lowest in the variants without fertilizers - 14,251-14,285 p./ha (see Table 9).

The use of mineral fertilizers at a dose of $N_{56}P_{16}K_{16}$ increased the cost by 24.8%, the cost of production - by 0.52-18.2%. When fertilizers were applied at a dose of $N_{56}P_{16}K_{16}$ the highest net income was obtained - 7174-7212 p./ha, which is 2.6 times higher compared to the unfertilized variant. At the same time, the profitability was practically identical for all the forecrops and ranged from 40.2 to 40.5%.

Thus, to increase crop productivity and improve barley plant nutrition it is recommended its cultivation after legumes (peas) with fractional fertilization at a dose of $N_{56}P_{16}K_{16}$, which contributes to the efficiency and competitiveness of grain production in the current market circumstances.

Табл. 7. Урожайность ячменя в зависимости от предшественников и удобрений (2017–2019 гг.), т/га
Table 7. Barley yield depending on the forecrops and fertilizers (2017-2019), t/ha

Forecrop	Option		Increase from the use of fertilizers		Payback of 1 kg of fertilizer by grain gain, kg
	No fertilizer	$N_{56}P_{16}K_{16}$	t/ha	%	
Potato	3,10	3,38	0,28	109,00	3,18
Peas	3,15	3,55	0,40	112,70	4,54
Buckwheat	3,12	3,43	0,31	109,90	3,52
LSD_{05}	A – 0,085; B – 0,051; AB – 0,076; P – 2,54%				

Табл. 8. Качественные показатели зерна ячменя в зависимости от предшественников и удобрений (2017–2019 гг.)
Table 8. Qualitative indicators of barley grain depending on the forecrops and fertilizers (2017-2019)

Forecrop	No fertilizer		$N_{56}P_{16}K_{16}$	
	Weight of 1 thousand grains, g	Crude protein, %	Weight of 1 thousand grains, g	Crude protein, %
Potato	42,2	10,1	44,4	12,1
Peas	42,8	10,4	45,8	12,7
Buckwheat	42,4	10,2	44,5	12,3

[9] *Kashukoev M.V., Khokonova M.B.* Effect of barley precursors on the formation of brewing qualities of grain and malt // Vestnik of the Russian Agricultural Science. 2009. N 5. pp. 49-50.
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Табл. 9. Экономическая эффективность возделывания ячменя в зависимости от предшественника и удобрений (2017–2019 гг.)

Table 9. Economic efficiency of barley cultivation depending on the forecrop and fertilizers (2017-2019)

Forecrop	Option	Production costs, rubles/ha	Cost of grain, rubles/t	Net income, rubles / ha	Crop yield, %
Potato	No fertilizer	14 251	4453	2749	19,3
	$N_{56}P_{16}K_{16}$	17 788	5263	7212	40,5
Peas	No fertilizer	14 285	4995	2715	19,0
	$N_{56}P_{16}K_{16}$	17 826	5021	7174	40,2
Buckwheat	No fertilizer	14 267	5169	2733	19,2
	$N_{56}P_{16}K_{16}$	17 799	5199	7201	40,5

CONCLUSIONS

1. When sowing barley with buckwheat and peas, the soil was looser (1.10-1.11 g/cm^3) compared with the cultivation on potatoes, when it was in a denser state (1.15 g/cm^3).

2. The largest reserves of productive moisture were observed against the background of $N_{56}P_{16}K_{16}$ and seeding on buckwheat - 166.0 mm, which is 15.3 mm higher than the unfertilized background. For potatoes and peas this difference was 12,2 and 7,7 mm respectively.

3. The largest decrease in moisture reserves by harvest time was observed on the fertilized variants for all crops - 66.8-72.7% compared to the unfertilized background.

4. The content of nitrate nitrogen was higher for the forecrop peas on the fertilized variants (53 mg/kg soil). The highest concentration of mobile phosphorus was recorded for all forecrops against the background of mineral fertilizers (194-204 mg/kg). The highest concentration of potassium was recorded for peas with 97 mg/kg of fertilizer, which added 22 mg/kg compared to the unfertilized variant.

5. The greatest biological activity of the soil manifested itself on the fertilized variants for the forecrop peas - 33.3%.

6. The lowest number of weeds was noted for the forecrop buckwheat in the variants without fertilizers - 20.7 units/m^2, on fertilized variants it increased by 24.1%. The use of herbicides reduced the number of annual and perennial weeds by 86,0-91,0 and 65-88% respectively.

7. The highest barley yield was obtained for peas on the background of mineral fertilizer at the dose of $N_{56}P_{16}K_{16}$ (3,55 t/ha). The increase in this case was 0.40 t/ha (112.7%) to the variant without fertilizers.

8. The highest content of crude protein in barley grain was recorded in the variants with the use of mineral fertilizers in the concentration of $N_{56}P_{16}K_{16}$ for the forecrop peas (12.7%). The weight of 1 thousand grains was increased by 3.0 g and amounted to 45.8 g compared to the unfertilized variant.

9. The variants without the use of fertilizers required the lowest costs - 14,251-14,285 rubles/ha. On the background of NPK they increased by 24.8%. The lowest cost of grain was noted in the variants without fertilizers - 4453-5169 rubles / t. At the background of N56P16K16 it rose by 0,52-18,2%. The highest income was obtained on the fertilized variants (7174-7212 rubles / ha), the profitability in this case was 40,2-40,5%.

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ЭФФЕКТИВНОСТЬ ПРИМЕНЕНИЯ МИКРОУДОБРЕНИЙ В ИНТЕНСИВНОЙ ТЕХНОЛОГИИ ВОЗДЕЛЫВАНИЯ ПОДСОЛНЕЧНИКА

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Рассмотрена эффективность применения некорневых подкормок подсолнечника микроудобрениями Боро-Н и Фертикс марка Б в условиях полевого опыта. Опыт проведен в 2020–2022 гг. на серых лесных почвах Брянской области. В качестве объекта исследований использован гибрид подсолнечника Факел. Предшественником в опыте были однолетние травы. Посев проводили пунктирным способом с шириной междурядий 70 см при норме высева 55 тыс. семян/га. Площадь опытной делянки 33 м^2, учетной – 5 м^2 при трехкратной повторности. Размещение делянок систематическое. Агротехника возделывания подсолнечника рассчитана на получение планируемой урожайности семян 3,5–4,5 т/га. Схема опыта включала три варианта обработки микроудобрениями Боро-Н (2,0 л/га) + Фертикс марка Б, ВР (2,0 л/га): без применения микроудобрений (контроль), одна обработка, две обработки. Установлено, что однократное применение некорневой подкормки баковой смесью микроудобрений Боро-Н + Фертикс марка Б в период формирования 6–10-го настоящего листа повышает урожайность семян подсолнечника на 7%, рентабельность их производства на 88%, условный чистый доход на 3,8 тыс. р./га. Двукратное применение этих микроудобрений в период формирования 6–10-го настоящего листа и в фазе конец бутонизации – начало цветения увеличила урожайность культуры на 12%, условный чистый доход на 4,8 тыс. р./га. Дополнительная обработка растений подсолнечника перед цветением, несмотря на снижение рентабельности производства семян на 30%, повышала урожайность культуры на 5%, условный чистый доход на 27%.

Ключевые слова: подсолнечник, микроудобрение, некорневая подкормка, урожайность, экономическая эффективность

EFFICIENCY OF MICROFERTILIZER APPLICATION IN INTENSIVE SUNFLOWER CULTIVATION TECHNOLOGY

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The efficiency of sunflower foliar top dressing application with Boro-N and Fertix mark B microfertilizers under field experimental condition was considered. The experiment was conducted in 2020-2022 on gray forest soils of the Bryansk region. Sunflower hybrid Fakel was used as an object of research. Annual grasses were the forecrop in the experiment. Seeding was carried out by the punctuated method with the width of inter-row space (70 cm) at a seeding rate of 55 thousand seeds/ha. The area of the experimental plot is 33 m^2, the area of the registration plot is 5 m^2 with threefold repetition. Plot placement is systematic. Sunflower farming technology is designed to produce a planned seed yield of 3.5-4.5 t/ha. The experimental scheme included three variants of treatment with microfertilizer Boro-N (2.0 l/ha) + Fertix mark B, BP (2.0 l/ha): without microfertilizer application (control); one treatment; two treatments. It was established that foliar dressing with a tank mixture of Boro-N + Fertix mark B fertilizers once a year during the period of 6-10 true leaves increases the sunflower seed yield by 7%, the profitability of sunflower production by 88%, and the conditional net income by 3.8 thousand rubles/ha. Double application of these microfertilizers during the formation of 6-10 true leaves and in the phase of the end of budding - the beginning of flowering increased the crop yield by 12%, the conditional net income by 4.8 thousand rubles / ha.

Additional treatment of sunflower plants before flowering, although reducing the profitability of seed production by 30%, increased the yield of the crop by 5%, conditional net income by 27%.

Keywords: sunflower, microfertilizer, foliar top dressing, yield, economic efficiency

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INTRODUCTION

The main amount of oil-bearing raw materials and up to 75% of all oil-bearing crops grown in the Russian Federation are oil sunflowers (*Helianthus annuus* L.). Sunflower is the main oil-bearing crop in the Russian Federation and the third in the world after soybeans and peanuts. Over 52% of sunflower seeds in the world are produced in two countries, Russia and the Ukraine [1-3].

In recent years, sunflower has been growing steadily in the structure of the cultivated area of crops in Russia and currently amounts to more than 9 million hectares [4]. This is due to the fact that in modern agricultural production conditions, sunflower is one of the high-margin crops (the profitability level reaches 430-680%), which makes it profitable for cultivation [5]. Sunflower oilseeds are one of the main components of the country's food security in terms of providing the population with the required vegetable oil and raw materials for the processing industry and livestock breeding[1] [6].

The Bryansk Region is a non-typical region for sunflower cultivation for oilseeds[2]. However, in recent years the area under the crop has been growing rapidly. In 2022, it was planted on more than 15,000 ha, and 40,400 tons of sunflower were threshed with an average yield of 2.7 t/ha [7, 8], although modern varieties and hybrids have a higher genetic potential (6.0-6.5 t/ha) [9].

Soil and agroclimatic conditions in the Bryansk region meet the basic biological requirements of the crop. The duration of the growing season of the early- maturing and early-ripe sunflower varieties and hybrids is 80-100 and 100-120 days, respectively, which allows them to be cultivated for seed in the central regions of Russia [10]. The breeders of the All-Russian Research Institute of Oil Crops have created sunflower varieties and hybrids of different ripeness groups with high productivity that are resistant to biotic and abiotic stressors [11]. In this regard, agricultural producers have an opportunity to select a wider range of sunflower varieties and hybrids adapted to the growing conditions for cultivation for seeds in more northern latitudes [12].

An important reserve for increasing sunflower yields along with the introduction of adaptive varieties and hybrids is to improve the elements of intensive agricultural technologies of the cultivated crop [13, 14]. Traditional sunflower cultivation technology

[1]*Kostenkova E.V., Bushnev A.S., Pashtetsky V.S.* Technological aspects of confectionary sunflower cultivation in arid conditions of the crimean peninsula // IOP Conference Series: Earth and Environmental Science: International Conference on World Technological Trends in Agribusiness. 2021. P. 012073.

[2]*Belous N.M., Vaskin V.F., Kuzmitskaya A.A., Kubyshkin A.V., Schmidt Y.I.* Dynamics of crop production and rational use of agricultural lands // IOP Conference Series: Earth and Environmental Science: VI International Scientific Conference on Advanced Agritechnologies, Environmental Engineeringand Sustainable Development – Chemical, Ecological, Oil-and-Gas Engineering and Natural Resources. 2022. P. 042009.

is based on the integrated use of high-yield seeds, optimization of water and nutrient regimes, and the implementation of integrated plant protection [15]. Many specialists argue that 50% of the yield potential of crops is achieved by introducing new varieties and hybrids, and 50% by improving their cultivation technology [16].

The most important role in the formation of yield and its chemical composition belongs to a balanced plant nutrition with macro- and microelements. In this regard, fertilization is the main method of regulating the content of humus and nutrients in the soil-plant system [17]. The proportion participation of fertilizers in the formation of crop yield in the Non-Black Soil Zone of the Russian Federation, according to various estimates, reaches 25-40% [18]. However, the issue of doses, timing and methods of their application remains relevant and is contradictory in a number of studies. In addition, depending on the ripeness group of the hybrid (variety), sunflowers show different responsiveness to fertilizers [5], and the event itself on the application of fertilizers is resource-intensive.

One of the ways of effective use of mineral fertilizers, which allows increasing the yield and improving its quality, as well as reducing the cost of material resources, is foliar fertilization. In recent years, micro-fertilizers have become increasingly widespread[3] [18, 19]. The macro- and microelements contained in their composition are not only a source of nutrition, but also contribute to the improvement of plant immunity, reduction of stress resistance from the used agrochemicals and adverse natural and climatic phenomena [20], enhance the development of the root system, assimilating apparatus, activate photosynthesis, increasing the yield and its quality [21]. Compensation of nutrient deficiencies by foliar application, especially during the critical phases of growth and development of the crop, is a necessary technique [20].

Evaluation of the effectiveness of foliar feeding on high-yield sunflower varieties and hybrids with high adaptive capacity for the conditions of the Bryansk region is urgent and of practical relevance.

The purpose of the study was to investigate the effect of foliar micro-fertilizers Boro-N and Fertix mark B on sunflower seed yield and economic efficiency indicators.

The research objectives are to:

– determine the dependence of sunflower seed yield on the frequency of foliar feeding;

– give an economic assessment of the use of foliar sunflower micro-fertilizers Boro-N and Fertix mark B.

MATERIAL AND METHODS

The studies were carried out in 2020-2022 on the experimental field of the Bryansk State Agrarian University (Bryansk Region). The soil of the experimental plot is gray forest light loamy strongly dusty, formed on carbonate loams, with a high content of humus (3.3%), close to the neutral reaction of the environment (pH_{salt} 5.7), with a very high content of mobile forms of phosphorus (26.5 mg/100 g soil) and potassium content (19.4 mg/100 g).

The object of the study is a sunflower hybrid Fakel. Agro-ecological tests of sunflower varieties and hybrids on the experimental field conducted in 2020-2022 showed that this hybrid is highly adapted to the conditions of the Bryansk region. On average, over the 3 years of research, its growing season was 110 days, plant height - 174 cm, weight of 1000 seeds - 65.7 g, huskiness - 29.5%, biological yield - 4.15 t / ha.

Annual grasses were used as a forecrop in the experiment. Seeding was carried out by the dotted method using SPCH-6 seeder with 70 cm row-spacing to a depth of 5 cm. The seed rate was 55 thousand seeds/ha.

The main fertilizer was $N_{120}P_{120}K_{120}$ for the planned yield of 3.5-4.5 t/ha. Azophoska (16 : 16 : 16) was used as this fertilizer, which

[3]*Nikiforov V.M., Nikiforov M.I., Chekin G.V., Silaev A.L., Smolsky E.V., Nechaev M.M.* Efficiency of multifunctional chelate complexes used during spring wheat cultivation // IOP Conference Series: Earth and Environmental Science: the proceedings of the conference AgroCON-2019. 2019. P. 012127.

was applied under pre-sowing cultivation at a depth of 5-7 cm.

The experimental scheme included three variants of treatment with micro-fertilizer Boro-N (2.0 l/ha) + Fertix mark B, BP (2.0 l/ha): without micro-fertilizer application (control), one treatment, two treatments.

The second variant used one foliar feeding with a tank mixture of micro-fertilizers during the formation of 6-10 true leaves, in the third - two: the first - during the formation of 6-10 true leaves; the second - in the phase of late budding - the beginning of flowering.

Micro-fertilizers used in the experiment have the following characteristics: Boro-N, WS - easily assimilable liquid concentrated fertilizer for foliar and root dressing for the prevention and treatment of boron deficiency conditions. It contains readily available boron, 150 g/l (11%) + amine nitrogen, 51 g/l (3.7%). Fertix mark B, BP - concentrated liquid fertilizer for foliar and root fertilizing. It contains microelements in easily assimilable concentrated form (chelates): N - 210 g/l, MgO - 25, SO_3 - 26.2, Cu - 3.9, Fe - 4.5, Mn - 8.8, Mo - 0.08, Zn - 7.8, Ti - 0.2, B - 7.8, Na_2O - 37.5 g/l.

Sunflower plant protection system included autumn application of Total 480, WS herbicide (3.0 l/ha), soil spraying with Sarmat, SC herbicide (3.0 l/ha) before sunflower emergence, crop treatment with Legion Combi, EC herbicide (0.8 l/ha) during 2-6 leaves weed phase, and insecticide Cepellin, EC (0.15 l/ha) when pests appear.

The area of the experimental plot was 33 m^2, and the area of the registration plot was 5 m^2. Repeatability was threefold, placement was systematic.

The micro-fertilizers and protectants used in the experiment are approved for use in the Russian Federation in 2020-2022.

The experimental work was carried out accompanied by laboratory observations and analyses according to the generally accepted methods of field experiments. Economic efficiency of mineral fertilizers application was calculated according to the method of the Institute of Soil Science and Agrochemistry (Minsk, 2010).

RESULTS AND DISCUSSION

Seed yield of the sunflower hybrid Fakel ranged from 3.76 to 4.40 t/ha depending on the experiment variant and the year conditions (see Table 1).

The lowest yield was recorded under the conditions of 2020: the average for the crop was 4.04 t/ha, varying from 3.76 to 4.27 t/ha. Slightly higher it was in 2021 - with an average of 4.08 t/ha and varied from 3.84 to 4.29 t/ha. The maximum yield was recorded in 2022 with a crop average of 4.29 t/ha and variation from 4.03 to 4.40 t/ha depending on the experiment variant.

The minimum yield of sunflower seeds was observed in the control variant (without the use of micro-fertilizers). Depending on the conditions of the year, it was from 3.76 to 4.03 t/ha with an average value of 3.88 t/ha.

The application of foliar feeding of vegetative sunflower plants with a tank mixture of Boro-N (2.0 l/ha) and Fertix mark B (2.0 l/ha) during the formation of the 6th-10th true leaf

Табл. 1. Урожайность семян подсолнечника в зависимости от числа обработок микроудобрениями, т/га

Table 1. Sunflower seed yield depending on the number of microfertilizer treatments, t/ha

Option	Yield				+/- to the control, t/ha
	2020	2021	2022	Average	
Control (without treatment)	3,76	3,84	4,03	3,88	–
Boro-N, BP treatment (2.0 l/ha) + Fertix mark B, BP (2.0 l/ha): one	4,09	4,12	4,25	4,15	0,27
two	4,27	4,29	4,40	4,32	0,44
LSD_{05}	0,16	0,14	0,13	0,14	

increased the crop yield by an average of 0.27 t/ha (from 3.88 to 4.15 t/ha) and gave a reliable increase of the crop yield compared to the control variant from 0.22 (2022) to 0.33 t/ha (2020).) to 0,33 t/ha (2020) at LSD_{05} = 0,13-0,16 t/ha.

The maximum yield of 4.27 to 4.40 t/ha (average - 4.32 t/ha) was obtained using two foliar sunflower dressings with a tank mixture of micro-fertilizers during the formation of 6-10 true leaves and in the phase of late budding - beginning of flowering. Yield increase compared to the control in this variant was 0.37 to 0.51 t/ha, 0.44 t/ha on average.

The reliable yield increase from additional foliar fertilizer in the phase of the end of budding - the beginning of flowering to the variant with a single application of micronutrients in the phase of 6-10th true leaf was recorded. Yield increment depending on the year was 0,15 to 0,18 t/ha (average 0,17 t/ha) with LSD_{05} 0,13 to 0,16 t/ha.

With the value of the sunflower seed yield increase as a result of foliar fertilization with a tank mixture of Boro-N + Fertix brand B microfertilizers 0.27 t/ha (one fertilization) and 0.44 t/ha (two fertilizations) and the price of seed at 30,000 rubles per ton, the cost of the yield increase to the control was 8100 and 13,200 rubles/ha respectively (see Table 2).

The costs to the control variant, including the cost of purchasing micro-fertilizers, their application, as well as the cost of harvesting and refinement of the yield increase amounted to 4298.8 rubles / ha in the variant with one foliar fertilizer and 8366.5 rubles / ha - in the variant with two.

Thus, the conditional net income to the control in the variant with one treatment was 3801,2 rubles / ha, with two - 4833,5 rubles / ha, the increase in the level of profitability to control corresponded to 88.4 and 57.8%.

Despite the fact that the level of profitability in the variant with two foliar feeding is 30.6% lower than in the variant with a single application of micro-fertilizers, the rate of conditional net income in the variant with two treatments is higher by 1032.2 rubles / ha than in the variant with one.

Табл. 2. Экономическая эффективность применения некорневых подкормок микроудобрениями Боро-Н + Фертикс марка Б

Table 2. Economic efficiency of foliar fertilizer application with Boro-N + Fertix mark B microfertilizers

Indicator	Treatment multiplicity	
	one	two
Crop yield, t/ha	4,15	4,32
Yield increase compared to the control, t/ha	0,27	0,44
Cost of yield increase, rubles/ha	8100	13200
Additional costs to the control, rubles/ha	4298,8	8366,5
Conditional net income to the control, rubles/ha	3801,2	4833,5
Profitability to the control, %	88,4	57,8

CONCLUSIONS

1. The average sunflower seed yield in the experiment ranged from 3.88 to 4.32 t/ha.
2. Single foliar top dressing of vegetative sunflower plants with a tank mixture of microfertilizers Boro-N + Fertix mark B during the formation of the 6-10th true leaf at a dose of 2.0 + 2.0 L / ha helps to obtain seed yields of 4.15 t / ha, increasing the yield of seeds compared to the option without microfertilizers by 0.27 t / ha, and the indicator conditional net income by 3.8 thousand rubles / ha, and profitability of seed production by 88%.
3. Double foliar feeding by tank mixture of micro-fertilizer Boro-N + Fertix mark B during the formation of the 6-10th true leaf and in the phase of the end of budding - beginning of flowering at a dose of 2.0 + 2.0 l/ha provides a sunflower seed yield of 4.32 t / ha, increasing the seed yield relative to the option without micro-fertilizers by 0.44 t / ha, the conditional net income by 4.8 thousand. rubles/ha, the profitability of seed production by 58%.
4. Additional foliar fertilization with micro-fertilizers Boro-N + Fertix mark B in the phase of the end of budding - beginning of

flowering at a dose of 2.0 + 2.0 L / ha increases the sunflower seed yield by 0.17 t / ha and conditional net income by 1.0 thousand rubles / ha.

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ЭФФЕКТИВНОСТЬ ПРИМЕНЕНИЯ РЕГУЛЯТОРОВ РОСТА ПРИ ПРОИЗВОДСТВЕ ЧЕСНОКА (*ALLIUM SATIVUM* L.)

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Представлены результаты исследований регуляторов роста нового поколения при выращивании посадочного материала чеснока (*Allium sativum* L.). Эксперименты (2019–2021 гг.) проведены в полевых опытах в Московской области. Растения выращены на почве, содержащей 3,2% гумуса, 2,9 мг азота/100 г почвы, 26,8 мг фосфора/100 г почвы, 3,9 мг калия/100 г почвы, pH солевой вытяжки – 5,2. В период вегетации растений проведены три подкормки: первая – в фазу начала интенсивного роста листьев аммиачной селитрой (в дозе 30 г/м^2), вторая – через 2 нед после первой нитроаммофоской (30 г/м^2), третья – через 2 нед после второй сульфатом калия (50 г/м^2). Погодные условия в целом были благоприятными для выращивания чеснока. Полив растений проводили по мере необходимости. Опыты проведены на чесноке озимом сорта Гладиатор. Обработку посевного (воздушных луковичек) и посадочного материала (однозубковых луковиц и зубков) проводили путем замачивания в течение 30 мин, растения, полученные из них, – опрыскиванием растворами регуляторов роста. Препараты Лостор и Энергия М использовали в концентрации 0,01%, препарат Циркон – в концентрации 0,025% для обработки посадочного материала и в концентрации 0,1% при обработке надземной части растений. Установлено, что обработка воздушных луковичек и растений препаратом Лостор способствует повышению урожайности однозубковых луковиц на 18,8%, препаратом Энергия М – на 8,1%. Обработка однозубковых луковиц и растений препаратом Лостор способствует повышению урожайности многозубковых луковиц на 24,3%, препаратом Энергия М – на 16,2%. Применение препарата Лостор способствует увеличению содержания сухих веществ на 8,0% и увеличению суммы сахаров на 9,2%.

Ключевые слова: чеснок, воздушная луковичка, однозубковая луковица, многозубковая луковица, масса луковицы, урожайность, регуляторы роста

EFFECTIVENESS OF GROWTH REGULATORS IN GARLIC (*ALLIUM SATIVUM* L.) PRODUCTION

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The results of the studies of new generation growth regulators in the cultivation of planting material of garlic (*Allium sativum* L.) are presented. The experiments (2019-2021) were conducted in the field trials in the Moscow region. The plants were grown on the soil containing 3.2% humus, 2.9

mg nitrogen/100 g soil, 26.8 mg phosphorus/100 g soil, 3.9 mg potassium/100 g soil, pH of the salt extract - 5.2. During the growing season of the plants three fertilizer applications were made: the first - in the phase of intensive leaf growth with ammonium nitrate (at a dose of 30 g/m^2), the second - 2 weeks after the first with nitroammophoska (30 g/m^2), the third - 2 weeks after the second with potassium sulfate (50 g/m^2). The weather conditions were generally favorable for garlic cultivation. The plants were watered as needed. The experiments were conducted on winter garlic of the Gladiator variety. Seed (aerial bulbs) and planting material (one-toothed bulbs and cotyledons) were treated by soaking for 30 min, and the plants obtained from them were sprayed with growth regulator solutions. The preparations Lostor and Energy M, were used at a concentration of 0.01%, Zircon at a concentration of 0.025% for the treatment of the planting material and at a concentration of 0.1% for the treatment of the above-ground part of the plants. It was found that treatment of aerial bulbs and plants with Lostor promotes an increase in the yield of one-toothed bulbs by 18.8%, and by 8.1% with Energy M. Treatment of single-toothed bulbs and plants with Lostor increases the yield of multitoothed bulbs by 24.3%, and with Energy M by 16.2%. Application of Lostor promotes an increase in the dry matter content by 8.0% and an increase in the sum of sugars by 9.2%.

Keywords: garlic, aerial bulbil, monoclove bulb, multiclove bulb, bulb weight, yield, growth regulators

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INTRODUCTION

Several thousands of compounds of chemical, microbial and plant origin, characterized by the ability to regulate numerous processes associated with the growth and development of plants, are used in plant breeding. They allow to reduce the undesirable effects of negative environmental factors on cultivated plants, increase their resistance to diseases, contribute to an increase in yield, quality and preservation of products in the post-harvest period [1-3].

Researchers have shown the role of silicon-containing compounds in the soil formation process, in increasing the availability of phosphorus and nitrogen for plants from soil complexes. The stimulating and protective effect of such compounds on plants was found [4]. It was shown that the addition of growth regulators Vigor Forte and Humi-20 to the protectants reduced their negative impact on the dynamics of seedlings, growth and development of potato plants and their yields [5]. The important role of polyfunctional plant growth regulators in overcoming herbicide stress was revealed [6].

Studies carried out on garlic demonstrated high efficiency of growth regulators of different origin. Thus, it was found that the use of gibberellic acid (GA 3) on onion and garlic activates plant growth and leads to increased yield in rainfed and irrigated conditions [7-10]. The use of Epin Extra (in concentration of 0.5 ml/l for preplanting soaking of cloves for 24 h) and Zircon (in concentration of 1.0 ml/l) increased the yield of bulbs by 33.0 and 45.0% compared to control [11].

It was found that the use of preparations Epin Plus (in concentration of 0.002% for preplanting treatment of cotyledons in the phase of 3-5 leaves and in the phase of shoots emerging from the leaf axils) and Rostmoment (0.1%) has a fa-

vorable effect on the winter-hardiness of plants [12]. The positive effect of thiourea at a concentration of 100 ppm manifested itself in an increase in the size of cotyledons, bulb weight, yield, and in the cost-benefit ratio, which was 1 : 3.19 [13]. The growth regulator G2 (Cicocel) used at 1000 ppm appeared to increase the shelf life of garlic under normal environmental conditions [14].

An increase in the weight of one-toothed bulbs by 1.2-1.8 times, yield by 13-43%, reduction of lead and cadmium concentration by more than 2 times, reduction of infectivity of bulbs by bacterial diseases when using compositions of a number of growth-regulating substances were observed [15].

The study of the effect of growth regulators Energy M, Siliplant, Zircon showed that the use of Zircon contributed to an increase in the yield of garlic bulbs by 10.6-18.9%, and the use of Energy M and Siliplant reduced the proportion of cloves affected by phytopathogens to 4.7 and 6.4%, while this indicator was 15.3% in the control[1]. High efficiency of Energy M and other new generation growth regulators is shown on different species of cultivated plants [16-22].

The purpose of the study is to identify the effectiveness of growth regulators in the production of planting material of winter garlic.

The objectives of the research are to show the effectiveness of using modern highly effective growth regulators in planting garlic in the treatment of planting material (aerial bulbs, one-toothed and multi-toothed bulbs) and plants during the growing season.

MATERIAL AND METHODS

Experiments and research were conducted at the All-Russian Research Institute of Vegetable Growing - Branch of the Federal Research Centre of Vegetables (Vereya village, Ramensky district, Moscow region) in 2019-2021.

Soil conditions of the experiment: humus content in the soil was 3.2%, pH of the salt extract was 5.2, nitrogen content - 2.9 mg/100 g of soil (according to Kjeldahl), phosphorus - 26.8 mg/100 g of soil (according to Chirikov), potassium - 3.9 mg/100 g of soil (according to Maslova). The material for the study was aerial bulbils, one-toothed and multi-toothed bulbs of winter garlic (*Allium sativum* L.) variety Gladiator. The studies were performed using generally accepted methods[2-5].

During the growing season, plants were fertilized with ammonium nitrate (30 g/m^2) first at the phase of intensive leaf growth, with nitroammophoska (30 g/m^2) 2 weeks after the first, and with potassium sulfate (50 g/m^2) 2 weeks after the second. Weather conditions were generally favorable for garlic growing. Plants were watered as needed, and the weeds were controlled manually.

Seed (aerial bulbils) and planting material (one-toothed bulbs and cotyledons) were treated by soaking for 30 min, and the plants obtained from them were sprayed with growth regulator solutions. Lostor, Energy M at a concentration of 0.01% and Zircon 0.025% were used for the treatment of planting material. Treatment of the above-ground part of plants was carried out with the same drugs at a concentration of 0.1%. Plants were treated during vegetation for the first time in the phase of the beginning of intensive leaf growth and for the second time after 3 weeks. Water treatment was used as a control. The experiment with aerial bulbils was laid in 5-fold replications, the area of the registration plot was 1 m^2, the method of planting was row, the distance between the rows was 25 cm, the distance between the plants in the row was 0.5 cm. Experience with one-toothed bulbs and cloves was laid in 4-fold repetition, the area

[1]*Polyakov A.V., Alexeeva K.L., Alexeeva T.V.* Influence of growth regulators on yield and phytopathogen infestation of winter garlic in the Moscow region // Ecological state of the natural environment and scientific and practical aspects of modern agricultural technologies: Proceedings of the International Scientific and Practical Conference. Ryazan, 2018. pp. 318-322.

[2]Methodical guidelines for onion crop breeding. Edited by I.I. Ershov, A.F. Agafonov. MOSCOW: VNIISSOK, 1997. 122 p.

[3]*Dospekhov B.A*. Methodology of field experience (with the basics of statistical processing of research results): a textbook for students of higher agricultural educational institutions in agronomic specialties. Ed. 6-th, reprinted from the 5th edition. 1985 M.: Alliance, 2011. 350 p.

[4]*Litvinov S.S.* Methodology of Field Experiments in Vegetable Growing. MOSCOW: VNIIO, 2011. 650 p.

[5]*Ershov I.I., Vorobyova A.A., Abrakhina U.V.* Methodological guidelines for onion and garlic breeding. M.: VASKHNIL, 1984. 36 p.

of the registration plot was 2.5 m^2. The planting method was row wise, the distance between the rows was 25 cm, the distance between the plants in the row was 10 cm.

The material for the study was aerial bulbils weighing 0.8 g, one-toothed bulbs 2.0 g, and cotyledons 3.0 g. The manufacturer of Energy M and Lostor preparations was Flora C (OOO) and Zircon (ANO NEST M)[6].

RESULTS AND DISCUSSION

The studies showed that the treatment of aerial bulbils and plants obtained from them with Lostor increased the yield of one-toothed bulbs by 18.8% compared with the control, and with the use of Energy M - by 8.1%. In these variants, better plant survival was noted, which explains the reason for the yield increase (see Table 1). The proportion of one-toothed bulbs affected by phytopathogens in all the variants was not higher than 1.2%. Positive effect of the preparation on aerial bulbils and plants obtained from them was not found.

When using growth regulators on planting material and the plants obtained from one-toothed bulbs, a positive effect was noted for all analyzed indicators. For example, bulb regrowth was 11.7% higher when Lostor was used and 13.6% higher when Energy M was used. In these variants, bulb weight was 11,2 and 2,7% higher, while bulb yield was 24,3 and 16,2% higher compared to the control. The effectiveness of Zircon was similar to that of Lostor (see Table 1).

It was found that treatment of garlic grown from cloves with Lostor exceeded the control by 17.5% in bulb weight and 8.0% in yield. When Zircon was used, the weight of the bulbs exceeded the control by 19.3%, and the yield by 12.7% (see Table 1).

Analysis of single-toothed bulbs after 9 months of storage showed that when treated with Lostor, weight loss remained at the control

Табл. 1. Влияние регуляторов роста на урожайность луковиц, 2019–2021 гг.
Table 1. Effect of growth regulators on the bulb yield, 2019-2021

Experiment option	Number of plants during harvesting		Bulb weight		Bulb yield	
	pcs./m^2	% to the control	g	% to the control	t/ha	% to the control
Aerial bulbils						
Control	484	100,0	1,6	100,0	5,1	100,0
Lostor	560	115,7	1,6	100,0	6,1	118,8
Energy M	507	104,7	1,6	100,0	5,6	108,1
Zircon	450	93,0	1,0	63,0	4,6	90,0
LSD_{05}					0,4	
One-toothed bulbs						
Control	42,8	100,0	25,9	100,0	11,1	100,0
Lostor	47,8	111,7	28,8	111,2	13,8	124,3
Energy M	48,6	113,6	26,6	102,7	12,9	116,2
Zircon	47,8	111,7	28,7	110,8	13,7	123,4
LSD_{05}					0,6	
Bulbils						
Control	30,6	100,0	38,8	100,0	11,8	100,0
Lostor	28,0	91,5	45,6	117,5	12,8	108,0
Energy M	30,2	98,7	39,7	102,3	12,0	101,7
Zircon	28,7	93,8	46,3	119,3	13,3	112,7
LSD_{05}					0,7	

[6]Directory of Pesticides and Agrochemicals Permitted for Use in the Russian Federation, 2022. URL: https://www.agroxxi.ru/goshandbook.

level, with minimal losses from diseases, which amounted to 4.3%. The use of the preparations Energy M and Zircon had no positive effect on the analyzed parameters (see Table 2).

Our previous studies have showed that the use of organometallic compounds in garlic leads to a more than 2-fold decrease in the concentration of lead and cadmium, copper and zinc - by more than 20% relative to the control, the indicators in which were 12.54; 15.88; 1.30; 0.07 mg/kg, respectively [15].

However, in the case of low content of these trace elements in the soil, the use of Lostor did not lead to a decrease in copper, zinc and cadmium content in the cotyledons. Nevertheless, lead content in one-tooth bulbs (0,008 ± 0,0016) was significantly lower compared to the control (0,04 ± 0,006).

Chemical analysis showed that the content of dry matter as well as disaccharides in garlic cloves obtained by treatment with Lostor and Energy M preparations was registered higher compared to the control (see Table 3).

The decrease in ascorbic acid content seems to be caused by the fact that in the bulb, the endogenous ascorbic acid anion displaces the succinate tris ethanolamine (TEA) anion from hydrosuccinate, which is part of the drug Lostor, with the formation of TEA ascorbate. A similar situation is observed in the case of Energy M, when the ascorbate anion displaces the o-cresoxyacetic acid anion from Cresacin, which is part of its composition.

The possibility of such a mechanism was confirmed by experiments using pure Cresacin and ascorbic acid.

CONCLUSION

The studies showed high efficiency of Lostor application in garlic crops. It was proved that pre-sowing (preplanting) and double treatment of plants during the vegetation period contribute to increasing the yield of one-toothed and multi-toothed bulbs by 8.0-24.3%, increasing the content of dry matter in the cotyledons by 8.0% and disaccharides by 9.2%.

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Табл. 2. Лежкоспособность однозубковых луковиц чеснока после 9 мес хранения
Table 2. Shelf life of one-toothed garlic bulbs after 9 months of storage

Experiment option	Weight of the bulbs put in for storage, g	Weight of the bulbs after storage, g	Weight loss		Weight of sick bulbs	
			g	%	g	%
Control	1430	1200	230	16,1	105	7,3
Lostor	1550	1295	255	16,5	66	4,3
Energy M	2355	1860	495	21.0	190	8,1
Zircon	1900	1530	370	19,5	130	6,8

Табл. 3. Химический анализ зубков
Table 3. Chemical analysis of cloves

Experiment option	Dry matter, %	Sugars, %			Ascorbic acid, mg%
		Mono-	Di-	Sum	
Control	37,4	0,2	19,3	19,5	5,4
Lostor	40,4	0,2	21,0	21,3	4,0
Energy M	40,2	0,2	19,0	19,2	4,3

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ОМСКАЯ 42 – НОВЫЙ СРЕДНЕПОЗДНИЙ СОРТ ПШЕНИЦЫ МЯГКОЙ ЯРОВОЙ ДЛЯ ЮЖНОЙ ЛЕСОСТЕПИ И СТЕПИ

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Описаны результаты исследований по созданию сорта пшеницы мягкой яровой Омская 42. Сорт характеризуется высокими показателями устойчивости к засухе (ИУ *in vitro* = 0,55). Проведенные оценки устойчивости к листостебельным патогенам в 2017 и 2018 гг. показали, что сорт Омская 42 обладает средним уровнем устойчивости к мучнистой росе (ИУ = 0,47 и 0,59) и высоким – к бурой (ИУ = 0,05 и 0,18) и стеблевой ржавчинам (ИУ = 0,07 и 0,28). При значительном недостатке влаги и массовом развитии заболеваний в 2019 и 2020 гг. в период кущение – колошение (ГТК = 0,20–0,45) урожайность сорта Омская 42 была выше восприимчивого стандарта Серебристая соответственно на 2,15 и 2,88 т/га, устойчивого к этим заболеваниям сорта Элемент 22 – на 0,16 и 0,5 т/га. Длина колоса нового сорта на 0,5 см больше стандарта Серебристая. Существенное превышение в сравнении со стандартом выявлено по массе 1000 зерен (на 5,6 г). Результаты изучения сорта в международном экологическом питомнике КАСИБ (2015 и 2016 гг.) показали, что на опытных участках, где отмечено массовое поражение посевов бурой и стеблевой ржавчинами, сорт Омская 42 проявил высокую и умеренную устойчивость к этим заболеваниям, урожайность его была на 0,39–1,23 т/га выше восприимчивых сортов. Показатели качества зерна в годы передачи сорта на госсортоиспытание были следующие: содержание сырой клейковины 31,8%, белка – 16,36%, сила муки – 415 е. а., общая хлебопекарная оценка – 4,3 балла. С 2019 г. сорт включен в Госреестр селекционных достижений РФ по Западно-Сибирскому (10) региону как среднепоздний сорт. По качеству зерна он относится к сильной пшенице. В рамках программы импортозамещения внедрение в производство нового сорта Омская 42 позволит существенно увеличить и стабилизировать валовые сборы зерна в Омской области и Западно-Сибирском регионе России.

Ключевые слова: пшеница, сорт, патоген, устойчивость, качество зерна, урожайность

OMSKAYA 42 - A NEW MIDDLE–LATE VARIETY OF SOFT SPRING WHEAT FOR THE SOUTHERN FOREST-STEPPE AND STEPPE

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The results of research on the creation of the soft spring wheat variety of Omskaya 42 are described. The variety is characterized by high indices of drought tolerance (IR *in vitro* = 0.55). Assessments of resistance to leaf rust pathogens in 2017 and 2018 showed that the variety Omskaya 42 has a medium level of resistance to powdery mildew (IR = 0.47 and 0.59) and high resistance to brown rust (IR = 0.05 and 0.18) and stem rust (IR = 0.07 and 0.28). With a significant lack of moisture and mass development of diseases in 2019 and 2020 during tillering - earing (HTC = 0,20-0,45), the yield of the variety

Omskaya 42 was higher than the susceptible standard Serebristaya, respectively, by 2.15 and 2.88 t / ha, and the variety Element 22 resistant to these diseases - by 0.16 and 0.5 t / ha. The ear length of the new variety is 0.5 cm longer than the standard Serebristaya. Significant excess compared to the standard was revealed by the weight of 1000 grains (by 5.6 g). The results of the study of the variety in the international ecological nursery KASIB (2015 and 2016) showed that on the experimental plots with a mass infestation of crops with brown and stem rust, the variety Omskaya 42 showed high and moderate resistance to these diseases, its yield was by 0.39-1.23 t/ha higher than susceptible varieties. Indicators of grain quality in the years of transferring the variety for state variety testing were as follows: crude gluten content of 31.8%, protein - 16.36%, the flour strength - 415 e. a., the overall baking score - 4.3 points. Since 2019, the variety is included in the State Register of Breeding Achievements of the Russian Federation for the West Siberian (10) region as a middle-late variety. In terms of grain quality, it belongs to the strong wheat. As part of the import substitution program, the introduction of the new variety Omskaya 42 will significantly increase and stabilize the gross yield of grain in the Omsk region and the West Siberian region of Russia.

Keywords: wheat, variety, pathogen, resistance, grain quality, yield

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INTRODUCTION

The Omsk region is part of Western Siberia, one of the largest grain-producing geographical regions of the Russian Federation. The presence of four soil and climatic zones in the Omsk region (taiga and subtaiga, northern forest-steppe, southern forest-steppe and steppe) suggests the need to create varieties of different groups of ripeness. The total area of varietal crops of soft spring wheat in the Omsk region in 2021 was 1,287,923 ha. Forest-steppe and steppe are the most densely populated and economically developed zones of Western Siberia. The area of spring wheat sown in these zones is 1 159 277 ha (89,8%), middle-late varieties - 522 135 ha, or 40,5% of the spring wheat varieties. A total of 25 middle-late varieties are cultivated in the fields of the Omsk region, 12 of which were created by the Omsk Agrarian Scientific Center (Omsk ASC). They occupy 327,483 ha, or 62.7% of the share of all middle-late varieties. Uralosibirskaya variety is cultivated on the area of more than 122,303 ha, which is among the leaders by area in Russia since 2018. Among the 12 middle-late varieties: 6 are strong (Omskaya 18, Omskaya 24, Omskaya 28, Omskaya 37, Omskaya 42 and Uralosibirskaya) and 6 are valuable by grain quality[1]. However, in terms of resistance to fungal diseases and higher productivity, not all varieties meet the requirements of agricultural producers. The forest-steppe and steppe zones require middle-late varieties that can withstand the spring-summer drought, resistant to leaf rust diseases, lodging, with grain of high quality and stable yields from year to year. Since 2015, the threat of epiphytotics of stem rust has increased, in particular the new virulent race of stem rust, called Ug 99. In the years of epiphytotics, yield losses of susceptible varieties from this disease are more than 50%[2].

[1]Recommendations on the cultivation of crop varieties and the results of variety trials in the Omsk region for 2020. Omsk, 2020. 74 p.

[2]Overview of the phytosanitary state of crops in the Omsk region in 2019 and the forecast of the development of harmful objects in 2020. Branch of the Federal State Budgetary Institution "Rosselkhoztsentr" in the Omsk region. Omsk, 2020. 156 p.

According to researchers, the variety belongs to one of the main places in the yield increase, improvement of product quality and resistance to diseases [1-3]. Creation of varieties with wide homeostasis for such a vast region is a promising task of selection. Variability of weather conditions by year and even within a day is the main reason for variation in wheat yields in Western Siberia. One of the limiting factors for the stable yield of spring soft wheat is a frequently repeated drought. The number of years with pronounced drought in the southern forest-steppe and steppe of the Omsk region during the spring and summer period is about 30% [4-6]. Mainly during the growing season, the May-June drought with maximum precipitation in July (limits are 20 ÷ 199 in the southern forest-steppe) prevails, which contributes to the formation of a special forest-steppe West Siberian ecotype of spring wheat varieties in local conditions, which effectively use late precipitation.

The purpose of research is to study the features of the variety Omskaya 42 on the main breeding traits: yield, elements of productivity, resistance to adverse biotic and abiotic environmental factors and indicators of grain quality.

The objectives of the research are the characteristics of the variety Omskaya 42 on morphological traits, its advantages in comparison with the standards for yield, elements of yield structure, resistance to drought and leaf diseases, as well as grain quality.

MATERIAL AND METHODS

The work on the creation and evaluation of selection material of soft spring wheat was carried out according to the full selection scheme[3]. Intraspecific hybridization was used in the creation of this variety. Hybridization was carried out in the "grid yard". Source material and hybrid populations of *F1* to *F3* were sown with a hand seeder CP-1. Sowing of the selection nursery lines of the 1st year of study (SN-1) was carried out with the SPR-2 seeder (the seeding area of each line was 10 × 30 cm). In the hybrid nursery garden (HN) and the selection nursery of the 2nd year (SN-2), the area of the plot was 3 and 5 m^2. The selection nursery of the 3rd year (SN-3), as well as the competitive variety trial (CVT) were sown by SSFK-7 M planter, the plot area was 10 m^2.

The CVT nurseries for spring soft wheat were planted for 3 years in two sowing dates and in the sowing after the autumn plowing period. At the first sowing date, repetition was four times, at the second sowing date and at the sowing after the autumn plowing, repetition was three times. Seeding rate - 5.5 million germinated seeds/ha. The first sowing date is May 12-15, the second and after the autumn plowing - May 23-25. The varieties Element 22, Serebristaya and Omskaya 35 were used as standards in the study of varieties of the middle-late ripeness group. Harvesting in 2021 was carried out with a small-sized selection and seed-growing combine "WINTERSTEIGER-VIM". Due to mass development of leaf-rolling pathogens, the resistance to brown rust (*Puccinia recondita f. sp. tritici*), stem rust (*Puccinia graminis f. sp. tritici*), and powdery mildew (*Blumeria graminis f. sp. tritici*) under field conditions was evaluated according to the international scale[4].

The registrations were performed dynamically every 5-6 days from the onset of disease manifestation to its mass development. Based on the data obtained, the area under the disease progress curve (AUDPC) and the disease resistance index (IR) were calculated according to the classification proposed by the All-Russian Research Institute of Phytopathology: highly resistant (IR = 0.10 ÷ 0.35); moderately resistant (IR = 0.36 ÷ 0.65); weakly resistant (IR = 0.66 ÷ 0.80) and susceptible (IR > 0.80)[5].

[3]Methodology of state variety testing of crops. General part. M., 1985. Issue 1. 269 p.

[4]*Peterson R.F., Campbell A., Hannah A.* A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. Canadian journal of research. 1948. № 26(5). pp. 496–500.

[5]*Kovalenko E.D., Kolomiets T.M., Kiseleva M.I., Zhemchuzhina A.I., Smirnova L.A., Shcherbik A.A.* Methods for evaluation and selection of source material when creating wheat varieties resistant to brown rust: guidelines VNIIF. M., 2012. 93 p.

For the laboratory analysis of productivity structure elements, plants were manually harvested from 1 m^2 plots. Two middle-late varieties were used as standards: Silver, susceptible to frondiferous pathogens, and Element 22, characterized by moderate resistance to powdery mildew and high resistance to brown rust and stem rust (resistance genes *Lr26/Sr31, Sr35*) [7].

Under laboratory conditions, using automated plant breeder's workplace (APBW), the analysis of 9 elements of plant productivity was carried out. Studies to determine resistance to brown rust and stem rust in the phase of seedlings were carried out in artificial climate chambers (Biotron-4, Biotron-8) using benzimidazole method[6].

Brown and stem rust resistance genes were identified using PCR analysis. Brown and stem rust resistance genes were screened using primers for *Lr19*[7] gene marker, *Lr26*[8] gene marker, *Sr25*[9] gene marker, and *Sr31*[10] gene marker [8-10].

Technological properties were determined in the laboratory of grain quality of the Omsk Academy of Sciences by the standards and methods recommended by the State Commission for Variety Testing of Agricultural Plants on the basis of available equipment and calibrated instruments[11, 12].

Evaluation was carried out according to the following indicators: nature, vitreousness, weight of 1000 grains, protein and gluten content in the grain. Physical properties of the dough were determined on an AlveoLab and a Brabender farinograph. Baking quality was evaluated according to the following indicators: volume, appearance, porosity, elasticity and color of the crumb. The overall baking score was determined by the average values of these indicators.

RESULTS AND DISCUSSION

The variety Omskaya 42 is a result of crossing local breeding lines Lutescens 290/97-7 × Lutescens 167/98-4. Hybridization was conducted in 2004, the elite plant was selected in 2006, then a middle-late line Lutescens 6/04-4 was selected through staged study in the breeding nurseries (2007-2012), which was studied in the CVT nursery in 2013-2015 and submitted to state varietal trials (SVT) under the name Omskaya 42.

The line Lutescens 290/97-7 was isolated from the hybrid population from crosses of the variety Omskaya 21 × Reno (Norwegian variety, k-57056, with the *Pm4b* powdery mildew resistance gene). The variety Omskaya 21 was isolated from the hybrid population Novosibirskaya 22 × Spontaneous hybrid based on the sample from Canada. Evaluation to leaf rust diseases of this variety under field conditions showed that the variety belongs to the middle-late ripeness group, characterized by a high level of resistance to powdery mildew (IR < 0.35), but susceptible to brown and stem rusts. The breeding line Lutescens 167/98-4 was selected from a hybrid combination of Com. 90 × Omskaya 33. The line Kom. 90 was obtained in 1996 from A.I. Morgunov (pedigree NL456/VEE#5//PASA/3/BOW/ GEN// KAUZ). Mexican variety KAUZ has a wheat-rye translocation1RS.1BL (*Sr31/Lr26* genes) in the pedigree, as well as gene Lr13. Under

[6]*Mikhailova L.A., Kvitko K.V.* Laboratory methods of cultivation of brown rust pathogen // Mycology and phytopathology.1970. Vol. 4, N 3. pp. 269-270.

[7]*Gupta S.K. [et al.]* Haque Identification and validation of molecular markers linked to the leaf rust resistance gene Lr19 in wheat // Theor Appl Genet. 2006. N 113 (6). pp. 1027–1036.

[8]*De Froidmont D.* A co-dominant marker for the 1BL/1RS wheat-rye translocation via multiplex PCR // Journal of Cereal Science. 1998. Vol. 27. pp. 229–232.

[9]Li T.Y. *[et al.]* Seedling Resistance to Stem Rust and Molecular Marker Analysis of Resistance Genes in Wheat Cultivars of Yunnan, China // PLoS ONE. 2016. N 11 (10). pp. 1–14.

[10]*Das B.K. [et al.]* Development of SCAR markers for identification of stem rust resistance gene “Sr31” in the homozygous or heterozygous condition in bread wheat // Plant Breeding. 2006. Vol. 125 (6). pp. 544–549.

[11]Methods of State Variety Testing of Agricultural Crops: Technological Assessment of Cereals, Cereals and Legumes. M., 1988. 121 p.

[12]GOST P 54478-2011. Grain. Methods of determination of quantity and quality of gluten in wheat. Moscow: Standartinform. 2012. 19 p.

[13]A.C. of the Russian Federation No. 68818, patent No. 9658 (patent holder FSBSI "Omsk Scientific Research Center").

field conditions under natural and infectious background, this line was characterized by resistance to leaf-rolling pathogens. The mid-season-ripening variety Omskaya 33 has been in the State Register since 2002 and has a combination of genes with low efficiency to brown rust *Lr1, Lr3* and *Lr10*. The varieties Kavkaz, Grekum 114, Omskaya 20, which have high level of resistance to powdery mildew and delay development of rust pathogens, are included in the pedigree of the variety Omskaya 33. Thus, complex recombinant genome of Omsk 42 is a result of crossing of varieties of Russian and foreign selection, which family tree includes Caucasus, Omsk 20, KAUZ - carriers of wheat-rye translocation. Using PCR-specific markers the genes *Lr26* and *Sr31* localized on rye chromosome 1RS were identified in this variety. Thus, the variety is characterized by a favorable genotypic environment for the realization of the genetic potential of the short arm of rye chromosome 1RS.

Soft spring wheat variety Omskaya 42 belongs to the West Siberian forest-steppe ecological group. Variety - lutescens. The bush is semi-erect. The plant is medium-sized with a strong stem; the straw is medium-thick and hollow. The flag leaf is of intermediate type, medium pubescence, gray-green in color. Flag leaf and its sheath have medium waxy bloom; anthocyanin coloration of the lugs is absent. The spike is pyramidal, white, flaxless, hairless. The floral scales show awnlike shoots on 1/4 of the ear up to 1.0 cm long. The density of the ear is medium (up to 16-18 spikelets per 10 cm of the shaft). The glume is lanceolate in shape. The beak is sharp, short. The shoulder is straight, medium-sized. Grain scales are dense. The grain is semi-elongate, red, the furrow is narrow, superficial, the crest is weakly expressed. Weight of 1000 grains 36-42 g. Phenol staining of the grain is medium.

Biological characteristics of the variety. The variety is middle-late, ripening in 99 days (4 days later than the standard Omskaya 35, 2013-2015). In comparison with the variety Serebristaya, the new variety appeared to ripe 5 days later (103 vs. 98, 2014 and 2015). The data obtained from *in vitro* testing of the breeding material showed that the variety Omskaya 42 has an increased resistance to adverse abiotic environmental conditions, in particular to drought. The index of resistance (*ir*) of the variety Omskaya 42 and the standard Silver was 0,55 and 0,57 respectively, which indicates an increased resistance to drought [11]. Resistance to lodging is high (5 points versus 4.7 in the standard). At considerable lack of moisture and mass development of leaf diseases in 2019 and 2020 during tillering - earing (HTC = 0,20-0,45) the yield of the variety Omskaya 42 compared to the standard Serebristaya was higher by 2.15 and 2.88 t/ha and compared to the standard Element 22 - by 0.16 and 0.5 t/ha respectively.

Under field conditions, both on natural and infectious background, the new variety delays the development of the pathogens of brown and stem rust. In the seedling phase, the variety is moderately resistant to these pathogens (lesion score 2), as well as to yellow spot and net blotch (1-2 points). It is characterized by medium resistance to powdery mildew and kernel smut, as well as the standard cultivar Serebristaya (4,6-32,8%), it is weakly affected by loose smut (less than 7%).

Among the breeders and phytopathologists there is no consensus on the type of resistance in the created varieties. We are supporters of creating varieties with different types of resistance depending on the ripeness groups. In selections carried out in early breeding nurseries, special attention is paid to both morphological traits of productivity and disease resistance. In later nurseries for varieties of middle late group of ripeness along with resistant genotypes those are selected that prevent the development of the pathogen, but at the end of the growing season are affected by it, thus accelerating the ripening. Assessments of resistance to leaf-rolling pathogens showed that the variety Omskaya 42 is characterized by an average level of resistance to powdery mildew (IR = 0.47 and 0.59 in 2017 and 2018, respectively). The records of brown rust and stem rust lesions carried out in the dynamics

showed that the susceptible standard Serebristaya was affected by 5 and 20-30%, respectively, in the first two registrations, and by 100% in the last one. The variety Omskaya 42 and the Element 22 standard, resistant to these pathogens, were not affected by rust diseases in the first two registrations. In the last evaluation, the variety Omskaya 42 had the maximum lesion 60%, and Element 22 - 40%. The disease is less harmful for such varieties, as the incubation period of the parasite is lengthened, and the varieties "escape" from severe damage. In epiphytotic years, the yield of the resistant varieties Omskaya 42 and Element 22 was 5.02 and 5.09 t/ha, respectively, and the susceptible variety Serebristaya was 3.04 t/ha, i.e. 2.0 t/ha less. The peculiarity of the resistant varieties is adaptability to environmental conditions. The variability of their yields by year is medium (*CV* = 11%), and in the variety Serebristaya - strong (*CV* = 43.3%). The results of analysis of variance showed that the proportion of the influence of genotype in the study of the variety Omskaya 42 and middle-late standards 2016-2020 was 51.5%, environmental conditions - 39.9%.

The advantage of the variety Omskaya 42 is also noted in the elements of the yield structure in Table 1.

In fact, with the same productive bushiness (1.4 pc), the length of the ear of the new variety is marked by 0.5 cm more than the standard Serebristaya. Also, the variety exceeds the standard by indicators: the number of grains in the ear and per plant by 1.0 and 3.6 pcs, respectively, the weight of grain from the main ear and per plant by 0.28 and 0.26 g, respectively. The essential excess in comparison with the standard was detected on the mass of 1000 grains (by 5,6 g).

The study of the variety in the international ecological nursery KASIB (Russia and Kazakhstan, 2015 and 2016) showed: the period of seedlings - wax maturity in the variety Omskaya 42 came on average 2 days later than the average late standard; plant height in both the standard and the new variety ranged from 56 to 103 cm. On the two experimental plots where brown and stem rust lesions were observed, the variety Omskaya 42 showed high and moderate resistance to these diseases, its yield was 0.39-1.23 t/ha higher than the susceptible varieties. The maximum yield was recorded in 2015 at Kurhansemena point (5.33 t/ha).

When identifying the variety Omskaya 42 using DNA-markers to fungal diseases, it was found that in its genotype a complex of genes *Lr26/Sr31* was found. The detected complex is located on the wheat-rye translocation 1BL. RS, the presence of which imparts a number of other economically useful features to varieties in addition to resistance [12, 13].

It is important to study genetic resources and identify valuable samples to create varieties that form the yield even under adverse environmental conditions [14-16]. Grain quality parameters of the new variety, when transferred to the state variety plots (SVP) (CVT,

Табл. 1. Результаты изучения сорта Омская 42 в КСИ, 2013–2015 гг.

Table 1. Results of the study of the Omskaya 42 variety in the CVT, 2013-2015

Indicator	Omskaya 42	Serebristaya	± to the standard
Sprouting - wax ripeness, days	99,0	98,0	+1,0
Resistance to lodging, score	5,0	4,7	0,3
Plant height, cm	92,2	90,9	1,3
Productive bushiness	1,4	1,5	–0,1
Spike length, cm	9,6	9,1	0,5
Number of spikelets in a spike, pcs.	16,4	15,4	1,0
Number of grains in a spike, pcs.	40,7	37,1	3,6
Number of grains per a plant, pcs.	52,3	50,4	1,9
Grain weight of the main spike, g	1,57	1,29	0,28
Grain weight per a plant, g	1,92	1,66	0,26
Thousand-kernel weight, g	37,7	32,1	5,6
Yield, CVT, first term, t/ha, LSD_{05}= 0,29	3,37	2,97	0,40
Yield, CVT, after cereals, t/ha	2,94	1,95	0,99

2013-2015): the grain unit reached 711 g/l, weight of 1000 grains - 39.5 g, vitreousness - 51%. Baking indicators were high, corresponded to the strong wheat: gluten content in the grain - 31.8%, protein - 16.36%, strength of the flour - 415 e. a., the ratio of elasticity to extensibility by alveograph - 1.76 e. a., valorimetric score - 85 e. v., liquefaction dough by farinograph - 33 e. f. According to the results of the laboratory baking the volume of bread was 980 cm^3, total baking score - 4.3 points. When studying the variety Omskaya 42 in the demonstration nursery from 2016 to 2020 the following data were observed on average: for protein - 16.81%, gluten - 33.2%, the total baking score - 4.2 points.

State variety trials of the variety Omskaya 42 took place from 2016 to 2018 on three variety plots located in the southern forest-steppe (Sherbakulsky) and steppe (Cherlaksky and Pavlogradsky) zones of the Omsk region, the standard was a middle late variety Serebristaya (see Table 2). The data show that regardless of the variety site, the yield of the new variety with high resistance to rust diseases exceeded the susceptible standard Serebristaya by 0.28 - 0.90 t/ha. The high yield increase in the average for the 3 years of testing was noted on Sherbakulsky SVP, it was 0.9 t/ha to the standard Serebristaya, and to the Element 22 - 0.35 t/ha. On the variety plots in the steppe zone, the yield of the variety Omskaya 42 was at the level of the standard Element 22. The maximum yield of the variety Omskaya 42 was observed in 2017 at the Sherbakulsky SVP (4.88 t/ha) and in 2018 at the Cherlaksky SVP (4.66 t/ha).

Assessment of technological quality revealed the advantage of the new variety in the main indicators compared with the standard Element 22. Table 3 shows the data on the grain quality in two variety plots belonging to the steppe zone. The new variety in the Cherlaksky variety plot exceeded the standard in protein content by 1.2% and in gluten by 2.0%, and in the Pavlogradsky - by 1.5% and 3.3%, respectively.

In terms of the flour strength, the variety surpassed the standard by more than 3 times. Bread volume of the variety Omskaya 42 at the Cherlaksky SVP was higher by 340 cm^3, at the Pavlogradsky - by 400 cm^3. The overall baking score is excellent, higher than the standard by more than 1.1 points.

The new variety Omskaya 42 successfully passed the production test in the PFE Budanov (Omsk region, Kormilovsky district) and the PFE Omskoye (Omsk district). In addition, the variety is widely cultivated in the farms of the Russian Scientific Production System "Siberian seeds".

Pre-sowing tillage is recommended for KPE-3,8, KPSh-9; sowing by SZP-3,6 seeding machine on May 15-22, seed embedding depth 6-8 cm with seeding rate 4.5-5.0 million germinating grains/ha. Crop treatment against monocotyledonous weeds with Ovsugen (0,4-0,6 l/ha), against dicotyledons - Oktapon (0,8-1,0 l/ha). Depending on weather conditions, harvesting of the variety is one- or two-phase.

Табл. 2. Урожайность сортов пшеницы мягкой яровой на ГСУ южно-лесостепной и степной зонах Омской области, 2016–2018 гг., т/га

Table 2. Yield of soft spring wheat varieties at the SVT in the southern forest-steppe and steppe zones of the Omsk region, 2016 - 2018, t/ha

SCTS	Omskaya 42	Serebristaya	Element 22	± to Serebristaya	± to Element 22
Sherbakulsky	3,85	2,95	3,50	0,90	0,35
Cherlaksky	3,55	3,12	3,65	0,43	–0,10
Pavlogradsky	2,97	2,69	3,13	0,28	–0,16
LSD_{05}	0,28				

Табл. 3. Качество сорта пшеницы мягкой яровой Омская 42 на ГСУ в степной зоне Омской области, 2018 г., т/га

Table 3. The quality of the soft spring wheat variety Omskaya 42 at the SVT in the steppe zone of the Omsk region, 2018, t/ha

Variety	Grain unit, g/l	Protein content in grain, %	Gluten quantity in grain, %	Flour strength, e.a.	The volume of bread of 100 g of flour, ml	Total baking score, point
Cherlaksky SVT						
Omskaya 42	791	15	29,2	323	1190	4,5
Element 22	807	13,8	27,2	94	850	3,4
Pavlogradsky SVT						
Omskaya 42	710	16,3	36,3	363	1250	4,7
Element 22	762	14,8	33	106	850	3,4

The proposed agro-technology is used in a number of advanced farms of the southern forest-steppe of the Omsk region.

Economic efficiency. From the introduction of the new variety of soft spring wheat Omskaya 42 with the observance of the technology of cultivation on fallow, the economic effect in the forest-steppe zone is 4250 rubles / ha. Due to the high level of yield and resistance to diseases and good baking properties, the new variety can successfully compete with the varieties of similar ripeness group.

CONCLUSION

The variety Omskaya 42 is included in the State Register of the Russian Federation in 2019 for the West Siberian (10) region[13].

Soft spring wheat variety Omskaya 42 is the result of crossing of the Russian and foreign breeding varieties, the pedigree of which includes Caucasus, Omskaya 20, KAUZ - the carriers of wheat and rye translocation. Using PCR - specific markers in this variety *Lr26* and *Sr31* genes were identified. The variety Omskaya 42 is a middle-late variety, which belongs to strong wheat in terms of grain quality. The type of the variety is lutescens, the bush is semi-erect, the plant is medium-grown with a sturdy stem. The density of the ear is medium, the weight of 1000 grains is 36-42 g. The variety is highly resistant to drought and high - to lodging.

Under field conditions both on natural and infectious background, the new variety retains the development of pathogens of brown and stem rusts, has a medium level of resistance to powdery mildew and kernel smut, weakly affected by loose smut (not more than 7%). In the seedling phase, the variety shows moderate resistance to rust pathogens (damage score of 2).

The results of studying the variety in the international ecological nursery KASIB (2015 and 2016) showed that on the experimental plots where mass defeat of crops by brown and stem rusts was observed, the variety Omskaya 42 showed high and moderate resistance to these diseases, its yield was by 0.39-1.23 t/ha higher than susceptible varieties. According to grain quality the variety corresponds to strong wheat: raw gluten content - 31,8%, protein - 16,36%, flour strength - 415 e. A., the general baking score - 4,3 points. With mass development of leaf diseases, the variety Omskaya 42 exceeded the susceptible standard Serabristaya by more than 2.0 t/ha, and the highly resistant to these diseases standard Element 22 - by 0.16 t/ha and higher by yield.

As part of the import substitution program, the introduction of the new variety Omskaya 42 will significantly increase and stabilize the gross yield of grain in the Omsk region and the West Siberian region of Russia.

[13]A.C. of the Russian Federation No. 68818, patent No. 9658 (patent holder FSBSI "Omsk Scientific and Research Center").

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АКТУАЛЬНОСТЬ УВЕЛИЧЕНИЯ ДОЛИ ОЗИМОЙ РЖИ В ПРОИЗВОДСТВЕННЫХ ПОСЕВАХ ЗАПАДНОЙ СИБИРИ

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Озимая рожь, обладающая многими ценными свойствами, является очень важной культурой в зерновом клине. Проведенный анализ многолетних данных о размерах посевных площадей озимой ржи в России свидетельствует об их стремительном сокращении. В связи с этим приведен пример реализуемой Правительством Финляндии программы «Рожь», направленной на популяризацию и увеличение потребления продукции из ржаной муки, а также опыта создания информационного центра, занимающегося просветительской деятельностью среди населения. Рассмотрено состояние Государственного реестра селекционных достижений, допущенных к использованию, по озимой ржи: установлено, что на долю сортов отечественной селекции приходится 87,1%, иностранной – 12,9%. При этом для возделывания в Западной Сибири рекомендовано 18 сортов исключительно отечественной селекции, в том числе четыре сорта тетраплоидной ржи. За последнее десятилетие в регионе зарегистрировано пять сортов озимой ржи. Представлено соотношение величины посевных площадей под культурой в Российской Федерации в целом, Алтайском крае и Новосибирской области. Проанализированы данные по Новосибирской области за 2019–2021 гг. по урожайности основных озимых культур, объемам высева сортов и гибридов ржи озимой, включенных в Госреестр. Изучено положение дел в производстве озимой ржи и продуктов ее переработки, а также перспектива использования этой культуры в севооборотах Западной Сибири. Приведены показатели максимальной урожайности сортов и гибридов озимой ржи, перечислены их преимущества и недостатки. Аргументированы значимость создания коллекции сортов и гибридов на территории региона и необходимость увеличения производства озимой ржи и продуктов ее переработки.

Ключевые слова: озимая рожь, коллекция сортов и гибридов озимой ржи, посевные площади, урожайность, ржаная мука

RELEVANCE OF INCREASING THE SHARE OF WINTER RYE IN PRODUCTION CROPS OF WESTERN SIBERIA

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Winter rye, which has many valuable properties, is a very important crop in the grain area. The analysis of long-term data on the size of sown areas of winter rye in Russia shows their rapid decline. In this regard, the example of the “Rye” program, implemented by the Finnish government to promote and increase the consumption of rye flour products, as well as the experience of establishing an information center engaged in educational activities among the population is presented. The state of the State Register of Breeding Achievements Approved for Use in winter rye was considered: it was revealed that domestic breeding varieties accounted for 87.1%, foreign - 12.9%. At the same time, 18 varieties exclusively of domestic breeding were recommended for cultivation in Western Siberia, including four varieties of tetraploid rye. Over the past decade, five varieties of winter rye have been registered in the region. The ratio of the size of sown areas under the crop in the Russian Federation as a whole, the Altai Territory and the Novosibirsk Region is presented. The data

for the Novosibirsk region for 2019-2021 on the yield of major winter crops, the volume of sowing of winter rye varieties and the hybrids included in the State Register were analyzed. The situation in the production of winter rye and its products, as well as the prospects for the use of this crop in crop rotations in Western Siberia were studied. Indicators of maximum yield of winter rye varieties and hybrids are given, their advantages and disadvantages are listed. The importance of creating a collection of varieties and hybrids in the region and the need to increase the production of winter rye and its products are justified.

Keywords: winter rye, collection of varieties and hybrids of winter rye, land under cultivation, productivity, rye flour

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INTRODUCTION

Winter rye is one of the most important strategic crops. The Transcaucasus and the adjacent regions of West Asia are considered to be the main area of origin of the *Secale* genus. For centuries, rye provided complete nutrition for the population of Russia, being the raw material for the production of rye bread, it was considered a national symbol. This bread was tasty and affordable for the Russian people. The biological characteristics of rye correlate well with the soil and climatic conditions of most of the agricultural regions of Central Russia, the Volga region, the Urals, Western and Eastern Siberia. In Siberia, winter rye began to be cultivated from the 1st half of the 17th century, which coincides with the introduction of agriculture by the Russian settlers[1] [1].

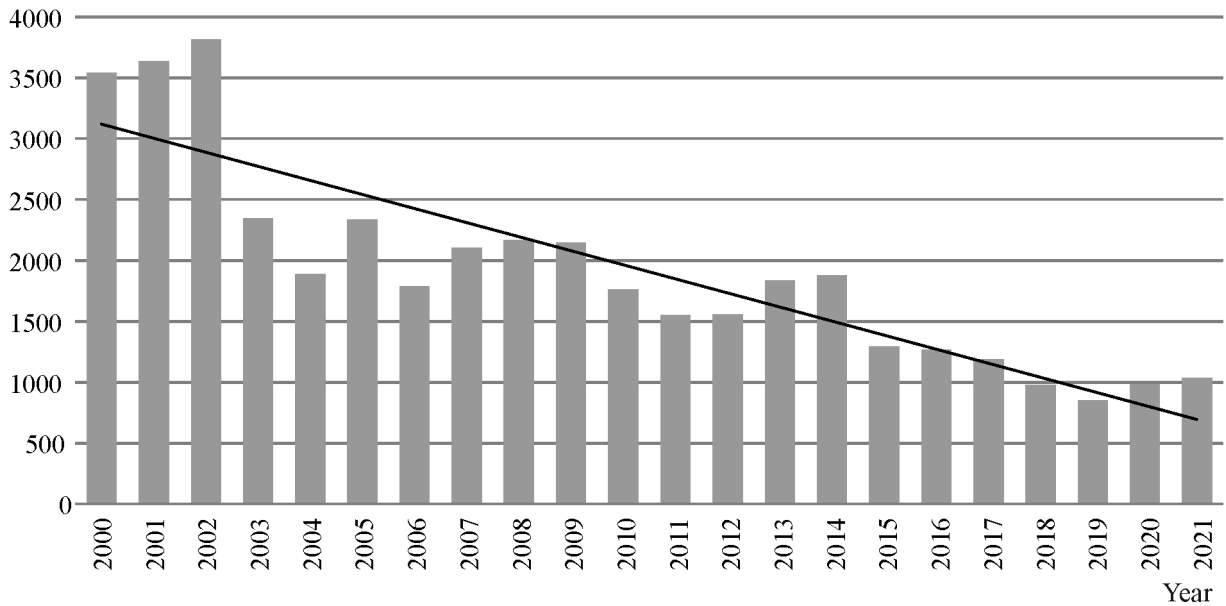
Winter rye, which is included in the group of grain crops, has a number of valuable natural properties: winter hardiness, frost and drought resistance, the ability to sprout quickly in the spring and to grow on low fertile (acidic, sandy, peaty) soils, preserving its yields. Due to these qualities, rye is firmly entrenched in the areas with unfavorable soil and climatic conditions, has gained popularity among farmers and is by right a safety net crop [1].

The use of winter rye in crop rotations gives a good agronomic effect, as everyone knows its ability to inhibit the growth of weeds and due to the developed root system improve soil structure. For many years in the country as a whole there has been a reduction of cultivated areas under the crop[2] (see figure). In particular, in the Novosibirsk region the winter grain crop area accounts for only a small share of the total sown area.

According to the data presented in the figure, it is clear that the sown area in 2000-2002 was not less than 3500 hectares, since 2003 there has been a decrease in the sown area, and since 2015 their value has not exceeded 1500 hectares.

[1] *Ivanov A.P.* Rye. Moscow: Selkhozizdat, 1961. 304 p.

[2] *Goncharenko A.A.* Production and breeding of winter rye in Russia // Vestnik of the Russian Agricultural Science. 2010. N 1. pp. 22-26.



Посевные площади озимой ржи в хозяйствах всех категорий на территории Российской Федерации (по данным Росстата), тыс. га[3]

Sown areas of winter rye in the farms of all categories in the Russian Federation (according to Rosstat), thousand hectares[3]

Rye contains proteins, essential amino acids (valine - 0.7% in dry matter; isoleucine - 0.7; leucine - 1.0; lysine - 0.6; threonine - 0.3; tryptophan - 0.1% on absolutely dry basis), minerals (Ca, Fe, F, P, K, Zn, Mn, Cu), vitamins A, B, E in considerable quantity. Because of this it is a raw material suitable for the production of functional foods. Rye is considered a useful cereal because of the large amount of dietary fiber that contains arabinoxylan, cellulose, β glucan, fructans and lignin, which have a positive effect on health. Rye is mainly used to make bread and bakery products, as well as in the industry for the production of liquor products. In addition, rye grain is part of many food products: breakfast cereals, porridges, pasta, etc. (see footnote 1) [2-4]. It should be noted that only rye bread made of coarse flour on sourdough, which was and still is a symbol of national identity of Russia, can be considered full-fledged. In the old days they used to say that rye bread is a weapon against hunger. Today it can be named the weapon against illnesses [3]. Rye bran is a by-product of flour production. They consist mainly of dietary fiber and are a valuable source of many biologically active compounds. It is noteworthy that rye bran has a fairly high content of ferulic acid, which is used in food, pharmaceutical and cosmetic industries [4].

Rye grain is practically not used for mixed fodder, although it is a complete concentrated feed. In terms of nutrients, it is not inferior to barley and wheat, and in terms of sugar it exceeds them by 2 times. Rye protein compared to wheat protein has a higher biological value due to the better ratio of amino acids in its composition. When using concentrated feed containing winter rye grain of forage direction, a significant increase in body weight and improved meat quality of animals (rabbits, broiler chickens, pigs) are noted [5, 6].

The presence of so-called anti-nutritive substances (non-starch polysaccharides, phytic acid, pentosans, pectins) in winter rye limits its use in mixed fodder. Pentosans, which make up the cell membrane of the endosperm, dissolve during digestion, which leads to a decrease in the digestibility of feed and assimilation of nutrients. The most effective ways to solve this

[3]Crop acreage in the Russian Federation (farms of all categories; thousand hectares). 1990–2021 URL: https://rosstat.gov.ru/enterprise_economy

Табл. 1. Сорта, включенные в Государственный реестр селекционных достижений, допущенных к использованию в Западно-Сибирском регионе, за 2012–2022 гг.[4]

Table 1. Varieties included in the State Register of Selection Achievements approved for use in the Western Siberian region for the period 2012-2022[4]

Variety	Year of inclusion	Release region*	Originator/patent holder
Irtyshskaya	2014	10, 11	Omsk Agrarian Scientific Center
Narymchanka	2015	10	Siberian Federal Scientific Centre of Agro-BioTechnologies RAS
Sibir 4	2016	10	Omsk Agrarian Scientific Center
Sudarushka	2021	10	Siberian Federal Scientific Centre of Agro-BioTechnologies RAS
Chulpan 9	2021	4, 9, 10	Ufa Federal Research Center RAS

*4 – Volga-Vyatka; 9 – Ural; 10 – West-Siberian; 11 – East-Siberian.

Табл. 2. Посевные площади ржи озимой в РФ и отдельных регионах Западной Сибири в 2019–2021 гг., га[5]

Table 2. Sown areas for winter rye In the Russian Federation and in certain regions of Western Siberia in 2019-2021, ha[5]

Region	2019	2020	2021
RF as a whole	849 871	981 625	1 036 467
Novosibirsk region	10 994	12 072	24 279
Altai Territory	24 960	28 976	46 177

Табл. 3. Средняя урожайность озимой ржи, озимой и яровой пшеницы в Новосибирской области в 2019–2021 гг., ц/га[6]

Table 3. The average yield of winter rye, winter wheat, spring wheat in the Novosibirsk region in 2019-2021, c/ha[6]

Year	Winter rye	Winter wheat	Spring wheat
2019	22,3	24,3	16,6
2020	17,2	20,6	17,7
2021	24,8	28,5	22,0

problem and to increase the content of sugars in winter rye are the selection of culture for quality and effective technological methods: fermentation of grain, heat and barothermal treatment (extrusion), which allow to include winter rye in the diet of animals without any problems [1, 5-8].

In the 80s of the 20th century in Finland there was a situation similar to the current situation in the Russian Federation: there was a decrease in the consumption of rye bread by the population, which led to an increase in the number of diabetic patients. In order to change the situa-

[4]The State Register of Breeding Achievements Approved for Use. Moscow: Rosinformagrotech, 2022. Vol. 1: Plant varieties. 646 p.

[5]Sowing areas of the Russian Federation in 2019 / Federal State Statistics Service (Rosstat). M., 2020; Sown areas of the Russian Federation in 2020 / Federal State Statistics Service (Rosstat). M., 2021; Sown areas of the Russian Federation in 2021 / Federal State Statistics Service (Rosstat). M., 2022.

[6]Gross harvest and crop yield in the Russian Federation in 2019 / Federal State Statistics Service (Rosstat). M., 2020. Part 1; Gross harvest and yield of agricultural crops in the Russian Federation in 2020 / Federal State Statistics Service (Rosstat). M., 2021. Part 1; Gross harvest and yield of crops in the Russian Federation in 2021 / Federal State Statistics Service (Rosstat). M., 2022. Part 1.

tion, the government of Finland develops and implements the program called "Rye" aimed at popularization and increase in the consumption of rye flour products. To achieve these goals, research groups have been established at the country's leading universities, working in close cooperation with the scientists of other European countries. As part of the program, the Finnish government and bakery companies opened the Information Center "Bread", which on the basis of ongoing scientific research was engaged in educational activities among the population. The result was not long in coming - the Finns have for many years shown a positive trend in the consumption of rye bread [3]. Today, everyone in Finland knows that it is necessary to consume about 25 g of fiber per day, 5 g of which, according to Finnish scientists, can be obtained from one slice of whole-grain rye bread. According to recommendations, consumption of rye bread should provide 1/3 of calories per day, ie, six to nine pieces of 30 g for men, five to seven pieces for women [9]. Thus, the Finns have shown a good example of the introduction of food products made from rye flour into the diet of the population.

VARIETAL DIVERSITY, CROP AREAS, YIELDS, AND PRODUCTION

Currently in the Russian Federation, according to the official data posted on the website of the State Commission of the Russian Federation for the Testing and Protection of Breeding Achievements, 93 breeding achievements in winter rye are approved for use, among them the share of domestic breeding is 87.1%, foreign - 12.9%. For cultivation in the West Siberian region 18 sorts of exclusively domestic selection are recommended, four of them are tetraploid rye varieties (Vlada, Siberia, Siberia 4, Tetra short). In 2012-2022 five winter rye varieties, mostly of Siberian selection, were registered in Western Siberia (see Table 1).

Over the past 3 years, there has been a positive trend in the increase of the cultivated areas under the crop both in Russia as a whole and in the Novosibirsk Region and the Altai Territory in particular, which indicates the renewed demand and interest in the production of winter rye (see Table 2).

The winter type of plant development most fully corresponds to the conditions of the short growing season in Siberia, which allows a better use of the agroclimatic potential of the zone and obtain higher yields compared with the spring forms[7]. The average yield of winter rye is 2-3 cwt/ha lower than that of winter wheat (see Table 3).

Despite the small area under the crop, the varietal composition of rye is represented by more than ten varieties and hybrids. The undoubted leaders are varieties of the Siberian selection - Tetra short, Vlada, and Siberia, which were included in the State Register more than 15 years ago. Winter hybrid rye is also used in crop rotations (for example, KVS Aviator, KVS Ravo, ZU Forzetti). High share of row crops - over 20% - is also noteworthy (see Table 4).

The average winter rye yield in the Novosibirsk region and the Altai Territory in 2019-2021 did not exceed 25 c/ha (see Table 5). Since the individual components of yield during the growing season are influenced by various negative factors, only a small part of the potential yield is realized in practice. For example, German experts say that with average winter wheat yield of 60-70 centners/ha only 25-33% of potential yield is realized[8].

The data presented in Table 5 confirm this point of view: with an average maximum yield of 72.6 c/ha the share of using the yield potential is not higher than 34.2%. Such variety diversity in such a small area, the lack of new varieties, and low yields reduce the interest of producers in the crop and complicate seed production.

[7] *Artemova G.V.* Results and methods of winter rye breeding in conditions of Western Siberia // Achievements of Science and Technology of AIC. 2007. N 12. pp. 16-17.

[8] *Shpaar D.* Grain crops: cultivation, harvesting, processing and use. M., 2008. 656 p.

Табл. 4. Объемы высева сортов и гибридов озимой ржи на территории Новосибирской области в 2019–2021 гг., т

Table 4. Sown varieties and hybrids of winter rye in the Novosibirsk region in 2019-2021, tons

Variety/hybrid	2019	2020	2021
For the Novosibirsk region as a whole	2739,5	4900,8	4043,4
Vlada (2007)	1000,3	1301,6	1026,5
Tetra korotkaya (1986)	987,6	1652,2	1809,4
Sibir (1999)	120,0	342,2	92,0
In memory of Kunakbaev (2010)	50,0	299,7	90,0
Bukhtarminskaya (1992)	12,0	3,7	22,6
KVS Aviator (2019)	–	64,8	5,9
Petrovna (2003)	–	10,0	8,0
KVS Ravo (2016)	–	25,0	0,6
KVS Eterno (2018)	–	–	1,0
ZU Forzetti (2018)	–	–	0,7
Helltop (2016)	–	9,6	–
Row	569,6	1192,0	986,7

Note. Here and in Table 7 the year of inclusion in the State Register is given in parentheses.

Finding ways to restore the sown areas and development of the grain market is the challenge not only for the agrarians, but also for the industry research institutes. The solution of the grain problem in the context of the development of the winter rye market is possible by increasing the consumption of rye products by the population, which contributes to improving the quality and longevity of life [10, 11].

The main use of winter rye is traditionally the production of flour, bread and bakery products [4, 12]. According to Rosstat, the volume of rye flour production in 2016-2020 remained at the level of 600 thousand, i.e., less than 10% of all flour produced in the country (see Table 6). At the same time, much less bread and bakery products from rye flour were produced in the same period.

Real rye bread is much healthier than wheat bread. Rye is the least caloric of all crops and serves as an excellent raw material for the production of healthy food. In Russia, 80% of diseases is associated with nutrition. This is not surprising, given that bread, which once nourished and preserved the strength and health of the Russian people, since the 1960s has become a mediocre product. People, ennobling flour, threw out together with bran practically the most valuable part of grain. Rye grain and rye bread from roughage flour as a treasure trove

Табл. 5. Средняя урожайность озимой ржи и доля использования потенциала урожайности в Новосибирской области и Алтайском крае в 2019–2021 гг.[7, 9]

Table 5. Average winter rye yield and percentage of use of the yield potential in the Novosibirsk region and the Altai Territory in 2019-2021[7, 9]

Year	Average yield, c/ha		Average maximum yield (according to the State Register), c/ha	% of yield potential utilization	
	Altai Territory	Novosibirsk region		Altai Territory	Novosibirsk region
2019	24,8	22,3	72,6	34,2	30,7
2020	19,6	17,2		27,0	23,7
2021	19,9	24,8		27,4	34,2

[9]Characteristics of plant varieties included in the State Register of the Breeding Achievements Approved for Use. URL: https://gossortrf.ru/gosreestr/

Табл. 6. Производство различных видов муки, хлеба и хлебобулочных изделий в России в 2016–2020 гг., тыс. т[10]

Table 6. Production of flour, bread and bakery products by type in the Russian Federation in 2016-2020, thousand tons[10]

Production	2016	2017	2018	2019	2020
Flour from cereals, vegetables and other vegetable crops; mixtures from them	9775	9610	9606	9419	9178
Such as:					
wheat and wheat-rye flour	9005	8837	8768	8607	8382
rye flour	595	608	659	647	609
Short-lived bakery products	6082	5935	5777	5614	5319
Such as:					
wheat flour bread	2273	2174	2140	2129	1918
wheat and wheat-rye flour bread	1839	1761	1710	1613	1522
bakery products from wheat and wheat-rye flour	46,5	43,9	59,3	27,4	17,5

of useful substances and highly effective health remedy should again take the leading place in human life [3].

Despite all the difficulties, agrarians of the Novosibirsk region and all of Western Siberia are trying to increase the efficiency of rye crops, including through the sowing of hybrids. According to the Gossortkommission (State Commission of the Russian Federation for the Testing and Protection of Breeding Achievements), the maximum yield of rye hybrids significantly exceeds the yield of the varieties (see Table 7). Also, hybrid forms of rye, unlike varieties, have alignment of stems, and are able to compensate for fallen plants. Due to the high productive bushiness, seeding rates of the hybrids are much lower, which allows to save on the seeding material.

It should be noted that winter rye varieties have better winter hardiness than hybrid forms. There are a number of unfavorable factors in the production of winter rye grain: limited markets and intended use; lower purchase prices compared to many crops of the grain group; insufficient technical equipment of grain production [1, 10].

Табл. 7. Максимальная урожайность сортов сибирской селекции и гибридной озимой ржи, включенных в Госреестр, ц/га (см. сноску 9)

Table 7. Maximum yield of the varieties of Siberian breeding and hybrid winter rye included in the State Register, c/ha (see footnote 9)

Variety/Hybrid	Maximum yield obtained at the state crop testing site
Vlada (2007)	58,0
Irina (2004)	60,8
Petrovna (2003)	62,4
Sibirskaya 87 (2011)	66,8
Sibir 4 (2016)	56,6
Sudarushka (2021)	56,4
KVS Aviator (2019)	92,0
KVS Prommo (2018)	95,0
KVS Ravo (2016)	85,9
KVS Tajo (2021)	126,0
KVS Eterno (2018)	123,4

[10]Industrial production in Russia. 2021: statistical digest / Federal State Statistics Service (Rosstat). M., 2021. 305 p.

[11]GOST R 52325-2005. Seeds of agricultural plants. Variety and sowing qualities. General technical conditions (with amendments). Moscow: Standartinform, 2005; GOST 12038-84. Seeds of agricultural crops. Methods for determination of germinating ability (as amended and supplemented) // Seeds of agricultural crops. Methods of Analysis: Collection of State Standards. Moscow: Publishing house of standards, 2004; GOST 12041-82. Seeds of agricultural crops. Method for determination of humidity (as amended) // Seeds of agricultural crops. Methods of Analysis: Collection of State Standards. Moscow: IPK Standard Publishers, 2004.

One of the important conditions for obtaining high yields of winter rye is sowing of high-quality seeds. Sowing qualities of seeds are regulated by GOSTs[11], characterized by indicators of germination, moisture, weediness, germination energy, etc.

Due to the anatomical and morphological features (specifically pointed shape of the grain, the germ root protruding beyond the grain, thin fruit and seed shells), rye seeds are more injured during harvesting and post-harvesting compared to the seeds of other cereals. Thus, up to 50% of the seeds can be injured in the germ area. To protect such seeds from soil microorganisms, they should be treated before sowing. The treatment is carried out mainly against fusarium root rot, snow mold, and Helminthosporium spot disease. Together with disinfection it is necessary to treat the plants with biological stimulants and micronutrients. As a result of such measures plants resistance to external conditions of abiotic and infectious nature increases. The efficiency of seed pretreatment with a complex of preparations is due to the fact that in this case the effect on the organism occurs in the earliest period of its development, when it is particularly sensitive to external conditions[12].

The sowing date is decisive in rye cultivation technology, as it affects the autumn development of plants, the degree of their tillering and overwintering. In a number of farms in the southern forest-steppe of the Novosibirsk region in 2021 with late sowing dates it was noted that plants in the autumn period did not have time to properly germinate and accumulate the necessary nutrients for overwintering, as a result, such plants were subjected to frost. Since after the harvest of the forecrop there is little time to prepare the soil for sowing winter rye and often farms do not have time to carry out all agronomic techniques due to weather conditions, agricultural producers do not pay proper attention to the culture in question. In addition, the situation is complicated by the fact that in the region the variety diversity of winter rye is represented by a small set of varieties and the variety renewal is slow. Therefore, it is necessary to form and study the collection of rye varieties and hybrids to determine the optimal for the conditions of Western Siberia samples.

CONCLUSION

Interest in winter rye is gradually increasing, but agricultural producers refer to the technology of cultivation of this crop, often for objective reasons, on the residual principle, do not pay the necessary attention to agricultural engineering, soil preparation, do not observe the depth and time of sowing, which ultimately leads to loss of yield and reduction of product quality. Under optimal timing of sowing winter rye in Western Siberia to prevent damage of the winter grain crop area by diseases and pests, seed dressing should be envisaged. It is necessary to form a collection of varieties and hybrids of the culture, which will reveal their genetic and biological potential for the purpose of further breeding. Such research will increase the interest of agricultural producers, promote the inclusion of winter rye in crop rotations and increase production volumes.

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ОЦЕНКА ГОЛОЗЕРНЫХ ФОРМ ОВСА ЯРОВОГО ПО ЭЛЕМЕНТАМ СТРУКТУРЫ УРОЖАЯ В УСЛОВИЯХ СЕВЕРНОГО РЕГИОНА

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В связи с увеличением в последние годы интереса к возделыванию и использованию голозерного овса была произведена оценка голозерных образцов овса ярового конкурсного сортоиспытания по урожайности зерна и элементам ее структуры. Исследования проведены в 2013–2021 гг. Изучено 11 голозерных образцов овса ярового селекции Федерального исследовательского центра «Немчиновка». В качестве стандарта использован сорт Тюменский голозерный. В ходе эксперимента урожайность образцов варьировала от 1,9 до 2,9 т/га. По урожайности выделились четыре образца: 52h2467 (2,9 т/га), 38h2273, 11h2619 (по 2,5 т/га у каждого) и 2h2348 (2,3 т/га). Прибавка к стандартному сорту у указанных образцов составила 0,1–0,7 т/га при $НСР_{05}$ = 0,13–0,53 т/га. Максимальную урожайность зерна (на 32% больше стандарта) в конкурсном сортоиспытании показал образец 52h2467. За 9 лет исследований наибольшая урожайность наблюдалась при продуктивной кустистости 1,1–1,4 шт., массе 1 тыс. зерен 30,2–35,2 г и массе зерна с метелки 0,90–2,06 г. Согласно результатам корреляционного анализа, именно продуктивная кустистость (r = 0,72), масса зерна с метелки (r = 0,70) и масса 1 тыс. зерен (r = 0,38) являются основными элементами структуры урожая, оказывающими наиболее сильное влияние на урожайность зерна в условиях Северного региона.

Ключевые слова: овес яровой, голозерные формы, урожайность, масса зерна с метелки, масса 1 тыс. зерен

EVALUATION OF NAKED FORMS OF SPRING OATS BY ELEMENTS OF THE CROP STRUCTURE IN THE CONDITIONS OF THE NORTHERN REGION

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Due to the increased interest in the cultivation and use of naked oats in recent years, the evaluation of naked samples of spring oats of competitive variety testing by grain yield and the elements of its structure was carried out. The studies were conducted in 2013-2021. Eleven naked spring oat samples of the "Nemchinovka" Federal Research Center selection were studied. The Tyumensky Golozerny variety was used as a standard. During the experiment, sample yields ranged from 1.9 to 2.9 t/ha. Four samples stood out in terms of yield: 52h2467 (2.9 t/ha), 38h2273, 11h2619 (2.5 t/ha each), and 2h2348 (2.3 t/ha). The increase to the standard variety in these samples was 0.1-0.7 t/ha with LSD_{05} = 0.13-0.53 t/ha. The maximum grain yield (32% more than the standard) in a competitive variety trial showed the sample 52h2467. During the 9 years of research the highest yield was observed with productive bushiness 1.1-1.4 units, the weight of 1 thousand grains 30.2-35.2 g and the weight of grains per a panicle 0.90-2.06 g. According to the results of the correlation analysis, the productive bushiness (r = 0,72), the weight of grains per a panicle (r = 0,70) and the weight of 1 thousand grains (r = 0,38) are the main elements of the crop structure, which have the strongest impact on the yield of grain in the Northern region.

Keywords: spring oats, naked forms, yield, grain weight from a panicle, weight of 1000 grains

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INTRODUCTION

Spring oats (Avena sativa L.) is one of the most common and important cereal crops in the northern region of the Russian Federation. In our country, as well as in the rest of the world, glumiferous oats is more common. However, in recent decades there has been a growing interest in naked-grain forms [1]. They are, in fact, a new crop in agriculture [2]. In Russia, the beginning of introduction of naked oats dates back to 2000, when the Tyumensky Golozerny variety was included in the State Register. Breeding work with naked-grain forms of spring oats in the Arkhangelsk region has been carried out since 2013. As of 2021, 16 varieties of naked- grain oats were included in the State Register of Breeding Achievements Approved for Use, while not a single variety was released in the Northern region[1].

Interest in the cultivation of huskless oats has significantly increased in recent years in most countries of the world. This is due to the increased dietary and therapeutic and prophylactic properties of such grain. Naked oats (*Avena sativa* subsp. *Nudisativa* (Husn.) Rod. et Sold.) are more technologically advanced in processing due to the absence of the film and are superior to filmy oats in nutritional value, protein, oil and starch content [3-5]. At present, naked oats are becoming increasingly important for agricultural production and processing industry.

The potential of a variety largely depends on the conditions of the growing season, so currently the priority is the cultivation of stable in yield, ecologically plastic, resistant to biotic and abiotic factors of the environment varieties[2]. Undoubtedly, the creation and introduction of naked grain varieties will allow to produce high-quality grain in the conditions of the Northern region of Russia.

The purpose of the study is to evaluate naked-grain samples of spring oats of competitive variety trials by grain yield and elements of its structure.

The main task is to carry out a comparative assessment of naked-grain oat samples by the basic elements of productivity.

MATERIAL AND METHODS

The study was conducted in the nurseries of competitive variety trials of spring oats in 2013-2021 on the experimental field of the N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences (Arkhangelsk region, Kotlas). The research material consisted of two varieties and nine samples of the breeding material of naked-grain oats compared with the standard - Tyumensky Golozerny variety. The soil of the experimental plot was characterized as highly cultivated sod-podzolic. Annual crops were used as a forecrop. Soil samples were taken according to GOST[3]. By mechanical com-

[1]State Register of the Breeding Achievements Approved for Use. Moscow: Rosinformagrotech, 2021. T. 1: Plant varieties. 719 p.

[2]*Khaletsky S.P., Vlasov A.G., Shempel Z.V., Trushko A.A.* Main directions and results of oat breeding // Strategies and priorities of agriculture and field crops breeding in Belarus: materials of the international scientific and practical conference Zhodino, 2017. pp. 262-263.

[3]GOST 28168-89. Soils. Sampling. Moscow: Standartinform, 2008. 7 p.

position the soil is heavy loamy gleyic, characterized by high humus content (3.7%). The reaction of the soil solution is neutral (pH = 6.5). The content of phosphorus in 100 g of soil was 23.5 mg/g, potassium - 27.8 mg/g (by Kirsanov), total nitrogen - 0.11%[4]. Plowing horizon thickness reached 20-22 cm. Agronomic techniques in the experiments were those generally accepted in the area, with minimal material and technical inputs.

The nursery by the type of competitive variety trials was sown at the rate of 6 million germinated grains per 1 hectare. The repetition was 4-fold. The registration plot was 10 m^2. Setting of experiments, phenological observations, field registration and yield structure determination were carried out according to the methodical guidelines on barley and oat breeding and the International Classifier CMEA of the Avena genus[5, 6]. For the structural analysis the sheaves were taken from 1 m in four repetitions during the period of the end of waxing - beginning of full ripeness of grain. Such elements of the yield structure as productive bushiness, panicle length, number of spikelets and grains in panicle, weight of grains per panicle, weight of 1 thousand grains were studied. Correlation analysis was used to estimate the interrelation of the grain productivity and the yield structure elements. The correlation relation was evaluated according to B.A. Dospekhov: $r < 0,3$ - weak, $r = 0,3$-$0,7$ - medium, $r > 0,7$ - strong[7]. Statistical data processing was performed according to B.A. Dospekhov's field experiment method[8] using Microsoft Office Excel 2007, Agros 2.07 computer program package, and StatGraphics 5.1 program from Windows.

During the experiment, climatic conditions differed in heat and moisture availability. The period of multi-year studies (2013-2021) is presented in the analysis of the dynamics of the main meteorological indicators.

According to A.V. Bykova et al.[9], in recent years in the Kotlassky District of the Arkhangelsk region there is a tendency towards an increase in the temperature regime throughout the growing season (see Fig. 1).

According to the sum of effective temperatures during the whole period of research there was an increase of the climatic norm compared to the average long-term data (1067°), except for 2017 (1049°). Lack of moisture and high temperatures were recorded in 2013 and 2016. Plant vegetation in 2013, 2016, and 2021 occurred at elevated sums of effective temperatures, exceeding the long-term average by 401, 464, and 390°, respectively (37-43% of normal). By the sum of effective temperatures, 2017 was at the level of the multiyear average.

The amount of precipitation in 2015, 2019 exceeded the average annual data by 1.5 times (337-367 mm). The driest was 2013 - the amount of precipitation was slightly below the norm. Weather conditions in 2013, 2020 and 2021 were characterized by a very uneven distribution of precipitation by ten-day periods, in some ten-day periods of June - August precipitation was absent.

According to the grading, moisture during the growing season is divided into: 1) optimal, if HTC = 1,0-1,5; 2) excessive, if HTC > 1,6; 3) insufficient, if HTC < 1,0; 4) weak, if HTC < 0,5[10]. The average value of the hydrothermal coefficient for the conditions of the Arkhangelsk region is from 1.5 to 2.5. In 2013-2021, the average value of HTC reached 1.7 (see Fig. 2), which corresponds to excessive moisture.

[4] Results of the agrochemical survey of soils of FSUE "Kotlasskoye" agricultural lands of the Rosselkhozakademiya of the Kotlassky District and the program for maintaining soil fertility. Arkhangelsk, 2019, 32 p.

[5] Methodological guidelines for the selection of barley and oats. Kirov, 2014. 64 p.

[6] International CMEA Classification of the genus *Avenal*. Saint-Petersburg, 1984. 38 p.

[7] *Dospekhov B.A.* Methodology of field experience (with the basics of statistical processing of research results). 5-th edition, revised and extended. Moscow: Agropromizdat, 1985. 351 p.

[8] *Dospekhov B.A.* Methodology of Field Experience. Moscow: Alliance, 2014. 351 p.

[9] *Bykova A.V., Maltseva N.E., Pavlova D.S., Subbotina M.N., Soklakova O.S., Lukashova O.P.* Impact of Climate Change on Agriculture // Natural and Mathematical Sciences in the Modern World: Proceedings of the 14th International Scientific and Practical Conference Novosibirsk, 2014. pp. 114-121.

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In terms of the degree of moisture, the highest HTC was recorded in 2019; the optimum ranged from 1.2 to 1.4 in 2013, 2016, 2020, and 2021.

Agrometeorological data were provided by the Northern Hydrometeorology and Environmental Monitoring Department of the Hydrometeorological Center (Kurtsevo post).

RESULTS AND DISCUSSION

There were 11 naked oats specimens in the nursery of competitive variety trials in 2013-2021. Table 1 shows the data on productivity of the studied variety samples.

The elements of grain productivity play no less important role in increasing the yield [6]. The value of productivity is composed of the total elements of the structure: the mass of 1 thousand grains, grain number, the mass of grain per panicle, productive bushiness.

According to the results of the studies, the average yield of the samples for these years ranged from 1.9 to 2.9 t / ha, the standard variety Tyumensky Golozerny value of this indicator was 2.2 t / ha. According to the yield four naked-grain samples stood out: 52h2467 (2,9 t/ha), 38h2273, 11h2619 (2,5 t/ha each) and 2h2348 (2,3 t/ha). Addition to the standard in this case was 0.1-0.7 t/ha. The maximum yield was demonstrated by the variety 52h2467, exceeding the standard by 32%.

The duration of the growing season is a trait directly related to the yield and quality of grain [7, 8]. The vegetation period of the studied variety samples averaged 81-95 days per year.

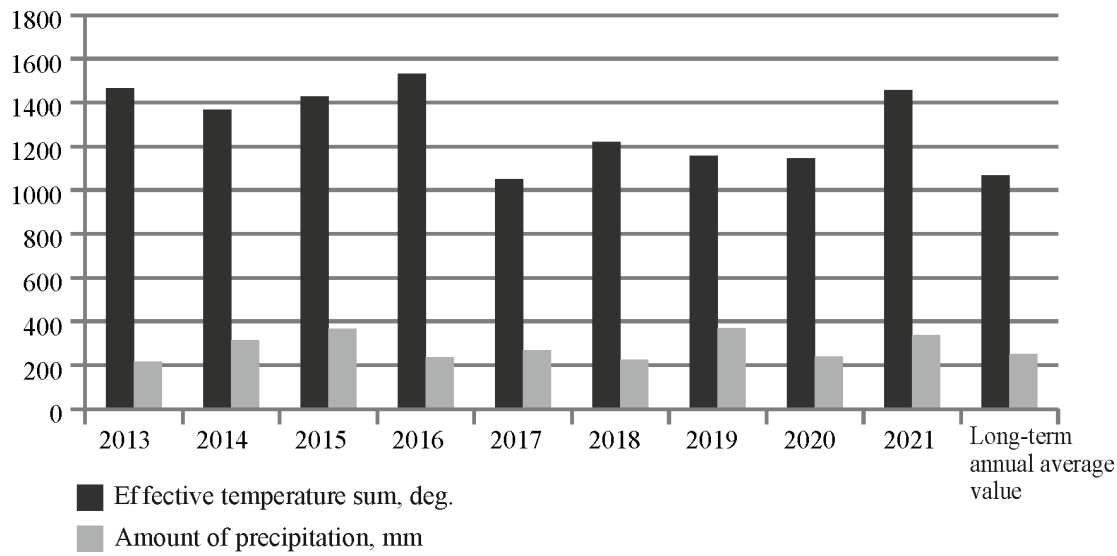

Рис. 1. Сумма эффективных температур и количество выпавших осадков за вегетационный период (2013–2021 гг., д. Курцево, Архангельская область)

Fig. 1. The sum of effective temperatures and the amount of precipitation during the growing season (2013-2021, Kurtsevo, Arkhangelsk region)

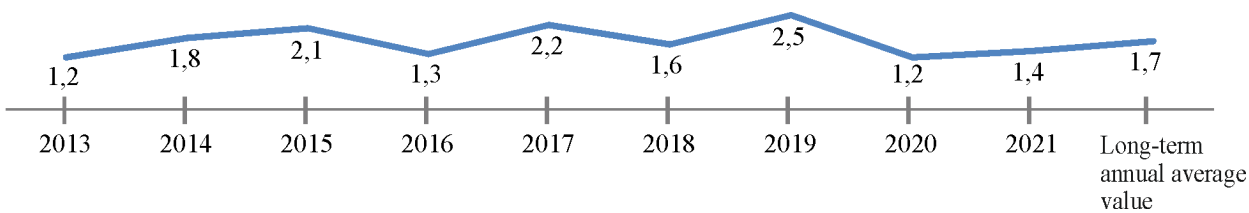

Рис. 2. Величина гидротермического коэффициента за вегетационный период (2013–2021 гг., д. Курцево, Архангельская область)

Fig. 2. Hydrothermal coefficient for the growing season (2013-2021, Kurtsevo, Arkhangelsk region)

Табл. 1. Урожайность голозерных сортообразцов овса ярового, участвовавших в конкурсном сортоиспытании (2013–2021 гг.), т/га

Table 1. Yield of naked varieties of spring oats in competitive variety testing (2013-2021), t/ha

Variety	Year									Average yield
	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Tyumensky Golozerny (standard)	2,9	3,1	2,7	1,4	1,7	1,2	2,7	2,3	2,1	2,2
38h2273	2,9	2,8	3,1	1,8	1,8	–	–	–	–	2,5
2h2348	2,7	3,1	3,3	1,3	1,7	–	–	2,0	2,0	2,3
11h2267	1,8	3,2	3,0	1,8	–	–	–	–	–	2,5
H 2619	–	–	2,6	–	2,1	1,4	2,6	–	–	2,2
57h2396	–	–	2,6	1,4	1,7	–	–	–	–	1,9
H 2588	–	–	–	2,1	2,4	1,1	2,4	–	–	2,0
H 2618	–	–	–	–	2,0	1,3	2,3	–	–	1,9
Nemchinovsky 61	–	–	–	–	–	–	–	2,1	2,0	2,1
52h2467	–	–	–	–	–	–	–	3,2	2,6	2,9
Azil	–	–	–	–	–	–	–	1,8	2,0	1,9
On average by years	2,6	3,1	2,9	1,6	1,9	1,3	2,5	2,3	2,1	2,3
LSD_{05}	0,53	0,17	0,29	0,31	0,27	0,13	0,18	0,55	0,26	–

Табл. 2. Хозяйственно-ценные признаки голозерных сортообразцов овса ярового (2013–2021 гг.)

Table 2. Indicators of economically valuable traits of naked samples of spring oats (2013-2021)

Variety	Yield, t/ha	Ratio to the standard, %	Vegetation period, days	Thousand kernel weight, g	Number of filmy grains, %	Infestation with loose smut, pcs. /m^2
Tyumensky Golozerny (standard)	2,2	–	87	27,9	1,24	0,2
38h2273	2,5	114	84	33,9	1,36	–
2h2348	2,3	105	83	30,2	1,77	0,7
11h2267	2,5	114	85	32,7	1,30	–
H 2619	2,2	100	95	27,6	1,27	0,5
57h2396	1,9	86	81	35,8	1,46	0,1
H 2588	2,0	91	89	28,3	1,28	1,2
H 2618	1,9	86	94	28,0	1,65	0,7
Nemchinovsky 61	2,1	96	85	32,6	0,59	–
52h2467	2,9	132	83	35,2	1,35	–
Azil	1,9	86	83	32,1	1,03	–
LSD_{05}	0,32	–	–	3,05	0,31	–

Thus, the considered samples mainly belong to the mid-ripening, samples H 2618 and H 2619 - to the middle-late (see Table 2).

High filminess is a negative trait in naked grain forms of oats. In our studies, the proportion of filmy grains was 0.59-1.77%, in the standard variety Tyumensky Golozerny - 1.24%. Nemchinovsky 61 (0.59%) was characterized by the minimum opacity of grains on average for 2013-2021, the other samples significantly (by 0.21-0.53%) exceeded the standard for this indicator.

During the years of research there were cases of disease such as loose smut. The number of affected plants ranged from 0.1 to 1.2 pcs/m^2, in Tyumensky Goloserny variety it was 0.2 pcs/m^2. Resistance to loose smut was shown in samples 38h2273, 11h2267, 52h2467, Nemchinovsky 61 and Azil.

Structural analysis of the samples was performed during the experiment (see Table 3).

Productive bushiness is one of the important features that determine the yield. In our experiments, the average value of productive bushiness in the studied cultivars was 1.2 stems and ranged from 1.0 (very weak) to 1.4 (weak).

The value of the variety is determined by its productivity, which is in direct relation to such indicators as the number of spikelets and grains in the panicle, the mass of grains from the panicle, the mass of 1 thousand grains.

By the weight of 1 thousand grains naked forms are inferior to filmy forms on average by 8 g, which is the main reason for their lower yields. In the experiment six samples were distinguished by this indicator: 57h2396, 52h2467, 38h2273, 11h2267, Nemchinovsky 61, Azil (see Table 2), which corresponds to a very high mass of 1 thousand grains according to the international classifier CMEA and significantly exceeds the characteristics of the variety Tyumensky Goloserny. On average, the weight of 1

Табл. 3. Элементы структуры урожая голозерных сортообразцов овса ярового, участвовавших в конкурсном сортоиспытании (2013–2021 гг.)

Table 3. Elements of the crop structure of naked oat varieties in competitive variety testing (2013-2021)

Variety	Yield, t/ha	Panicle length, cm	Productive bushiness, pcs.	Number of spikelets in a panicle, pcs.	Number of grains per a panicle, pcs.	Weight of grains from a panicle, g
Tyumensky Golozerny (standard)	2,2	14,5	1,0	22,5	38,7	1,17
38h2273	2,5	17,3	1,1	22,5	42,8	1,05
2h2348	2,3	16,6	1,1	21,0	37,6	0,95
11h2267	2,5	17,8	1,2	23,0	35,8	0,90
H 2619	2,2	15,2	1,0	22,8	43,1	1,20
57h2396	1,9	18,7	1,1	27,3	50,0	0,77
H 2588	2,0	15,4	1,0	25,8	42,1	1,0
H 2618	1,9	15,5	1,0	23,1	46,2	1,15
Nemchinovsky 61	2,1	14,9	1,2	20,6	20,4	1,09
52h2467	2,9	11,6	1,4	21,7	21,0	2,06
Azil	1,9	13,3	1,1	18,2	31,0	0,86
LSD_{05}	0,32	2,04	0,12	2,44	9,60	0,34

Табл. 4. Коэффициенты корреляции средних значений элементов структуры урожая и продуктивности голозерных сортообразцов овса ярового (2013–2021 гг.)

Table 4. Correlation coefficients between the average indicators of the elements of the crop structure and the productivity of naked varieties of spring oats (2013-2021)

Indicator	Productive bushiness, pcs.	Thousand kernel weight, g	Panicle length, cm	Number of spikelets in a panicle, pcs.	Number of grains per a panicle, pcs.	Weight of grains from a panicle, g	Vegetation period, days
Yield, t/ha	0,72	0,38	−0,25	−0,18	−0,46	0,70	−0,27
Productive bushiness, pcs.		0,75	−0,35	−0,27	−0,75	0,61	−0,57
Thousand kernel weight, g			0,13	0,03	−0,31	0,13	−0,81
Panicle length, cm				0,57	0,67	−0,73	−0,11
Number of spikelets in a panicle, pcs.					0,66	−0,17	0,13
Number of grains per a panicle, pcs.						−0,53	0,34
Weight of grains from a panicle, g							0,08

thousand grains in the studied samples ranged from 27.6 to 35.8 g, in the standard variety Tyumensky Goloserny it was 27.9 g.

The panicle length of the naked spring oat specimens reached 11.6-18.7 cm. Four samples were distinguished by the length of the panicle: 57h2396, 11h2267, 38h2273, 2h2348, in the standard this value was at 14,5 cm.

Oat productivity is determined mainly by panicle weight and the degree of its ear grain content. In the studied samples the average number of grains in a panicle was fixed in the range of 20,4-50,0 units. In comparison with the standard (38,7 pcs) the sample 57h2396 stood out.

Grain weight per head in the experiment ranged from 0.77 to 2.06 g. The highest average weight of grain per head (2.06 g) was noted in the sample 52h2467, in the variety Tyumensky Golozerny it was 1.17 g.

The average number of spikelets in a panicle ranged from 18.2 to 27.3 units. Compared with the standard Tyumensky Goloserny (22.5 pcs), the varieties 57h2396 and H 2588 stood out.

A correlation analysis of the yield and yield structure elements by indicators for 2013-2021 was carried out.

Significant relationship between productivity and productive bushiness (r = +0.72), productivity and grain weight per panicle (r = +0.70), average relationship between grain productivity and grain weight per panicle (r = +0.38) were found (see Table 4).

In determining the elements which ensure productivity of oats, the significant relation between productive bushiness and the weight of 1 thousand grains (r = +0,75), average connection between the number of ears in panicle and the number of grains per panicle (r = +0,66), panicle length and the number of ears in it (r = +0,57) were noted. Negative correlation between the weight of 1 thousand grains and the vegetation period, productive bushiness and the number of grains per panicle, panicle length and the weight of grains per panicle were established.

The correlations between the weight of 1 thousand grains and the length of the panicle, the weight of grains per panicle and the duration of the growing season were not significantly affected. Negative correlations of the number of grains per head with almost all elements of the yield structure were observed.

According to the results of the correlation analysis, it is productive bushiness (r = 0,72), the weight of grains per head (r = 0,70) and the weight of 1 thousand grains (r = 0,38) can be attributed to the elements of the yield structure, which have a significant impact on the yield of grain in these conditions.

CONCLUSION

In order to carry out further breeding work during the competitive variety testing, four naked spring oat varieties with high yield indices were identified: 52h2467, 38h2273, 11h2619, 2h2348. When identifying the priority elements of the yield structure in the conditions of the Northern region and the correlation relationships between them, it was found that the greatest influence on the yield of the naked forms of oat grain had: productive bushiness, the grain weight per panicle and the weight of 1 thousand grains.

Overall, for 9 years (2013-2021) there is a significant strong relationship between productive bushiness and the weight of 1 thousand grains (r = +0.75), the average relationship between the number of spikelets in the panicle and the number of grains per panicle (r = +0.66), the length of the panicle and the number of spikelets in it (r = +0.57).

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РАЗРАБОТКА ТЕХНОЛОГИИ ПОЛУЧЕНИЯ ОЗДОРОВЛЕННОГО СЕМЕННОГО МАТЕРИАЛА КАРТОФЕЛЯ СОРТА ЧАРОИТ

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Изучено влияние питательных сред различного состава на рост и развитие оздоровленных микрорастений картофеля сорта Чароит в условиях *in vitro*. Рассмотрено три варианта составов питательной среды: питательная среда по прописи Мурасиге-Скуга, среда Мурасиге-Скуга со сниженным содержанием минеральных компонентов до 1/2 и до 1/3. Изучены следующие параметры микрорастений: высота, ризогенез, число листьев и междоузлий, общая масса растения, масса листьев, масса корней, масса стебля, масса побега. На питательной среде с 1/2 минеральных компонентов высота микрорастений картофеля на 28-е сутки выращивания увеличилась на 12%, масса побега – на 17% за счет увеличения массы листьев на 33% и массы корневой системы в 2 раза, общая биомасса растений – на 28%. При использовании питательной среды с 1/3 минеральных компонентов для культивирования оздоровленных микрорастений картофеля сорта Чароит на 28-е сутки культивирования наблюдали уменьшение массы побега на 17% за счет снижения массы стебля (25%), масса корневой системы увеличилась на 140%. В данных вариантах питательной среды ризогенез начался раньше и протекал более активно, чем в контроле. Оптимальным вариантом для выращивания микрорастений *in vitro* определена среда с 1/2 содержанием минеральных компонентов от нормы. При аэрогидропонном выращивании растений с разной плотностью расположения (21, 27 и 55 растений/м^2) наблюдали увеличение высоты растений, выращиваемых на секциях установок с плотностью посадки 55 растений/м^2, на 27%. Растения с плотностью посадки 21 растение/м^2 отличались от других вариантов увеличенным числом стеблей. В урожае миниклубней доля фракций, пригодных для дальнейшего семеноводства, составляла более 50% при использовании на аэрогидропонных установках всех изучаемых плотностей посадки растений. Максимальное количество миниклубней зафиксировано при выращивании растений с плотностью посадки 55 растений/м^2, и данный вариант рекомендуется для использования при выращивании миниклубней картофеля сорта Чароит аэрогидропонным способом.

Ключевые слова: картофель, меристемная технология оздоровления, состав питательной среды, аэрогидропоника, плотность посадки растений

DEVELOPMENT OF TECHNOLOGY FOR OBTAINING HEALTHY SEED MATERIAL OF POTATO VARIETY CHAROIT

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The effect of nutrient media of different composition on the growth and development of healthy potato microplants of the Charoit variety under in vitro conditions was studied. Three variants of nutrient medium compositions were considered: nutrient medium according to Murashige-Skoog prescription, Murashige-Skoog medium with a reduced content of mineral components to 1/2 and to 1/3. The following microplant parameters were studied: height, rhizogenesis, number of leaves and internodes, total plant weight, leaf weight, root weight, stem weight, shoot weight. On a nutrient medium with 1/2 mineral components, the height of potato microgrowers on the 28th day of cultivation increased by 12%, the shoot weight - by 17% by increasing the weight of leaves by 33% and the weight of the root system twofold, the total plant biomass - by 28%. When using a nutrient medium with 1/3 of mineral components for cultivation of healthy potato varieties Charoit

microplants on the 28th day of cultivation, a decrease in the shoot weight by 17% was observed due to a decrease in the stem weight (25%), and the weight of the root system increased by 140%. In these variants of nutrient medium, rhizogenesis began earlier and proceeded more actively than in the control. A medium with 1/2 content of mineral components of the norm was determined to be optimal for growing microplants in vitro. When aerohydroponic plants were grown with different plant densities (21, 27, and 55 plants/m^2), a 27% increase in the plant height of the plants grown on plant sections with a planting density of 55 plants/m^2 was observed. The plants with a planting density of 21 plants/m^2 differed from the other variants by an increased number of stems. In the minituber yield, the proportion of fractions suitable for further seed production was more than 50% when using all planting densities studied on aerohydroponic plants. The maximum number of minitubers was recorded when growing plants with a planting density of 55 plants/m^2, and this option is recommended for use in the cultivation of minitubers of the potato variety Charoit by aerohydroponic method.

Keywords: potato, meristem technology, nutrient medium composition, aerohydroponics, planting density

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INTRODUCTION

Potato microclonal multiplication allows to obtain high-quality planting material devoid of viral infection, thus allowing to realize the potential of the variety. The transition to virus-free planting material allows to increase potato yields by at least 20%[1] [1-5]. Currently, potato seed production involves the cultivation of minitubers from revitalized potato microplants. The composition of the nutrient medium is one of the decisive factors influencing the growth and development of potato microplants. As a carrier of macro- and microelements, vitamins, carbohydrates and growth regulators, the nutrient medium has a great influence on the morphometric parameters of potato microplants, so it is necessary to select the optimal combination of its components [6-8].

In the work of N.V. Lebedeva[2] it is shown that the reduction of the mineral part of the Murashige-Skoog medium has a positive effect on the formation of plant explants. In addition, growing microplants on MS nutrient medium with full mineral part leads to inhibition of growth and development of potato.

It is also worth noting that the plants root better on the medium with a depleted mineral part[3].

A series of experiments to identify the effect of different concentrations of mineral part in the MS nutrient medium on potato microgrowers of the variety Charoit were carried out. Many factors are important in obtaining minitubers of potato on aerohydroponic modules: the composition of the nutrient solution, the spectral composition of light, aeration mode, etc. One

[1]*Dolanbaeva G.T., Nikolaeva V.N., Zharkova S.V.* Obtaining healthy potato planting material in vitro by apical meristem culture // Agrarian Science to Agriculture: Proceedings of XVII International Practical Conference (Barnaul, 9-10 February 2022). Barnaul, 2022. pp. 213-214.

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[3]*Shirokov A.I., Kryukov L.A.* Fundamentals of plant biotechnology: electronic teaching aid. Nizhny Novgorod: Nizhny Novgorod University, 2012. 49 p.

important and poorly understood issue is the density of plants on aerohydroponic modules [9-11]. I. Farran and A.M. Mingo-Castel [12] studied two variants of potato planting density: 60 and 100 plants/m^2. The best results were obtained with lower planting density, they were 802 minitubers/m m^2. S. Abdullateef and colleagues [13] reported that the highest number of minitubers per plant was obtained at a planting density of 25 plants/m^2, a total of 40.82. At the same time, the yield of potato plants per m^2 did not depend on the planting density. A series of experiments to identify the effect of different planting densities on the plant parameters and minituber yields in the cultivation of potato variety Charoit on aerohydroponic modules were conducted.

The purpose of the study is to investigate the effect of different compositions of nutrient media on the growth and development of potatoes during *in vitro* cultivation and different planting densities during cultivation on aerohydroponic modules.

MATERIAL AND METHODS

The work was carried out at the Siberian Research Institute of Agriculture and Peat - branch of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences (SibNIISKhiT - branch of SFSCA RAS) in 2020. The object of the experiments was revitalized maternal microclones of the potato *Solanum tuberosum* L. of the variety Charoit.

The variety Charoit is ultra-early, the period from planting to the beginning of the formation of a marketable crop is 60-70 days. The tuber is elongated-oval with very small buds. The skin is yellow. The flesh is creamy. The weight of a commercial tuber is 120-160 grams. The starch content is 14-17%. The taste is excellent. The marketability is 94-98%. The storability is 96%. It is resistant to the causative agent of potato cancer, viral diseases, and is moderately resistant to potato scab and rhizoctoniose [14, 15].

All microplants were diagnosed by real-time PCR before starting the experiment. Three variants of the nutrient medium compositions were studied (see Table 1).

The composition of the nutrient medium used as a control was selected on the basis of the data given in the literature[4] (see footnote 2) and was successfully used for several years by the authors of this work for cultivation of healthy potato microgrowers by microtransplanting.

During the experiment, potato cuttings were cultivated at 20-22 °C with a photoperiod of 16/8 h light/dark in the tubes for 28 days under illumination by OSRAM fluorescent lamps, cold daylight, the section illumination capacity was 5 thousand lx. Thirty plants were grown on each variant of the nutrient medium. The repeatability was threefold. The resulting potato plants in vitro were planted on Fagro series aerohydroponic modules in sections with different planting densities - 9 plants per section of the module (21 plants/m^2), 12 plants per section (27 plants/m^2) and 24 plants per section (55 plants/m^2). The variant with planting density of 55 plants/m^2 was used as a control variant in the experiment. This variant of planting density was chosen based on the analysis of literature data and design features of aerohydroponic system "Fagro" [16].

Cultivation of potato plants on aerohydroponic plants was carried out in two stages: firstly, under long day conditions (16-hour photoperiod) with nutrient solution for the first and second phases of growth (developed by Yu. Ts. Martirosyan), solution injection mode 40 sec, aeration 3 min at 20-22°C, then under short day conditions (10–12-hour photoperiod) using a nutrient solution for the third phase of the plant growth (development of Yu.Ts. Martirosyan), solution injection mode 1 min, aeration 15 min at 16-18°C.

The results were statistically processed using the Windows Statistica 10.0 software package. Mann-Whitney non-parametric test was used to compare numerical values.

[4] *Trofimets L.N., Boyko V.V., Anisimov B.V. et al.* Non-viral seed production of potatoes: recommendations. Moscow: Agropromizdat, 1990.

Табл. 1. Состав питательной среды для выращивания оздоровленных растений картофеля
Table 1. Nutrient medium composition for growing healthy potato plants

No.	Experiment option	1	2	3
	Title	MS medium (control), mg/l	MS medium with 1/2 mineral components content, mg/l	MS medium with 1/3 mineral components content, mg/l
Macrosalts				
1	NH_4NO_3	1650	825	550
2	KNO_3	1900	950	633,34
3	$CaCl_2\ 2H_2O$	440	220	146,67
4	$MgSO_4\ 4H_2O$	370	185	123,34
5	KH_2PO_4	170	85	56,67
Microsalts				
6	H_3BO_3	6,2	3,1	2,07
7	$MnSO_4 \cdot 4H_2O$	22,3	11,15	7,44
8	$CoCl_2 \cdot 6H_2O$	0,025	0,0125	0,0084
9	$ZnSO_4\ 7H_2O$	8,6	4,3	2,87
10	$CuSO_4\ 5H_2O$	0,025	0,0125	0,0084
11	$Na_2MoO_4\ 2H_2O$	0,25	0,125	0,084
12	KI	0,83	0,415	0,28
Ferric chelate				
13	$Fe_2SO_4\ 7H_2O$	27,8	13,9	9,27
14	Na_2-ЭДТА $\cdot 2H_2O$	37,3	18,65	12,44
Vitamins				
15	Thiamine	2,5	2,5	2,5
16	Pyridoxine	5	5	5
17	Ascorbic acid	2,5	2,5	2,5
Other				
18	Saccharose	30000	30000	30000
19	Agar-agar	7000	7000	7000

RESULTS AND DISCUSSION

The results of the study of different compositions of the nutrient medium on the growth performance of potato variety Charoit plants are presented in Table 2. In Table 2 and further the studied compositions of nutrient medium are numbered as follows:

1 – Murashige-Skoog medium for micropropagation (control);

2 – Murashige-Skoog medium for micropropagation with 1/2 mineral components;

3 – Murashige-Skoog medium for micropropagation with 1/3 mineral components.

The survival ability of the Charoit potato microgrowers on all the studied compositions of the nutrient medium was 100%.

Under the research data, the nutrient medium with the half content of mineral components resulted in an increase in the height of the grown potato microgrowers on the 21st (by 1.27 cm, or 14%) and on the 28th (by 1.35 cm, or 12%) day of development. When using the nutrient medium with 1/3 mineral components, an increase in the plant height on the 14th (1,39 cm, or 24%) and the 21st (1,07 cm, or 12%) day of development was also registered, but on the 28th day, only a tendency to an increase in this indicator (by 0,75 cm, or 7%) was noted. The studied compositions of the nutrient medium did not cause changes in the number of the internodes and leaves of healthy potato microgrowers of the variety Charoit. The tendency to an increase in the number of internodes was determined when using the nutrient medium with half the content of mineral components. Experimental data show that in the variants with reduced content of mineral components rhizogenesis began earlier and proceeded more actively than in the control.

The effect of different compositions of the nutrient medium on the morphological parameters of the growing plants is shown in Table 3.

Growing of potato variety Charoit microgrowers on the nutrient medium with 1/2 mineral components resulted in an increase in shoot mass by 0.06 g, or 17%, due to an increase in the leaf mass (by 0.05 g, or 33%) and the root system mass (by 0.05 g, or 100%). Total plant biomass was also increased (by 0.11 g, or 28%). When the nutrient medium with 1/3 mineral components was used, there was a 0.06 g (17%) decrease in the shoot mass (0.06 g, or 25%) due to a decrease in the stem mass (0.06 g, or 25%). At the same time, the mass of the root system, in contrast, was increased (by 0.07 g, or 140%).

The cost of the different variants of the nutrient medium is presented in Table 4.

The nutrient media studied differ from each other in cost, but insignificantly (see Table 4).

Табл. 2. Влияние различных составов питательной среды на ростовые показатели оздоровленных микрорастений сорта Чароит

Table 2. Effect of different compositions of nutrient media on the growth performance of the recovered Charoit microplants

Experiment option	Indicator	Days				
		3 rd	7 th	14 th	21 st	28 th
1	Height, cm	0,19 ± 0,02	1,63 ± 0,10	5,90 ± 0,32	8,99 ± 0,25	10,89 ± 0,24
2		0,25 ± 0,03	1,49 ± 0,10	6,94 ± 0,42	10,26 ± 0,38*	12,24 ± 0,34*
3		0,23 ± 0,03	1,53 ± 0,12	7,29 ± 0,37**	10,06 ± 0,39*	11,64 ± 0,39
1	Number of leaves, pcs.	0	2,29 ± 0,10	4,82 ± 0,14	6,04 ± 0,13	7,38 ± 0,12
2		0	2,17 ± 0,10	4,87 ± 0,16	6,36 ± 0,15	7,70 ± 0,16
3		0	2,27 ± 0,12	4,84 ± 0,12	6,11 ± 0,13	7,18 ± 0,15
1	Number of internodes, pcs.	0	1,06 ± 0,10	3,26 ± 0,16	4,83 ± 0,13	6,23 ± 0,13
2		0	0,98 ± 0,09	3,58 ± 0,20	5,16 ± 0,16	6,48 ± 0,17
3		0	1,00 ± 0,10	3,34 ± 0,17	4,80 ± 0,15	6,07 ± 0,16
1	Rhizogenesis, pcs.	21	59	90	90	90
2		26	81	90	90	90
3		25	82	90	90	90

Here and in Tables 3, 5:
* Differences are significant with $p < 0.05$ compared to the control.
** Differences are significant with $p < 0.01$ compared to the control.
*** Differences are significant with $p < 0.001$ compared to the control

Табл. 3. Влияние различных составов питательной среды на морфологические показатели оздоровленных микрорастений сорта Чароит на 28-е сутки выращивания

Table 3. Effect of different compositions of nutrient media on the morphological parameters of the recovered Charoit microplants on day 28 of cultivation

Experiment option	Weight of leaves, g	Stem weight, g	Shoot weight, g	Root system weight, g	Total biomass, g	Root system length, cm
1	0,15 ± 0,004	0,20 ± 0,006	0,35 ± 0,008	0,05 ± 0,002	0,40 ± 0,009	3,95 ± 0,11
2	0,20 ± 0,005***	0,22 ± 0,005	0,41 ± 0,008***	0,10 ± 0,004***	0,51 ± 0,009***	4,32 ± 0,11
3	0,15 ± 0,007	0,15 ± 0,004***	0,29 ± 0,005***	0,12 ± 0,005***	0,40 ± 0,008	4,24 ± 0,10

The cheapest version is nutrient medium No. 3, containing 1/3 of mineral components.

Table 5 presents data on the effect of the planting density on morphometric parameters of revitalized potato plants during aerohydroponic cultivation.

Charoit potato plants grown on the aerohydroponic module sections at a density of 55 plants/m^2 differed from the other two variants by higher plant height (the difference was about 10 cm). In addition, the plants grown at a density of 21 plants/m^2 had a slightly higher number of stems per plant compared to the other variants.

The effect of the planting density on the yield and fractional composition of minitubers of the potato variety Charoit is shown in Table 6.

Analysis of the data presented in Table 6 shows that the maximum yield of minitubers per plant was in the variant 21 plants/m^2. At the same time, the maximum number of minitubers obtained from one section of the plant was noted in the variant with the density of 55 plants/m^2.

Табл. 4. Стоимость различных вариантов питательной среды

Table 4. Cost of different nutrient media options

No.	Nutrient medium composition variants	Price per 1 liter, roubles
1	Control	57,08
2	MS medium with 1/2 mineral components content	56,42
3	MS medium with 1/3 mineral components content	56,20

Табл. 5. Влияние плотности посадки на морфометрические параметры оздоровленных растений картофеля сорта Чароит при аэрогидропонном выращивании

Table 5. Influence of the planting density on the morphometric parameters of healthy potato plants of the Charoit variety in aerohydroponic cultivation

Experiment option	Culture period		
	Bedding	100th day of cultivation	
	Plant height, cm	Plant height, cm	Number of stalks, pcs.
1 (21 plants/m^2)	14,12 ± 0,58	33,44 ± 1,35***	2,17 ± 0,26***
2 (27 plants /m^2)	16,30 ± 0,26	33,54 ± 1,27***	1,58 ± 0,19*
3 (55 plants /m^2) (control)	14,25 ± 0,31	45,98 ± 1,19	1,13 ± 0,05

Табл. 6. Влияние плотности посадки на урожайность и фракционный состав миниклубней при выращивании оздоровленных растений картофеля сорта Чароит

Table 6. Influence of the planting density on the yield and fractional composition of minitubers when growing recovered Charoit potato plants

Experiment option	Number of minitubers per section unit, pcs.	Number of minitubers per a plant, pcs.	Share of minitubers of different fractions, %			Share of minitubers of the fractions suitable for seed production, %	Number of minitubers of the fractions suitable for seed production per one section unit, pcs.
			Small	Medium	Large		
1 (21 plants /m^2)	134,5	14,9	21,2	53,5	25,3	78,8	106
2 (27 plants /m^2)	149,5	12,5	22,1	51,8	26,1	77,9	117
3 (55 plants /m^2)	195	8,1	28,5	50,8	29,4	71,5	139

CONCLUSION

The use of the nutrient medium with a 2-fold reduced content of mineral components to grow revitalized Charoit microplants led to an increase in the plant height, increasing the total biomass by increasing the mass of the leaves and the root system. The plants were longer and thinner with massive leaves and root system. On the medium with 1/3 of mineral components the Charoit potato plants were distinguished by the reduced mass of shoots (due to the reduction of the stem mass) and the increased mass of the root system relative to the control. Experimental plants had a thinner stem, but a more developed root system.

For cultivation of healthy potato microplants of the Charoit variety both for accelerated production of a large number of plant copies and for further transplanting to aerohydroponic systems, the nutrient medium with 1/2 of mineral components is optimal from the studied compositions.

When aerohydroponic cultivation of the revitalized potato variety Charoit plants with different planting densities (21 plants/m^2, 27 plants/m^2 and 55 plants/m^2) was conducted an increase in the height of the plants grown in the plant sections with a density of 55 plants/m^2 was observed. Potato plants on aerohydroponic modules with a planting density of 21 plants/m^2 were distinguished by an increased number of stems.

In the minitubers yield the share of fractions suitable for further seed production was more than 50% when using aerohydroponic modules of all the studied planting densities. The maximum number of minitubers was recorded when growing plants with the planting density of 55 plants/m^2 and this option is recommended when growing minitubers of the potato variety Charoit by aerohydroponic method.

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ИСТОЧНИКИ УСТОЙЧИВОСТИ К ФИТОФТОРОЗНОЙ КОЖИСТОЙ ГНИЛИ ЗЕМЛЯНИКИ ДЛЯ СРЕДНЕГО УРАЛА

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Представлены результаты изучения гибридов земляники для дальнейшей селекции в период массового распространения заболеваний, способствующих недобору ягодной продукции, – серой и фитофторозной кожистой гнили ягод. Исследования выполнены в полевом опыте на Свердловской селекционной станции садоводства на коллекции живых растений открытого грунта в 2018–2021 гг. Объекты исследований – восемь элитных гибридов среднего и позднего сроков созревания, происходящих из семей: Соловушка × Totem, Соловушка × Dukat, Соловушка × Marmolada, Амулет × Marmolada. Контрольные сорта – Гейзер и Боровицкая. Изучение гибридов проведено в соответствии с общепринятыми методиками по комплексу хозяйственно ценных признаков и степени поражения грибной болезнью. В уральских условиях серая гниль отмечается почти ежегодно, фитофтора на ягодах – в отдельные годы. В благоприятные для развития фитофторы годы потери урожая у неустойчивых к заболеванию сортов среднего и среднепозднего сроков созревания могут быть значительными. На Среднем Урале болезнь наблюдают и на поздних сортах земляники. Установлено, что устойчивость к фитофторозной кожистой гнили контролируется полигенно при аддитивном влиянии нескольких генов и не зависит от рас возбудителя. Так как иммунитета у земляники к данному заболеванию нет, проведена работа с привлечением устойчивых сортов, выделенных при изучении в полевых условиях. В результате исследований выявлены устойчивые (с потерей урожая до 10%) среднеспелые гибриды 2-45-10 и 2-54-11, которые будут привлечены в селекционный процесс на признак устойчивости к фитофторозной кожистой гнили.

Ключевые слова: земляника, устойчивость, фитофторозная кожистая гниль, гибрид, источник

SOURCES OF STRAWBERRY RESISTANCE TO LATE BLIGHT LEATHERY ROT FOR THE MIDDLE URALS

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The results of the study of strawberry hybrids for further breeding in the period of mass spread of diseases contributing to the shortage of berry products - gray and late blight leathery rot of berries - are presented. The studies were carried out in a field experiment at the Sverdlovsk Horticultural Breeding Station on the collection of live plants in the open ground in 2018-2021. The objects of the study are eight elite hybrids of medium and late maturity, originating from the families Solovushka × Totem, Solovushka × Dukat, Solovushka × Marmolada, Amulet × Marmolada. The check varieties are Geyser and Borovitskaya. The hybrids were studied in accordance with the generally accepted methods for the complex of economically valuable characters and the degree of infestation by the

fungal disease. In the conditions of the Urals, gray rot is observed almost annually, and the late blight on berries - in some years. In the years favorable for the development of the late blight, yield losses in the varieties that are not resistant to the disease of medium and medium maturity dates can be significant. In the Middle Urals, the disease is also observed on the late varieties of strawberries. It was found that resistance to late blight leathery rot is controlled polygenetically through the additive effect of several genes and does not depend on the races of the pathogen. Since there is no immunity to this disease in strawberries, work was carried out with the use of resistant varieties isolated when studied in the field. As a result of the research the resistant (with yield loss up to 10%) medium-maturing hybrids 2-45-10 and 2-54-11 were identified, which will be involved in the breeding process for the trait of resistance to late blight leathery rot.

Keywords: strawberries; resistance, late blight leathery rot, hybrid, source

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INTRODUCTION

In the Middle Urals, as in many regions of strawberry cultivation, the main diseases causing berry rot are gray and phytophthora leathery blight [1-4]. While the lesion of gray rot is observed almost annually [5], the appearance of phytophthora rot on berries in the Ural conditions is observed in some years. This disease is promoted by the presence of dripping and liquid moisture during the formation and ripening of the crop, so the maximum development of the disease is observed after the rains[1].

Yield losses under the conditions favorable for the disease in susceptible varieties, mainly of middle and middle-late maturity dates, can be almost 100% [6, 7]. In the conditions of the Middle Urals, late varieties are also susceptible to the disease.

In recent years, studies have shown that resistance to *Phytophthora cactorum* (Leb. et Cohn) Schrot. causative agent) is controlled in garden strawberry polygenically and does not depend on fungus races [8-11]. In practical breeding, it is important to identify the sources of resistance in the field with their further involvement in hybridization[2].

Therefore, an effective way to solve this problem, which allows obtaining environmentally friendly berry products is the creation of new varieties of strawberry, combining in its

[1] *Benne R.* Industrial production of strawberries. Moscow: Kolos, 1978. 77 p.

[2] Program and methodology of varietal study of fruit, berry and nut crops (ed. by E.N. Sedov). Orel: VNIISPK, 1999. pp. 416-443.

genotype the complex of economically valuable features with resistance to the disease.

The purpose of the research is to identify new initial forms of strawberry resistant to phytophthora leathery blight for further breeding.

The research objectives are:

– to study the breeding material for the disease resistance trait and the complex of economically valuable traits,

– to identify the sources of resistance for breeding based on the results of the study.

MATERIAL AND METHODS

The studies were performed in the field experiment at the Sverdlovsk Horticultural Breeding Station, a structural subdivision of the Ural Federal Agrarian Scientific Research Center of the Ural Branch of the Russian Academy of Sciences (UrFASRC UB RAS) in the collection of living outdoor plants "Gene pool of fruit, berry and ornamental crops in the Middle Urals" (Sverdlovskaya SSS UrFASRC UB RAS, Ekaterinburg) in 2018-2021. The objects of the research are eight elite hybrids of the garden strawberry of middle and late maturity dates. The control varieties for mid-ripening hybrids are Geyser, for the late ones - Borovitskaya.

The soil of the plot is sod-podzolic, medium loamy. The experiment was set up in the spring of 2017 and 2019. The planting scheme - 0.9 × 0.2 m. The hybrids for the study were planted in three replications, the placement in the experiment was randomized. Agronomic techniques of cultivation were generally accepted for strawberry culture. The plot is located on dry-farming land.

The study was conducted according to the generally accepted methodology (see footnote 2): the number of affected berries per plot and the total number of removed berries were counted and converted to the percentage ratio. According to the methodology, the varieties resistant to the disease should have no more than 10% yield loss in the years favorable for the disease development, and no more than 5% in normal years; moderately resistant - up to 20 and 10%, respectively; unstable - with yield loss exceeding these limits. Processing of the data on yield and average berry weight of the studied hybrids was carried out in accordance with the generally accepted methodology[3]. Evaluation of the taste of fresh berries was determined organoleptically.

Hydrothermal coefficient (HTC) according to G.T. Selyaninov was used when determining moisture availability of the vegetation periods. Moisture availability was determined according to the following classification: excessive moisture - more than 1.6; sufficient moisture - 1.6-1.3; weak aridity - 1.3-1.0; aridity - 1.0-0.7; severe aridity - 0.7-0.4; dryness - less than 0.4[4].

Overwintering conditions in the years of observations were characterized as favorable for strawberry crop, the maximum degree of freezing of strawberry hybrids did not exceed 1.0-1.5 points. The conditions of the growing seasons 2018-2021 were not contrasting - HTC 0.8-1.3 (see Table 1), but differed greatly by months, from arid with deficit of precipitation (May - June 2019, May - July 2020, May - June 2021) to over-wet (July 2018, August 2020, July 2021).

Favorable conditions for the development of phytophthora leather blight were in 2018, 2021 (see Table 2).

Табл. 1. Показатели гидротермического коэффициента (ГТК) вегетационных периодов 2018–2021 гг.

Table 1. Indicators of the hydrothermal coefficient (HTC) of the growing seasons of 2018-2021

Year	Hydrothermal coefficient				
	May	June	July	August	Average
2018	1,3	1,3	1,7	1,0	1,3
2019	0,8	0,9	1,4	1,6	1,2
2020	0,6	0,9	0,3	2,6	1,1
2021	0,2	0,8	1,5	0,8	0,8

[3] *Dospekhov B.A.* Methodology of Field Experience. Moscow: Kolos, 1979. 416 p.

[4] *Fedorov A.V.* Agricultural hydrometeorology. L.-M.: Hydrometeoizdat, 1938. 271 p.

Табл. 2. Количество осадков в периоды формирования и созревания урожая земляники в 2018 и 2021 гг.

Table 2. The amount of precipitation during the periods of formation and ripening of the strawberry crop in 2018 and 2021

Year	Flowering date	Maturation date	The amount of precipitation from the norm in the periods, %	
			of crop formation	of maturation
2018	18.06–04.07	13.07–03.08	129	47
2021	24.05–04.06	25.06–18.07	76	143

In 2018, the berries were affected by the disease during the formation of the crop (during the filling of the berries), and in 2021 - already at maturity (precipitation was 143% of the norm).

RESULTS AND DISCUSSION

The studied elite strawberry hybrids during the study period showed a good level of winter hardiness trait, the degree of freezing of most seedlings did not exceed 1.0 points. In the hybrids 3-45-10 and 2-54-11 this index was slightly lower - 1.5 points (see Table 3).

The highest yielding hybrids were medium maturity 3-44-10 (10.5 t/ha) and late maturing hybrid 2-43-10 (7.4 t/ha). Hybrid 9-44-10 (5.3 t/ha) turned out to be low-yielding. The other hybrids in the experiment had no significant difference with the control varieties.

The large-fruited hybrids with medium maturity are 9-44-10, 3-44-10, 8-44-10 from the family Solovushka × Totem, the average weight of the berry was 9.9-11.7 g. Of the late-ripening varieties, the Borovitskaya hybrid 2-43-10 was significantly larger than the control (16.1 g). The rest of the hybrids had the same berry weight as the control varieties, the hybrids 8-44-10, 2-54-11, 9-44-10 (4.5 points) had a high fresh berry taste score. The taste of the majority of the hybrids studied in the experiment was at the level of controls or lower.

Phytophthora berry blight was observed in 2018 and 2021 (see Table 4). If in 2018 the yield losses from this disease were small (maxi-

Табл. 3. Краткая хозяйственно-биологическая характеристика элитных гибридов земляники, 2018–2021 гг.

Table 3. Brief economic and biological characteristics of elite strawberry hybrids, 2018-2021

Hybrid	Origin	Degree of subfreezing, point	Yield, t/ha	Average weight of berries, g	Assessment of taste, point
Geyser - control		1,0	7,8	8,2	4,4
3-44-10	Solovushka × Totem	1,0	10,5	10,6	4,2
8-44-10	Solovushka × Totem	1,0	8,4	11,7	4,5
3-45-10	Solovushka × Dukat	1,5	8,1	8,9	4,0
2-45-10	Solovushka × Dukat	1,0	7,0	8,2	4,4
2-54-11	Amulet × Marmolada	1,5	6,8	7,8	4,5
9-44-10	Solovushka × Totem	1,0	5,3	9,9	4,5
LSD_{05}			1,8	1,5	
Borovitskaya – control		2,0	4,2	9,9	4,0
2-43-10	Solovushka × Marmolada	1,0	7,4	16,1	4,0
1-43-10	Solovushka × Marmolada	1,0	5,5	13,9	4,3
LSD_{05}			1,7	5,2	

Табл. 4. Поражение фитофторозной кожистой гнилью ягод элитных гибридов земляники, 2018, 2021 гг.

Table 4. Infestation with late blight leathery rot of the berries of elite strawberry hybrids, 2018, 2021

Hybrid	Infestation of berries with phytophthora leathery blight by years, %	
	2018	2021
Geyser - control	3,5	33,6
2-45-10	0	1,1
2-54-11	0	4,7
8-44-10	3,3	22,8
9-44-10	6,1	29,6
3-45-10	2,0	41,3
3-44-10	3,4	52,2
Borovitskaya – control	0,9	14,6
2-43-10	0,6	18,3
1-43-10	1,2	37,4

mum - up to 6.1% - was recorded for the hybrid 9-44-10), in 2021 berry rot was quite significant (22.8-52,2% in the mid-ripening hybrids and 18.3-37,4% - in late hybrids). The lowest losses from the disease were observed in the hybrids 2-45-10 and 2-54-11 (1,1-4,7%).

The hybrids studied were divided into the following categories according to the maximum damage of berries by phytophthora skin rot (2021):

– resistant (yield losses up to 10%) – 2-45-10, 2-54-11;

– medium-resistant (from 10 до 20%) – 2-43-10;

– not resistant (more than 20%) – 8-44-10, 9-44-10, 1-43-10, 3-45-10, 3-44-10.

CONCLUSION

According to the results of the research, among the studied elite hybrids, two hybrids of medium maturity, resistant to phytophthora leathery rot were identified: 2-45-10 (Solovushka × Dukat) and 2-54-11 (Amulet × Marmolada). In the year of maximum development of the disease (2021) yield losses of the hybrids were 1.1 and 4.7%, respectively. The selected hybrids also combine in their genotype a set of economically valuable features at the level of the control variety Geyser. These hybrids will be used in breeding as new initial forms resistant to phytophthora leathery blight.

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ВЗАИМОСВЯЗЬ СЕЛЕКЦИОННЫХ ПРИЗНАКОВ ТАБУННЫХ ЛОШАДЕЙ ЗАБАЙКАЛЬЯ

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Представлены результаты изучения экстерьерно-конституциональных особенностей, фенотипической корреляции живой массы с промерами тела и индексами телосложения у табунных лошадей бурятской породы. Материалом исследований служили полновозрастные жеребцы (n = 7) и кобылы (n = 20), а также жеребчики (n = 20) и кобылки (n = 20) в возрасте 1,5 и 2,5 года. Установлено, что жеребцы-производители по живой массе превосходят стандарт породы на 25,8%, кобылы – на 23,8, жеребчики – на 28,0–28,5 и кобылки – на 12,3–25,7%. Обмер статей тела также свидетельствует об их преимуществе по всем основным промерам над стандартом. Расчет индексов телосложения показал, что особи характеризуются выраженными мясными формами. При этом самцы отличаются более сбитым, широкотелым и растянутым телосложением крепкой конституции. Анализ полученных данных свидетельствует, что лошади бурятской породы по живой массе и промерам статей тела относятся к массивному типу I экологической зоны. У взрослых особей и молодняка в возрасте 1,5 и 2,5 года выявлена положительная на достаточно высоком уровне корреляция между живой массой и всеми промерами. Более тесная связь живой массы у жеребцов и кобыл отмечена с обхватом пясти (r = 0,586 и 0,770), у жеребчиков и кобылок в возрасте 1,5 года – с обхватом груди (r = 0,903) и высотой в холке (r = 0,903) соответственно. С возрастом у жеребчиков усиливается связь живой массы с длиной тела (r = 0,902), у кобылок – с обхватом груди (r = 0,623). Выявленные взаимосвязи живой массы с экстерьерно-конституциональными особенностями у табунных лошадей позволят усилить давление на конкретный селекционный признак при отборе.

Ключевые слова: табунная лошадь, бурятская порода, живая масса, экстерьер, промер, индекс телосложения, корреляция

INTERRELATION OF THE BREEDING CHARACTERISTICS OF THE HERD HORSES OF TRANSBAIKAL

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The results of the study of exterior and constitutional features, the phenotypic correlation of live weight with body measurements and body built indexes in herd horses of the Buryat breed are presented. The research material was full-grown stallions (n = 7) and mares (n = 20), as well as horse colts (n = 20) and fillies (n = 20) aged 1.5 and 2.5 years. It has been established that stud stallions in live weight exceed the breed standard by 25.8%, mares - by 23.8%, colts - by 28.0-28.5% and fillies - by 12.3-25.7%. The measurement of the articles of the body also indicates their superiority

in all basic measurements over the standard. The calculation of the body built indexes indicates that individuals are characterized by pronounced meaty forms. At the same time, males are characterized by a more solid build, broad and stretched body of a strong constitution. Analysis of the obtained data shows that the horses of the Buryat breed in terms of live weight and body parts measurements belong to the massive type I of the ecological zone. In adults and young animals at the age of 1.5 and 2.5 years, a positive, at a fairly high level, correlation between live weight and all measurements was revealed. A closer relationship of the live weight in stallions and mares was noted with the cannon bone girth ($r = 0.586$; $r = 0.770$), in colts and fillies at the age of 1.5 years - with chest girth ($r = 0.903$) and height at the withers ($r = 0.903$), respectively. With age, in colts, the relationship between the live weight and the body length increases (r = 0.902), in fillies - with chest girth (r = 0.623). The revealed relationships of the live weight with exterior and constitutional features in herd horses will allow to increase the pressure on a specific breeding trait during selection.

Keywords: herd horse, Buryat breed, live weight, conformation, measurement, body index, correlation

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INTRODUCTION

Horse breeding develops in many directions and provides agriculture, the processing industry and the population with working, breeding, productive and sport horses, raw materials and food [1, 2].

The Russian Federation has a significant diversity of horse breeds, the State Register of Breeding Achievements Approved for Use includes 49 breeds and intra-breed types of horses, of which 23 are local breeds. Over the past 20 years, three breeds and four types of horses of different breeds have been created in herd horse breeding[1].

The main livestock population of herd horses (97.3%) is concentrated in ten subjects of the Russian Federation: the republics of Sakha (Yakutia), Kalmykia, Bashkortostan, Mountain Altai, Buryatia, Tyva, Khakassia, Altai and Transbaikal Territories, and the Astrakhan region. At the same time, the Yakut horse breed accounts for the largest share [3], and there are several hypotheses about its origin. According to one of them, the Yakut horse breed is a direct progeny of the horse brought by Yakut ancestors from the Baikal region [4]. The result of 45 years of selection and breeding work to improve the economically useful qualities of the Yakut horses was the creation of two new breeds - the Megezhekskaya and the Prilenskaya. In addition, the Kolyomsky and Yansky types of the Yakut horse breed, which are distinguished by their high meat qualities and have excellent adaptability to the harsh conditions of Yakutia, were bred [5].

Local horse breeds have unique adaptive qualities, able to use scarce pastures, graze during the winter and survive in harsh conditions with minimal human care [6].

At present, selection of farm animals based on exterior and constitutional features, among which body measurements and body mass indexes play an important role, is of particular importance [7–9].

[1]State Register of the Breeding Achievements Approved for Use. Vol. 2 "Animal Breeds" (official edition). Moscow: Rosinformagrotech, 2020. 229 p.

Knowledge of the correlative relationship between individual traits and its quantitative determination allow for selection for one or more traits, to provide for changes in some traits in the selection of other, which is important for successful breeding work.

Many works in sheep breeding[2], rabbit breeding[3], cattle breeding [4, 5] have been devoted to studying the correlation between phenotypic traits in cattle breeding [10].

However, along with this there are not enough data in the scientific literature on the study of the relationship between the body weight and exterior measurements that characterize meat productivity of individuals in herd horse breeding.

The main and most accessible indicator for assessing meat productivity is the live weight, and the value of the correlation of the same traits may vary depending on the breed, sex, age, environmental conditions and other traits.

The purpose of the study is to investigate the contingency of the breeding traits of herd horses of the Buryat breed.

MATERIAL AND METHODS

The material of the research was full-grown stallions (n = 7) and mares (n = 20), as well as stallions (n = 20) and mares (n = 20) of the Buryat breed aged 1.5 and 2.5 years. The studies were conducted at the agricultural production co-operative "Uldurga" in the Yeravninsky district of the Republic of Buryatia.

Body weight was determined by weighing on electronic scales Elephant-2000-5 with an accuracy of 0.5 kg. To evaluate the morphometric features of the exterior according to the generally accepted method, the main measurements of the body points were taken, cm: height at the withers, oblique body length, chest and cannon bone girth. On the basis of the results the indices of body build are calculated, %: stretchiness or form, broad-body or chest girth, blockiness or compactness and boniness index.

To evaluate the growth and development of herd horses of the Buryat breed in our work we used the indicators of the standard (1st class) of the Buryat breed.

The correlation coefficient was calculated directly on the values of the concomitant features using Microsoft Excel and PAST version 3.25 (2001) within the following significance levels: $*p < 0{,}05$; $**p < 0{,}01$; $***p < 0{,}001$.

The experimental data were processed using the Student's method of variation statistics[6].

RESULTS AND DISCUSSION

The main purpose of measuring animals by measurements is to evaluate each individual more precisely and thus to get rid of subjectivism, which can be in the process of visual appraisal[7]. Important for evaluation by measurement are the points which give an idea about the proportions of animal's body in the process of its growth and development.

Figure 1 shows the average live weight and body measurements of full-grown stallions and mares.

Analysis of the presented data shows that both stallions and mares are superior to the standard by body weight and measurements (Instruction on evaluation of horses of local breeds. Moscow: Agropromizdat, 1988). Progeny sires exceed the standard by 25,8% on body

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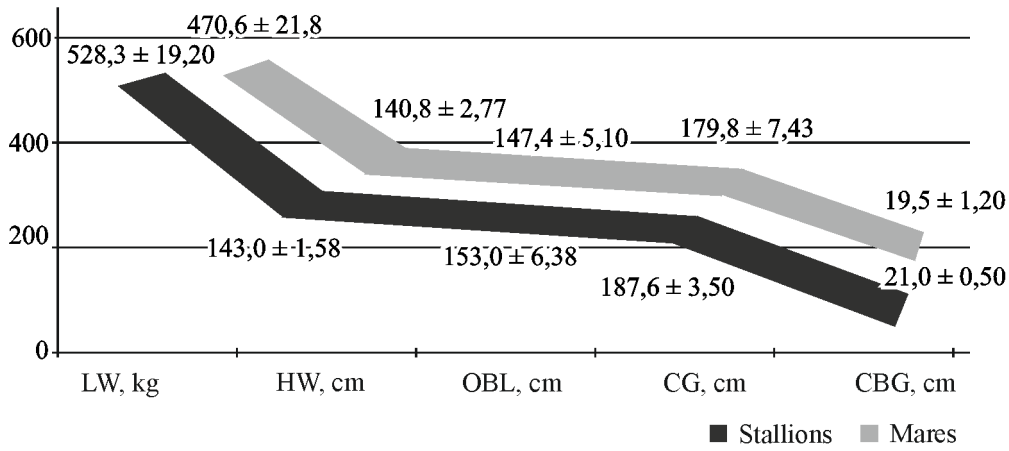

Рис. 1. Живая масса и промеры статей тела полновозрастных лошадей

Примечание. Здесь и в рис. 3, 4: ЖМ – живая масса, ВХ – высота в холке, КДТ – косая длина туловища, ОГ – обхват груди, ОП – обхват пясти

Fig. 1. Live weight and body measurements of mature horses

Note. Here and in Figs. 3, 4: LW - live weight, HW - height at the withers, OBL - oblique body length, CG - chest girth, CBG - cannon bone girth

weight, mares - by 23,8, height at the withers - 28,8 and 27,7, oblique body length - by 6,3 and 3,1, chest girth - by 11,0 and 7,7, cannon bone girth - by 13,5 and 8,3% accordingly.

I.A. Kalashnikov, E.N. Nazarova report that the Buryat horse breed has peculiar offspring with specific economically useful qualities and, based on the study of the productive qualities of horses depending on the ecological zone of breeding, propose to distinguish two types in each zone: massive and basic [11].

When evaluating the productive qualities of the Buryat breed horses of the Eastern Sayan ecotype, it was found that they have lower body measurements and live weight compared to other offspring. Thus, the average live weight of the stallions is 358 kg, mares 315 kg[8].

Based on the classification proposed in the study [11], the horses of the Buryat breeding plant APC "Uldurga" by live weight and measurements of body points belong to the massive type of the first ecological zone.

Table 1 shows the data on the live weight and measurements of the body points of stallions and mares at different ages.

According to all the studied productivity traits, young Buryat horses are superior to the breed standard (Instruction on the appraisal of the Buryat horses. Ulan-Ude, 2002). Thus, stallions at the age of 1,5 year are 28,5% superior by body weight, at the age of 2,5 year - 28,0%, mares - 12,3 and 25,7% respectively.

The measurement of the body points showed that stallions at the age of 1.5 years showed 5.7% better height at the withers than the standard, 6.4% better oblique body length, 6.6% better chest girth and 9.1% better cannon bone girth, at the age of 2.5 years - 1.7, 3.8, 3.4 and 7.4%, respectively. Similar results were obtained for the group of mares. At the age of 1.5 years, fillies exceed the standard of the breed by 5.6% according to the height at the withers, by 5.4% according to the oblique body length, by 4.5 according to the chest girth, by 2.4% according to the cannon bone girth, at the age of 2.5 years - by 2.1, 5.8, 6.2 and 2.4% accordingly.

At the age of 2.5 years, Yakut colts reach a live weight of 401 kg, mares 376 kg under the conditions of herd-winter grazing technology [12].

[8]*Anganov V.V., Tsybikova R.N.* Conformation evaluation in horses of the Eastern- Sayan ecotype of Buryat breed // Siberian Herald of Agricultural Science. 2016. № 3 (250). pp. 35-40.

Табл. 1. Живая масса и промеры статей тела молодняка лошадей
Table 1. Live weight and body measurements of young horses

Group, age, years	Live weight, kg	Height at the withers	Oblique body length	Chest girth	Cannon bone girth
		cm			
Stallions:					
1,5	347,0 ± 18,57	134,2 ± 2,28	137,2 ± 1,30	164,2 ± 6,38	18,0 ± 0,71
2,5	396,7 ± 17,41	138,3 ± 2,56	143,2 ± 4,26	169,6 ± 5,49	18,8 ± 0,41
Mares:					
1,5	280,8 ± 15,41[2]	131,0 ± 2,53	133,8 ± 2,61	158,9 ± 2,64	16,9 ± 0,87
2,5	377,2 ± 19,34	136,8 ± 3,48	141,8 ± 3,66	168,8 ± 6,48	17,4 ± 0,78

Примечание. [2] – $p < 0,01$.

Absolute values of measurements allow to compare the development of individual points in animals, but do not characterize the proportions of their body build (habitus).

Reasonably calculated body indices characterizing the ratio of anatomically related measurements give an opportunity to judge about the degree of development of an organism, proportions of its body, general constitutional type of an animal and the degree of expressiveness of the features of the desired productivity direction (see footnote 7).

The most important body mass indices in horse breeding include the indices of blockiness, stretchiness and broadness, high values of which are characteristic of beef animals. In addition, to characterize the development of the skeleton, to determine the strength of the skeleton, the boniness index is used. The boniness index is an indicator of body mass development, stretchiness characterizes the torso development in length, body broadness serves as an indicator of the strength and efficiency of the animal.

Fig. 2 and Table 2 show the body indices of full-grown horses and young horses, respectively.

The index of blockiness of adult horses of roadster breeds is 106-111%, the draft breed - 120%, the index of stretchiness - 100-102 and 106-108, the index of broadness - 108-115 and 123-130, the index of boniness - about 12 and 14-16% respectively. According to the data of the research [13] the index of blockiness for adult horses of roadster breeds ranges from 113.01-116.66%, stretchiness - 97.42-101.81, broadness - 111.42-117.49, boniness - 12.32-13.00%; the indices for stallions of the Russian draft breed are 120.1, 107.7, 129.2 and 14.3% respectively [14].

It follows from the data presented that, according to the body mass indexes, the aboriginal stallions and mares of the Buryat breed are characterized as animals with pronounced meat forms and are closer to the draft breeds by the indices. At the same time males have more compacted (+0.8%), broad (+4.6%) and stretched (+3.1%) body with strong bones (+1.0%). Similar results were obtained in the study [12] on herd horses of the Yakut breed. Stallions with an average live weight of 482 kg had the stretchiness index of 109.4%, broadness index - 136.6, blockiness index - 127.4%, mares with a live weight of 442.0 kg had 108.3, 134.9 and 124.6% respectively.

A similar picture was revealed in young horses. At the same time with age an increase in the stretchiness index by 2.5 abs.% in mares and by 3.1 abs.% in stallions, the massiveness index - by 1.7 and 3.1, the boniness index - by 1.2 and 0.7 abs.% respectively was noted.

According to the data of the work [12] the stallions of the Yakut breed at the age of 1,5 are characterized by the following indexes of

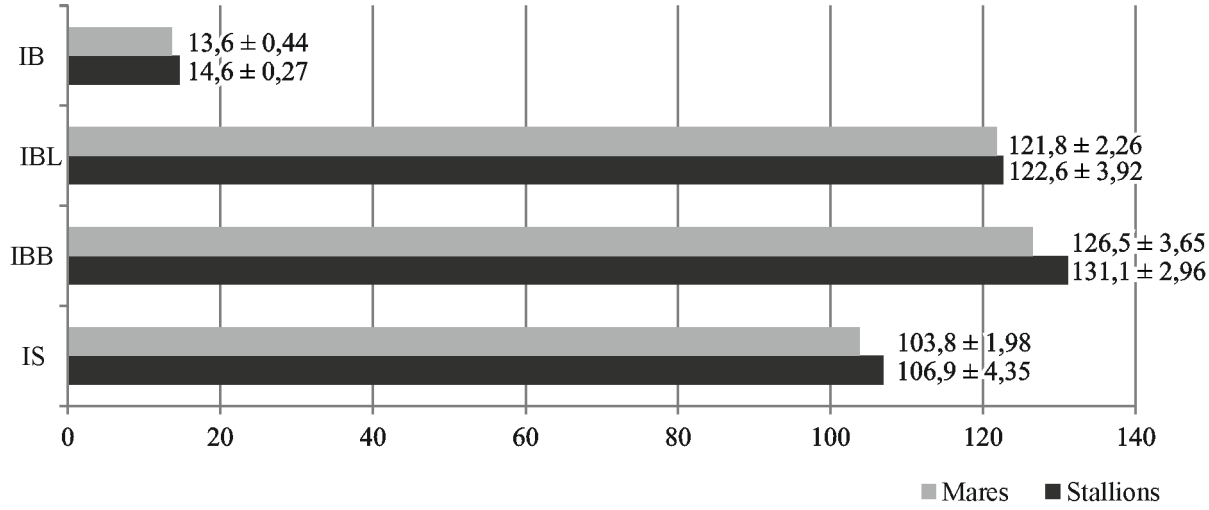

Рис. 2. Индексы телосложения полновозрастных лошадей, %.
Примечание. Здесь и в рис. 4: Индексы: ИКТ – костистости, ИСБ сбитости, ИШТ – широкотелости, ИРТ – растянутости
Fig. 2. Indexes of body build of mature horses, %
Note. Indexes: IB - index of boniness, IBL - index of blockiness, IBB - index of broad-body, IS - index of stretchiness

Табл. 2. Индексы телосложения молодняка лошадей, %
Table 2. Body indexes of young horses, %

Group, age, years	Index			
	of stretchiness	of broad bodiness	of blockiness	of boniness
Stallions:				
1,5	102,2 ± 1,41	122,3 ± 3,91	119,6 ± 4,75	13,4 ± 0,51
2,5	103,7 ± 4,44	123,3 ± 3,74	119,1 ± 4,65	13,7 ± 0,35
Mares:				
1,5	102,0 ± 1,35	121,2 ± 1,47	118,7 ± 1,93	12,1 ± 0,54
2,5	103,5 ± 2,69	122,5 ± 3,40	119,4 ± 5,05	12,5 ± 0,47

body build: stretchiness - 102,3%, broadness - 126,0, blockiness - 123,1, boniness - 13,4%, at the age of 2,5 - 107,1, 129,0, 120,2 and 13,8% of filles - 102,3, 126,0, 123,1 and 13,4% and 106,2, 127,7, 120,3 and 13,8% respectively.

A pronounced sexual dimorphism in herd horses of the Buryat breed should be noted. For example, males are heavier than females at the age of 1.5 years by 23.6% ($p < 0.01$), at 2.5 years by 5.2, adult horses by 12.3% ($p < 0.05$), higher at withers by 1.6, 2.4 and 1.1%, longer by 3.8, 2.5 and 1.0%, have a larger chest girth by 4.3, 3.3 and 0.5% respectively.

The study of correlations between the weight and body measurements of horses showed that the relationship between them is positive at a sufficiently high level (see Fig. 3, Table 3).

In sire stallions the average and below average correlation of live weight with cannon bone girth ($r = 0.586$), height at the withers ($r = 0.514$), chest girth ($r = 0.396$) and oblique body length ($r = 0.321$) was noted.

In fillies, a fairly strong correlation was found between the live weight and the cannon bone girth ($r = 0.770$), oblique body length ($r = 0.760$) and chest girth ($r = 0.755$), with a slight-

ly lower correlation with the height at the withers (r = 0.610). Similar results are presented in the works[9] [15]. The obtained data indicate that the highest correlation in the Buryat horses of the desirable type and the Kazakh mares of the zhabe type is observed between the live weight and the heel girth (r = 0.68 and 0.351), the lowest - between the height at the withers and the live weight it is the lowest (r = 0.18 and 0.168).

The studies of the authors10 obtained somewhat different results. It was established that the live weight of the Buryat breed fillies of the East Sayan (highland) ecotype is more correlated with the height at the withers (r = 0.64), a smaller correlation was noted with the cannon bone girth (r = 0.49). The correlation between the live weight and chest girth (r = 0.809) and oblique body length (r = 0.696) was high in Tajik herd horses; average correlation with the height at the withers (r = 0.463) and the cannon one girth (r = 0.327) was found [16].

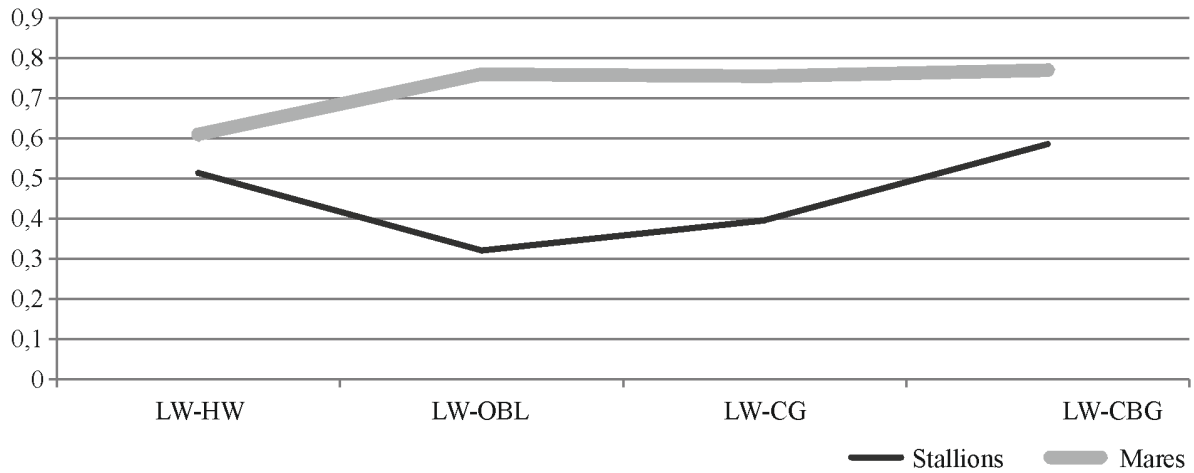

Рис. 3. Коэффициенты корреляции между живой массой и промерами статей тела полновозрастных лошадей

Fig. 3. Correlation coefficients between live weight and measurements of the body articles of mature horses

Табл. 3. Коэффициенты корреляции между живой массой и промерами статей тела молодняка лошадей

Table 3. Correlation coefficients between live weight and body measurements of young horses

Group, age, years	Live weight – height at the withers	Live weight – oblique body length	Live weight – chest girth	Live weight – cannon bone girth
Stallions:				
1,5	+0,696	+0,444	+0,903	+0,761
2,5	+0,331	+0,902	+0,484	+0,136
Mares:				
1,5	+0,903	+0,691	+0,623	+0,695
2,5	+0,740	+0,629	+0,714	+0,428

[8]*Anganov V.V., Tsybikova R.N.* Conformation evaluation in horses of the Eastern- Sayan ecotype of Buryat breed // Siberian Herald of Agricultural Science. 2016. № 3 (250). pp. 35-40.

[9]*Baimukanov D.A., Akimbekov A.R., Aubakirov H.A., Kenzhehodzhaev M.D., Alikhanov O., Nurmakhanbetov D.* Productivity of Kazakh horses of the Zhabe type of different populations // Effective Animal Husbandry. 2017. № 6 (36). pp. 48-51.

[10]*Anganov V.V., Tsybikova R.N.* Conformation evaluation in horses of the Eastern- Sayan ecotype of Buryat breed // Siberian Herald of Agricultural Science. 2016. № 3 (250). pp. 35-40.

The analysis of the obtained data shows that young Buryat horse breeds have a positive correlation of varying degrees between their live weight and all the main body measurements at the age of 1.5 years and at 2.5 years.

At the age of 1,5 year in stallions and fillies medium and strong correlation of the studied traits (r = 0,444-0,903 and 0,623-0,903) was noted. In males, the live weight is more closely related to chest girth, less so to the oblique body length, in females - to the height at the withers and the chest girth, respectively.

The relationship between the live weight of the stallions and the oblique body length increases with age; for fillies, the relationship with the chest girth increases. At the same time, the correlation with other measurements is somewhat weaker.

Such a variety of phenotypic correlations of traits in herd horses, in our opinion, is caused by genotypic factors and the factors of "genotype-environment" interaction.

There is no relative constancy in the relationship between the live weight and the body mass indexes in the context of sex and age groups of animals (see Fig. 4, Table 4).

It follows from the data presented that there is a positive correlation of the live weight with all body mass indices in fillies, with a stronger correlation with the boniness index and less with the blockiness index.

In breeding stallions, similarly, a closer correlation was found between the live weight and the boniness index, and a negative correlation was established with the blockiness index.

The obtained data on the close correlation between the live weight and the boniness index in males and females are confirmed by the correlation between their live weight and the cannon bone girth (r = 0.586 and 0.770, respectively).

Young horses at the age of 1.5 and 2.5 years have a positive correlation between the live weight and the boniness index. It should be noted that there is a close correlation between the live weight and the index of broadness and compactness in stallions at the age of 1.5 years and in fillies at the age of 2.5 years.

With age, stallions develop more intensively in length and width, as evidenced by the established relationship with the indices of stretchiness and broadness (r = 0.762 and 0.711), while fillies grow more in width (r = 0.310).

CONCLUSION

The revealed correlations between the studied traits allow us to conclude that the relative constancy of the positive and sufficiently high

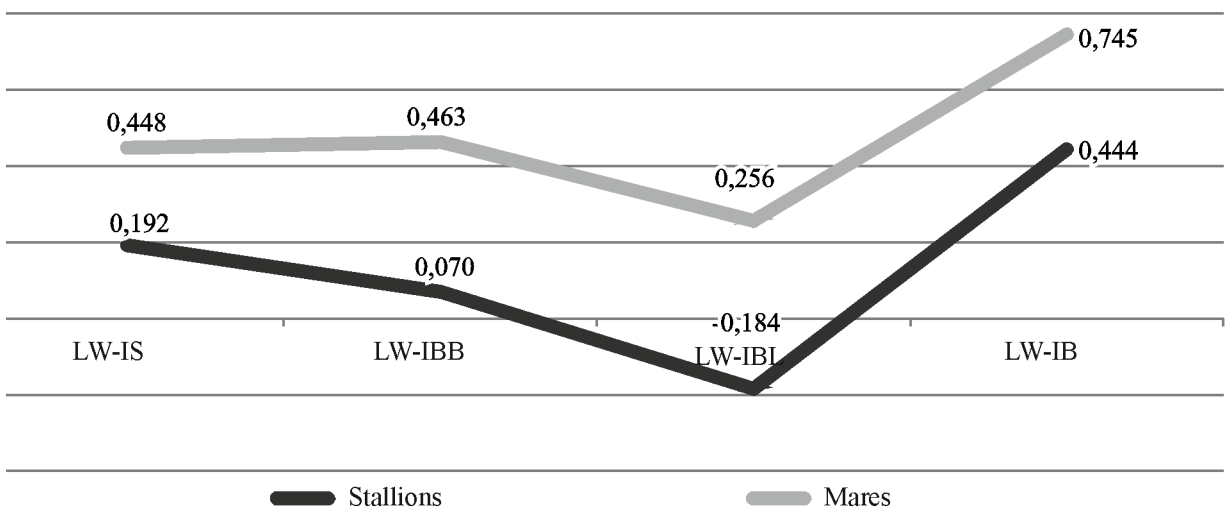

Рис. 4. Коэффициенты корреляции между живой массой и индексами телосложения полновозрастных лошадей

Fig. 4. Correlation coefficients between live weight and body built indexes of mature horses

Табл. 4. Коэффициенты корреляции между живой массой и индексами телосложения молодняка лошадей

Table 4. Correlation coefficients between live weight and body built indexes of young horses

Group, age, years	Live weight – stretchiness index	Live weight – broad bodiness index	Live weight – blockiness index	Live weight – oblique body length index
Stallions:				
1,5	–0,543	+0,710	+0,722	+0,439
2,5	+0,762	+0,711	–0,316	+0,130
Mares:				
1,5	–0,301	–0,569	–0,182	+0,456
2,5	–0,095	+0,310	+0,049	+0,021

correlation relationship between the live weight and body measurements and body mass indexes in herd horses will make it possible to increase pressure on a particular breeding trait during selection.

In adult individuals, live weight correlated to a greater extent with the cannon bone girth. When selecting stallions, paramount importance should be given to the oblique body length, in fillies to the chest girth. Evaluation of morphometric features of the exterior based on the measurement of individuals and calculation of the body indices will make it possible to predict the efficiency of breeding by live weight, which should be taken into account in further breeding work to improve the productive qualities of the Buryat herd horses.

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ГЕНОТИПИЧЕСКАЯ И ФЕНОТИПИЧЕСКАЯ ХАРАКТЕРИСТИКА ПОПУЛЯЦИИ ГЕРЕФОРДСКОГО СКОТА ЗАПАДНОЙ СИБИРИ

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Селекционно-племенная работа, направленная на повышение интенсивности роста молодняка и совершенствование стад, в конечном итоге заключается в накоплении высокопродуктивных животных, а в дальнейшем – родственных групп и линий. Ее проводят главным образом путем использования быков-улучшателей, прошедших двухэтапную оценку. Представлены результаты комплексной характеристики животных герефордской породы сибирской селекции из племенных хозяйств Новосибирской области. Установлено, что в ведущих племенных репродукторах в селекционной работе используются с учетом малочисленных прочих линий быки-производители линий Маер-Верна 88480, Болдуинс Лэда 10р, Баз Голд Сола 2v268279, Ярлыка 413 сибирской репродукции, а также Хелингтона 88910 финской селекции, Рэд Нота 28722279, Кингли 1 Хирроу 2976500345 и Уэтмор Хафлайта 377231 канадского происхождения. Лимит продуктивности по сроку хозяйственного использования в отелах колеблется от 2,5 до 9,4 лактаций, по живой массе – от 507 до 569 кг, молочности – от 189 до 204 кг, высоте в крестце – от 125 до 131 см и баллу за воспроизводство – от 8,2 до 9,3. В этих хозяйствах выращены на основе разнородно-улучшающего подбора родительских пар бычки-лидеры, которые включены в ремонтную группу быков-производителей. Живая масса в 15 мес составляет 458–616 кг и соответствует классу элита-рекорд. Среднесуточный прирост живой массы за период испытания с 8- до 15-месячного возраста в пределах 1052–1381 г.

Ключевые слова: порода, быки-производители, селекция, живая масса, молочность, изменчивость, поколение

GENOTYPIC AND PHENOTYPIC CHARACTERISTICS OF THE WESTERN SIBERIAN HEREFORD CATTLE POPULATION

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Breeding and pedigree work aimed at increasing the intensity of growth of young animals and improving herds, ultimately consists in the accumulation of highly productive animals, and in the future - related groups and lines. It is carried out mainly through the use of bulls-improvers, which have passed the two-stage evaluation. The results of the complex characterization of the animals of the Siberian selection of Hereford breed from the breeding farms of the Novosibirsk region are presented. It has been established that in the leading pedigree breeding units the stud bulls of the Maer-Vern 88480, Baldwins Leda 10r, Baz Gold Sol 2v268279, Yarlyk 413 of Siberian reproduction and imported Hellington 88 910 of Finnish selection, Red Note 28 722 279, Kingly 1 Hyrrow 2 976 500 345 and Highflight Wetmore 377 231 of Canadian origin are used in the breeding work with regard to small number of other lines. The productivity limit for the period of economic use in calves ranges from 2.5 to 9.4 lactations, live weight from 507 to 569 kg, milk yield from 189 to 204 kg, height at hips from 125 to 131 cm and the reproduction score from 8.2 to 9.3. On these farms, leader bulls were bred on the basis of heterogeneous and improving selection of parental pairs, which are included in the repair group of stud bulls. The live weight at 15 months is 458-616 kg and corresponds to the class of elite-record. The average daily gain of live weight during the test period from 8 - to 15 months of age is within 1052-1381 g.

Keywords: breed, stud bulls, breeding, live weight, milk yield, variability, generation

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INTRODUCTION

From 2010 to 2019 production of cattle for slaughter in live weight decreased from 3030.0 to 2827.1 thousand tons, or by 202.9 thousand tons (-6.7%), which resulted from the reduction in the number of milk-producing cows and herd over-replacements in the share of the fattening livestock [1]. They can be replaced only by animals of meat breeds, so the creation of new genotypes of cattle with high meat productivity is the main goal of breeding and pedigree work with large populations of specialized meat herds.

All breeds of animals bred in the world by artificial selection need constant improvement of breeding and productive qualities for the future. Otherwise, under the influence of both natural selection factors and environmental pressures, any breed will degenerate. Many researchers of the Russian Federation note low efficiency of breeding work, therefore domestic reproduction Herefords are improved by blood transfusion of Canadian breeding animals to improve both breeding and meat qualities[1–3] [1-5]. Similar studies have been started and continue in Siberian breeding farms.

Breeding work aimed at increasing the intensity of growth of young stock and improving herds ultimately consists in accumulation of high-yielding animals, and in the future - related groups and lines. It is mainly carried out by using bulls-improvers which have passed the two-stage appraisal. When breeding along the lines and using their combinations the superiority of young crossovers is noted in the number and quality of meat products, the ratio of nutrients in the carcass, the indicators of economic efficiency. This fact allows to state the possibility of producing beef of high quality oriented to the domestic market and ensures the priority of the domestic producer.

Differences in the growth and development of young animals of different breeding lines must be taken into account when drafting selection and breeding programs designed to improve the breeding and productive qualities of animals. For directed and effective selection, it is necessary to determine the modern genealogical structure of breeding herds and to evaluate the leading lines of animals of the most common meat breeds in a particular region created and available in them. Previously, we and other authors have published data on the discussed problems [6–12].

The purpose of the study is to give genotypic and phenotypic characteristics of the modern population of the Hereford cattle breed.

The research objectives are to:

– determine the genealogical structure of the Hereford breed herds in the pedigree breeding units "Voznesenskoye" and "Alliance" of the Novosibirsk region;

– evaluate the productive qualities of the

[1]*Dunin I.M., Butusov D.V., Shichkin G.I. et al.* State of beef cattle breeding in the Russian Federation // Yearbook on breeding work in beef cattle breeding on farms of the Russian Federation (2019). VNIIPlem. M., 2020. 442 p.

[2]*Khamiruyev T.N., Tyukavkin A.A.* Canadian selection Herefords in Transbaikalia // Meat cattle breeding in the arid territories of southern Middle Siberia: current status and prospects for development: proceedings of the interregional scientific and practical conference with international participation. Chita, 2017. pp. 76-80.

[3]*Kuzmina T.N.* Results of research to improve the genetic potential of the Hereford cattle breed of domestic selection // Scientific and information support of innovation development of the agroindustrial complex: materials of the XI international scientific and practical internet-conference, Pravdinsky, 2019. pp. 25-29.

stud bulls, as well as the cows of different lines and kin groups.

MATERIAL AND METHODS

Genotype and phenotype assessment of the population of the Hereford cattle of the pedigree breeding units "Voznesenskoye" and "Alliance" of the Novosibirsk Region was carried out according to the conventional method[4]. The researches were conducted on stud bulls and cows. The animals were weighed in the morning before feeding; the height at hips was measured with a measuring stick. Milkiness of cows was determined by the live weight of the calves at 205 days. The period of economic use of the stud bulls as well as cows by lactations was calculated according to individual breeding cards and the database of the IAS "Selax" Meat Cattle program. The reproductive ability of the cows (interlactation period) was estimated according to the appendix № 10 "Scale of estimation of cows on the complex of traits" in points: elite - 280- 365 days (10 points); elite - 366-401 (8); I class - 402-438 (7); II class - 439-475 (6), out of class - 476 days and more (0 points). Statistical processing of experimental data was performed according to the method of N.A. Plokhinsky (1969) using the computer program Snedecor.

RESULTS AND DISCUSSION

In the process of cattle breeding development different methods of farm animal breeding have historically developed. One of such methods, based on the use of the offspring of valuable ancestor bulls in breeding work, is line breeding. The use of this method allowed to get eight Hereford breed champions and more than 40 champions in Siberia.

The lines of 20 stud bulls are used at the leading pedigree breeding unit "Voznesenskoe" of the Novosibirsk region: Maer-Vern 88480, Baldwins Led 10r, Yarlyk 413 (Siberian reproduction), and also Hellington 88910 (Finnish selection), Red Note 2872279 (Canadian origin) (see Table 1).

According to the main indicators the stud bulls of the Hereford breed in the herd of the "Voznesenskoe" pedigree breeding unit are characterized by high consolidation (see Table 2).

Long term of use in the herd in relation to other groups have the bulls of the line Baz Gold Sol 2v268279 (Siberian selection) and Red Note 2872249 (Canadian) with the age of 7,0-7,3 years, which is more by 0,3-2,0 years (in relation to other groups). The leader is the record producer bull Dozor 40190 (elite) of the line Baz Gold Sol 2v268279 with the age of 8 years, live weight 960 kg and the height at hips of 143 cm, so the herd of stud bulls is more heterogeneous by main traits. The pedigree breeding unit "Alliance" is a young farm for breeding Hereford breed (see Table 3).

Табл. 1. Ведущие линии племенных репродукторов Сибири

Table 1. Leading lines of the pedigree breeding units of Siberia

Line	Age-sex group	
	stud bulls	cows
Pedigree breeding unit "Voznesenskoe"		
Maer-Vern 88480	4	65
Baldwins Led 10p	3	54
Yarlyk 413	3	22
Hellington 88910 (Finnish selection)	3	45
Red Note 2872249 (Canadian selection)	3	40
Other	4	205
Total	20	431
Pedigree breeding unit "Aliance"		
Maer-Vern 88480	3	–
Klen 70272	–	17
Baldwins Led 10p	–	33
Baz Gold Sol 2V	3	–
Kingley 2976500	3	–
Whitmore Highflight 377231	3	–
Naglen 4300967 (Canadian selection)	–	56
Standard 23979 (Canadian selection)	–	60
Total	12	166

[4]*Amerkhanov K.A., Dunin I.M., Sharkaev V.I. et al.* Norms of evaluation of the breeding qualities of beef cattle. Moscow: Ministry of Agriculture of the Russian Federation, 2010.

The age of the bulls was found to vary from 2.3 to 6.3 years. The live weight of the bulls of Kingley 345 and Wetmore 377231 lines was estimated as elite-record class, in other lines - as elite class. It should be noted that the bulls of the line Maer Vern 88480 have low live weight and approximately the same, which indicates their high homogeneity, both at the pedigree breeding unit "Voznesenskoe" and at the pedigree breeding unit " Alliance".

By all measures, the record-breaking bull Kai 8205 (elite) of the Baz Gold Sol line 2v268279 with 7 years of use, a live weight of 956 kg and the height at hips of 141 cm is leading. The bulls of both farms are of desirable high-growth exterior-constitutional type (see Figure 1).

The breeding nucleus of the cows of the "Voznesenskoe" pedigree breeding unit includes individuals of five lines of domestic, Finnish and Canadian reproductions (see Table 4).

As a result of the data analysis, it was established that the individuals derived from the bulls of imported breeding lines were superior in all indicators. The lactation period of the cows was 7.7-9.7 calvings. In terms of live weight of full-grown cows, Hellington and Red Note lines were in the lead (reliability of the difference is shown in Table 4).

The lowest alive weight (below the standard of the breed) in sows of the 2nd group of the line Baldwins Lada 10 p - 507,8 kg, which is lower than that of the analogues by 32,8-47,3 kg (6,5-9,3%) with high reliability (p>0,999). A large range in the trait indicates the possible effective selection of the animals of the breed-

Табл. 2. Продуктивность быков-производителей племенного репродуктора «Вознесенское» ($M \pm m$)
Table 2. Stud bulls productivity of the pedigree breeding unit "Voznesenskoye" ($M \pm m$)

Indicator	Line					Average by lines
	Maer-Vern 88480	Baz Gold Sol 2v268279	Hellington 9042 (Finnish selection)	Red Note 2872249 (Canadian selection)	Other lines	
	Group					
	1st (n =3)	2nd (n =3)	3rd (n =3)	4th (n =3)	5th (n =3)	16
Average age, years	5,8 ± 0,75	7,3 ± 0,67*3, 4	5,3 ± 0,33	7,0 ± 0,58*3	6,3 ± 0,33*3	6,6 ± 0,32*3
Live weight, kg	867,8 ± 26,6	919,3 ± 0,34	910,3 ± 1,55	915,7 ± 12,99	927,0 ± 14,57	900,0 ± 10,76
Height at hips, cm	139,3 ± 0,48	141,0 ± 1,53	139,7 ± 0,88	139,7 ± 1,45	140,7 ± 0,33	140,2 ± 0,39

Note. Hereinafter: *3 or *3, 4 indicates reliability of superiority of the mean value of this group animals with respect to the other group with the corresponding number

Табл. 3. Продуктивность быков-производителей племенного репродуктора «Альянс» ($M \pm m$)
Table 3. Stud bulls productivity of the pedigree breeding unit "Alliance" ($M \pm m$)

Indicator	Line					
	Maer-Vern 88480	Baz Gold Sol 2v268279	Kingley 1 Hirrow 2976500345	Whitmore Highflight 377231 (Canadian selection)	Other lines	Average by lines
	Group					
	1st (n =3)	2nd (n =3)	3rd (n =3)	4th (n =3)	5th (n =3)	6th (n =15)
Average age, years	4,7 ± 0,67	6,3 ± 0,33***3, 4, 6	2,3 ± 0,33	3,3 ± 0,33	5,7 ± 0,33**3, 4, 6	4,5 ± 0,44**3, 4
Live weight, kg	866,3 ± 72,5*3	927,0 ± 14,57***3,4,6	610,0 ± 12,7	769,3 ± 43,44**3,5	924,7 ± 26,43**3,6	819,5 ± 33,9***3
Height at hips, cm	139,7 ± 1,53	140,7 ± 0,33***4, 6	139,3 ± 0,67	138,3 ± 0,33	139,3 ± 0,88	139,5*4 ± 0,32

ing nucleus. Cows of the Hellington line (the 4th group) take the leading position by milk yield and at the age of 205 days they reach 197,0 kg. Animals of the imported lines of the 4th and 5th groups are characterized by the best expression of the type of the Hereford cattle. The breeding nucleus of cows of the pedigree breeding unit "Alliance" is represented by four lines (see Table 5).

The breeding stock is mainly represented by the cows of Naglen and Standard lines (*n* = 56-60). The cows of these lines had high indicators for almost all productivity data.

One of the important indicators in beef cattle breeding is reproductive capacity of cows (see Tables 4, 5). It determines whether a calf will be obtained or not in desirable dates of the calving in the process of mass insemination. The calving interval is equal to 366-365 days. The indicator is almost the same at the "Voznesenskoe" pedigree breeding unit without a reliable difference and is 8.2-8.8, at the farm "Alliance" it is 8.2-9.3. The best indicators are in the cows from Klen and Standard. In both breeding farms the reproductive ability of the cows is at a high required level.

Thus, the genealogical structure of the Hereford breed is formed by animals of both domestic lines and imported Finnish and Canadian reproductions. Cows with calves are shown in Fig. 2.

On the basis of heterogeneous-improving selection of parental sets, leading bulls were bred and included in the repair group of stud bulls (see Table 6, Fig. 3).

Bulls with a high expression of type and a harmonious build based on the results of use in the breeding stock will be evaluated by the quality of progeny "B" and included in the group of stud bulls with attachment to a particular group of cows (see Fig. 3).

Рис. 1. Быки-производители племенного репродуктора «Вознесенское»

Fig. 1. Stud bulls of the pedigree breeding unit "Voznesenskoye"

CONCLUSIONS

1. In the leading pedigree breeding units of Siberia "Voznesenskoe" and "Alliance" stud bulls of the lines Maer-Vern 88480, Baldwins Led 10p, Baz Gold Sol 2v268279, Yarlik 413 (Siberian reproduction), as well as Hellington 88910 (Finnish selection), Red Note 28722279, Kingley 1 Hirrow 2976500345 and Whitmore Highflight 377231 (Canadian origin) are used in the breeding work.

2. The lines are heterogeneous in productivity, the limit of productivity by the period of economic use in calves varies from 2.5 to 9.4 lactations. The live weight varies from 507 to 569 kg, milk yield - from 189 to 204 kg, height at hips - from 125 to 131 cm, reproduction score - from 8.2 to 9.3.

3. On the basis of heterogeneous-improving selection of parental sets the leading bulls were obtained, which are included in the repair group of stud bulls. The live weight at 15 months of age is 458-616 kg, which is 88-246 kg above the breed standard and corresponds to the elite-record class. The average daily gain of live weight for the test period from 8- to 15-months of age is within 1138-1381 g.

Табл. 4. Продуктивность коров разных линий племрепродуктора «Вознесенское» ($M \pm m$)
Table 4. Productivity of cows of different lines of the pedigree breeding unit "Voznesenskoye" ($M \pm m$)

Indicator	Line					
	Maer-Vern 88480	Baldwins Led 10p	Yarlyk 413	Hellington 88 910 (Finnish selection)	Red Note 2872249 (Canadian selection)	Average by lines
	Group					
	1st (n = 65)	2nd (n = 54)	3rd (n = 22)	4th (n = 45)	5th (n = 40)	6th (n = 226)
Economic use period in lactations	5,4 ± 0,33	4,9 ± 0,29	6,0 ± 0,66	9,4 ± 0,44***1–3, 5	7,7 ± 0,44	6,5 ± 0,2***1, 3–5
Live weight, kg	540,6 ± 4,64***2	507,8 ± 7,20	547,9 ± 7,24***2	549,8 ± 5,89***2	555,1 ± 5,45***2	537,9 ± 2,96***2, 5
Milking capacity at 205 days, kg	189,4 ± 1,61	190,7 ± 1,99	194,4 ± 2,69	197,0 ± 1,99**1, 2	193,3 ± 1,71	192,4*4 ± 0,88
Height at hips, cm	125,3 ± 0,22	127,2 ± 0,42***1, 3	125,9 ± 0,30	131,0 ± 0,57*1–3, 5	129,4 ± 0,68***1–3	127,7***1, 3, 4 5 ± 0,25
Score for reproduction	8,2 ± 0,24	8,2 ± 0,23	8,5 ± 0,33	8,8 ± 0,37	8,8 ± 0,26	8,5 ± 0,13

Табл. 5. Продуктивность коров разных линий племпродуктора «Альянс» ($M \pm m$)
Table 5. Productivity of cows of different lines of the pedigree breeding unit «Alliance» ($M \pm m$)

Indicator	Line				Average by lines
	Klen 70272	Baldwins Led 10p	Naglen 4300967 (Canadian selection)	Standard 23979 (Canadian selection)	
	Group				
	1st (n = 17)	2nd (n = 33)	3rd (n = 56)	4th (n = 60)	5th (n = 166)
Economic use period in calvings	2,5 ± 0,24	3,2 ± 0,17**1	3,0 ± 0,06**1	3,2 ± 0,06**4, 3, 5	3,0 ± 0,05*1
Live weight, kg	523,2 ± 7,71***2	556,9 ± 4,16***1	564,9 ± 5,53***1	569,8 ± 2,01***1, 2, 5	560,9 ± 2,52
Milking capacity at 205 days, kg	202,7 ± 2,49**2	194,3 ± 1,37	204,2 ± 2,1***2	204,8 ± 1,09***2	202,3 ± 0,94***2
Height at hips, cm	127,4 ± 0,35*2	126,5 ± 0,17***1, 3	129,1 ± 0,29***1, 2	131,6 ± 0,28***1–3	129,3 ± 0,21***1, 2
Score for reproduction	9,3 ± 0,37**3	8,6 ± 0,25	8,2 ± 0,19	9,3 ± 0,12*2, 3, 5	8,8 ± 0,11***3

а *б*

Рис. 2. Коровы с телятами племенных репродукторов:
а – «Вознесенское»; *б* – «Альянс»

Fig. 2. Cows with calves of the pedigree breeding unit
а – «Voznesenskoye»; *б* – «Aliance»

Табл. 6. Характеристика бычков-лидеров

Table 6. Characteristics of leader bulls

Nickname and number	Date of birth	Live weight at 15 months	Average daily live weight gain, g	Stud-bull nickname / line
Pedigree breeding unit "Voznesenskoe"				
Don 7021	02.01.2021	474	1138	Debut 5397 / Hellington
Airon 9401	23.10.2020	458	1052	Araks 40 295 / Red Note
Pedigree breeding unit "Aliance"				
Boets 1118	15.11.2020	616	1381	Baikal 8215 / Maer-Vern
Boss 21119	27.05.2020	525	1253	Baikal 8215 / Maer-Vern
Vostok 21233	21.12.2020	588	1238	Valdai 90215 / Whitmore Highflight

Рис. 3. Бычок Боец 1118 линии Маер-Верна 88480. Живая масса в 15 мес 616 кг, среднесуточный прирост – 1381 г, элита-рекорд

Fig. 3. Goby Fighter 1118 of the Maer-Vern 88480 line. Live weight at 15 months 616 kg. Average daily gain - 1381, elite record

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ПРИМЕНЕНИЕ МЕХАНИЗМА ЧЕБЫШЕВА В ПРОЕКТИРОВАНИИ ЭЛЕМЕНТОВ МЕХАНИЧЕСКИХ УСТРОЙСТВ ДЛЯ ЧЕСКИ ПУХА КОЗ

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Процесс вычесывания пуха коз до сих пор остается практически не механизированным, а потому очень тяжелым для операторов чески пуха. Для успешного развития отрасли требуется в том числе решить вопрос создания механических устройств, которые существенно облегчат работу операторов и позволят увеличить их производительность труда. Не менее важно обеспечить бережное вычесывание, которое не нанесет травмы животному и повысит качество пуха. В этой связи при проектировании механического устройства следует как можно точнее повторить процесс ручного вычесывания. Для этого была изучена траектория движения кончика зуба гребня при ручном вычесывании. По результатам анализа предложена схема вычесывающего устройства на основе шарнирно-рычажного механизма Чебышева. В рамках аналитического метода кинематического исследования механизмов выведены аналитические уравнения, связывающие известные параметры входного (ведущего) звена с неизвестными параметрами ведомых звеньев. Используя эти уравнения, можно с наперед заданной точностью рассчитать необходимые кинематические параметры (перемещения, скорости, ускорения, как линейные, так и угловые) выходного звена и ведомых звеньев. По итогам натурного моделирования и теоретических расчетов были установлены оптимальные габаритные размеры основных звеньев устройства. Применение предложенного механизма позволит снизить физические усилия и утомляемость оператора, повысить производительность благодаря уходу от ручного труда и усовершенствованию устройства.

Ключевые слова: механическое устройство, ческа пуха коз, механизм Чебышева

APPLICATION OF THE CHEBYSHEV MECHANISM IN THE DESIGN OF THE ELEMENTS OF MECHANICAL DEVICES FOR COMBING OUT THE DOWN OF GOATS

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The process of combing out down in goats still remains practically non-mechanized, and therefore very difficult for operators. For the successful development of the down goat breeding industry, it is necessary to conduct research in the development of mechanical devices that will significantly facilitate the work of operators and will increase their productivity. It is equally important to ensure careful combing of down, which will not cause injury to the animal and will improve the quality of the combed down. When developing a mechanical device for combing down in goats, it is necessary to repeat the process of manual combing of down as accurately as possible. To do this, an analysis of the trajectory of movement of the tip of the comb tooth during manual combing was carried out. Based on the results of the analysis, the scheme of a combing device based on the Chebyshev hinge-

lever mechanism was proposed. Analytical equations linking the known parameters of the input (leading) link with the unknown parameters of the driving links are derived within the framework of the analytical method of the kinematic study of mechanisms. Using these equations, it is possible to calculate with a predetermined accuracy the necessary kinematic parameters (displacements, velocities, accelerations, both linear and angular) of the output link and driving links. Based on the results of full-scale modeling and theoretical calculations, the optimal dimensions of the main parts of the device were established. The use of the proposed mechanism will reduce physical effort and operator fatigue, increase productivity due to the abandonment of manual labor and improvement of the device.

Keywords: mechanical device, combing out the goat down, Chebyshev mechanism

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INTRODUCTION

Down goat breeding is one of the branches of agriculture in which the question of complete mechanization of labor remains unresolved to this day. In most farms, down is combed manually with special combs that are easy to make and require little material cost. However, combing the down with a manual comb is labor-intensive and requires considerable physical effort. Currently, measures are being taken to improve the means of manual down combing and to mechanize this process. The manual down combing process, which is naturally formed, repeatedly worked out and is the most optimal, should be taken as a basis. The currently available tools for manual combing and combing out the down include: 2-way comb, pinched plate comb, down comb and the universal rake comb. There are also mechanical devices: a vibrating machine AVP 1, installation of drum type, tape device MLU 1 [1]. The main disadvantage of manual combs is a large physical load on the operator. The main disadvantage of mechanical devices is that they do not fully replicate the process of manual combing, which leads to uneven processing of wool and down and the loss of quality of the down fiber.

Further research is needed to improve the down combing device, to optimize the combing process and the combing technology, to reduce the operator's labor costs in order to give an impetus to the development of this field. To ensure the highest quality of down combing, it is necessary to develop a device that would maximally replicate the mechanism of manual combing, reduce physical effort and, consequently, operator fatigue, and increase labor productivity.

The research objectives are:

1) construction of a mathematical model of the combing device based on the Chebyshev articulation linkage;

2) analysis of combing tine movements;

3) determination of optimal dimensions of the main parts of the device.

The priority is to maximize the mechanical combing device's reproduction of the tine tip trajectory when manually combing the down.

MATERIAL AND METHODS

When studying the operation of complex mechanisms and machines, it is assumed that the motion of input links is given, and the motion of output links is studied depending on the given motion of the input links. It is important to understand that it is necessary to take into account not only the structure of the mechanisms and the geometrical relationship between the sizes of their links, but also the forces act-

ing on the links of the mechanisms, as well as those arising during their movement. When performing the force analysis of mechanisms, it is necessary to take into account the influence of external forces, link weight forces, friction and inertia forces on the links of mechanisms, elements of links, kinematic pairs and fixed supports; to establish the method of reducing dynamic loads that arise during the movement of the mechanism. Analysis of the dynamics of mechanisms involves determining the mode of their motion under the action of the above forces and the search for ways to ensure the specified modes of motion of the devices. The issue of determining forces is of great practical importance for establishing the strength of individual parts, calculating the power required to operate the mechanisms, the friction force in kinematic pairs, the deterioration of the rubbing parts, etc. Knowing the magnitude of the forces acting on individual links of the device, it is possible to choose the most rational dimensions for all the links, to select the design forms that ensure sufficient strength of the parts, etc.

The driving forces and forces of production resistances, depending on their physical and technological characteristics, can be functions of various kinematic parameters: displacements, velocities, accelerations and time. Usually, these forces are known or the diagrams of forces of works or powers are known.

Now in the process of kinematic study of mechanisms analytical method is used more and more often which consists in derivation of analytical equations linking known parameters of the input (leading) link with unknown parameters of the driven links. With the help of these equations, it is possible to calculate with a predetermined accuracy the kinematic parameters of interest (displacements, velocities, accelerations, both linear and angular) of the output link and slave units[1] [1, 2].

Since analytical calculations can be very cumbersome, calculations on them present a certain difficulty even in the presence of appropriate software. Now in the TMM Constructor program it is possible to calculate displacements, velocities, accelerations (not only linear, but also angular) of the considered Chebyshev mechanism.

RESULTS AND DISCUSSION

Let's turn to the equations of the kinematic parameters of the group in general form. This group together with the leading link and the rack forms a 4-link articulated arm (see Fig. 1).

The positions of the links are determined by angular parameters (1) - (4). The angular coordinate of the driving link (φ1, º) is known [2, 3] [1-4].

$$\varphi'_3 = \text{arctg}\,\frac{\sin\varphi_1}{\lambda_{01} + \cos\varphi_1}; \quad (1)$$

$$\varphi''_3 = \arccos\frac{\sin\varphi_1}{(\lambda_{21} + \lambda_{31})\sin\varphi'_3}; \quad (2)$$

$$\varphi_3 = \varphi'_3 + \varphi''_3; \quad (3)$$

$$\varphi_2 = \arcsin\frac{\lambda_{31}\cdot\sin\varphi_3 - \sin\varphi_1}{\lambda_{21}}, \quad (4)$$

$$\lambda_{01} = \frac{O_1O_2}{AO_1}; \lambda_{21} = \frac{AB}{AO_1}; \lambda_{31} = \frac{BO_2}{AO_1}.$$

Where

The velocities of the links are determined by the parameters (5) - (8). The angular velocity of the driving link (ω1, 1/s) is known.

$$\omega_2 = \omega_1\cdot\frac{\sin(\varphi_1 - \varphi_3)}{\lambda_{31}\cdot\sin(\varphi_2 - \varphi_3)}; \quad (5)$$

$$\omega_3 = \omega_2\cdot\frac{\sin(\varphi_2 - \varphi_1)}{\lambda_{31}\cdot\sin(\varphi_2 - \varphi_3)}; \quad (6)$$

$$V_{AO_1} = \omega_2\cdot(AO_1); \quad (7)$$

$$V_{BO_2} = \omega_3\cdot(BO_2). \quad (8)$$

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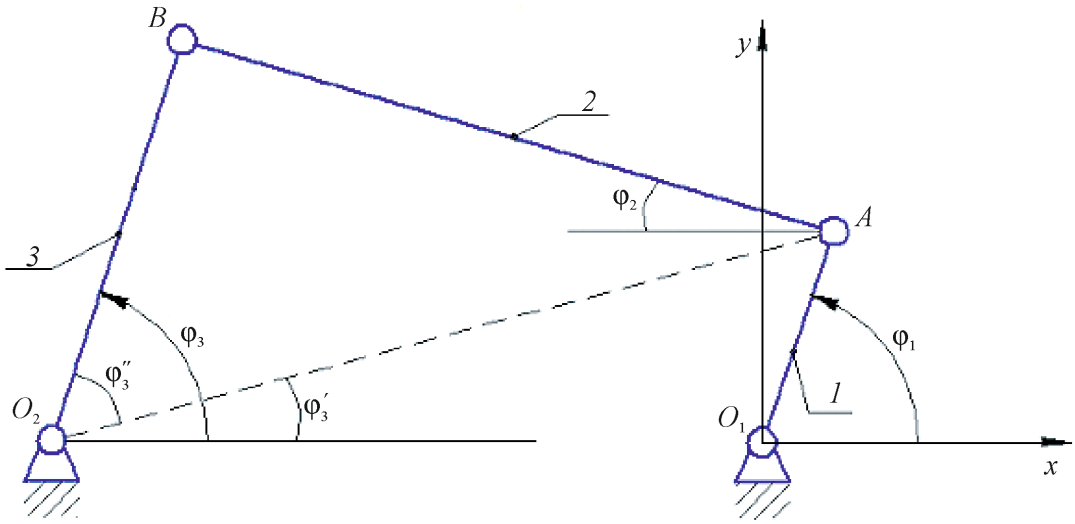

Рис. 1. Схема шарнирно-рычажного четырехзвенника:

1 – ведущее звено; *2* – шатун; *3* – коромысло; O_1O_2 – расстояние между опорами (длина стойки)

Fig. 1. The scheme of the hinge-lever four-bar linkage:

1 - driving link; *2* - connecting rod; *3* - rocker arm; O_1O_2 - distance between the supports (strut length)

Accelerations of the links are defined by the parameters (9) - (16). The angular acceleration of the driving link (ε1, 1/s2) is known.

$$\varepsilon_2 = \varepsilon_1 \frac{\omega_2}{\omega_1} + \frac{\omega_1^2 \cdot \cos(\varphi_1 - \varphi_3) - \omega_3^2 \cdot \lambda_{31} - \omega_2^2 \cdot \lambda_{21} \cdot \cos(\varphi_1 - \varphi_3)}{\lambda_{31} \cdot \sin(\varphi_2 - \varphi_1)}; \quad (9)$$

$$\varepsilon_3 = \varepsilon_1 \frac{\omega_3}{\omega_1} + \frac{\omega_2^2 \cdot \lambda_{21} + \omega_3^2 \cdot \lambda_{31} \cdot \cos(\varphi_3 - \varphi_2) - \omega_1^2 \cdot \cos(\varphi_1 - \varphi_2)}{\lambda_{31} \cdot \sin(\varphi_2 - \varphi_3)}; \quad (10)$$

$$W^{t}_{AO_1} = \varepsilon_1 \cdot (AO_1); \quad (11)$$

$$W^{n}_{AO_1} = \omega_1^2 \cdot (AO_1); \quad (12)$$

$$W_{AO_1} = \sqrt{[\varepsilon_1 \cdot (AO_1)]^2 + [\omega_1^2 \cdot (AO_1)]^2}; \quad (13)$$

$$W^{t}_{BO_2} = \varepsilon_3 \cdot (BO_2); \quad (14)$$

$$W^{n}_{BO_2} = \omega_3^2 \cdot (BO_2); \quad (15)$$

$$W_{BO_2} = \sqrt{[\varepsilon_3 \cdot (BO_2)]^2 + [\omega_3^2 \cdot (BO_2)]^2}. \quad (16)$$

To find the appropriate ratios of the lengths of the links that set the trajectory of the output link, it is necessary to draw the position plans of the mechanism.

The position plans allow us to judge about the nature of the movement of the links, about the maximum overall dimensions and, as a first approximation, about the operability of the mechanism.

Since in our case the visual trajectory of the output link motion (point *C*) is of interest first of all from the position of correctness of the technological process, it is necessary to conduct a series of trajectory constructions by combination of the appropriate ratios of the link lengths [1, 2, 5-7] (see Fig. 2).

If we denote the angular coordinates of the links φ1, φ2, φ3, φ4 respectively, then the trajectory of the output link (point *C*) is given by the relation:

$$\begin{aligned} x_C &= O_1A \cos\varphi_1 - (AB + BC)\cos\varphi_2 \\ y_C &= O_1A \sin\varphi_1 - (AB + BC)\sin\varphi_2 \end{aligned}. \quad (17)$$

Currently, most mechanical devices for combing goat down do not meet the requirements of technology. On this basis, it is necessary to determine the trajectory of the output link (point *C*) by plotting the position plans of

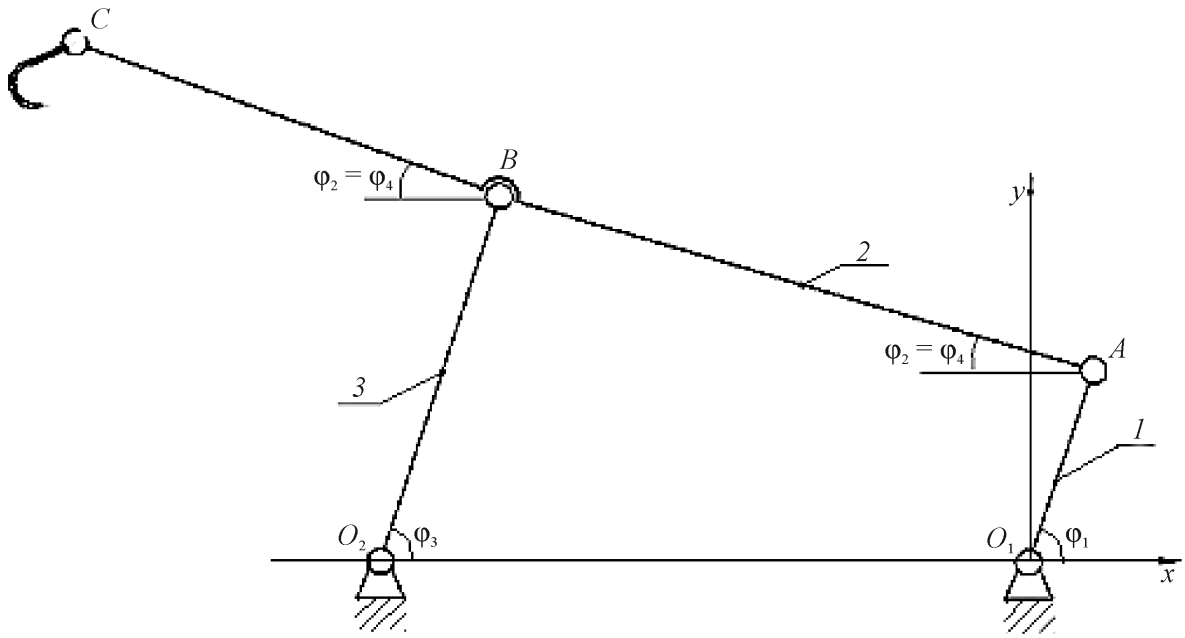

Рис. 2. Определение соответствующих соотношений длин звеньев

Fig. 2. Determination of the corresponding ratios of the links length

the mechanism and establish at what dimensions of the links this trajectory will most closely follow the trajectory of the operator's hand [8-12].

Formally, the trajectory of the tine movement in manual combing can be divided into three phases: introduction of the tines into the hair and down covering, movement in the combing area, exit of the tines from the hair and down covering of the animal. When entering, the tines move vertically and longitudinally. In the combing zone the comb moves only in the longitudinal direction. At this stage there is a rubbing of the fiber bundle for its separation from the skin. It is established that the active combing of the down takes place on a horizontal section of 400-600 mm, after which the comb should be withdrawn from the working zone. The last phase determines the moment when the tines leave the working area. Its duration is significantly shorter than the first two phases.

Full-scale simulation of the process and theoretical calculations made it possible to select the most optimal dimensions of the Chebyshev mechanism links, which would make it possible to bring the trajectory of the combing unit working link as close as possible to that of the comb during manual combing of the down. All possible trajectories of combing element movement have been calculated by means of obtained dependences (1) - (17), depending on the initial dimensions and initial positions of the links. The limits of change of the angular coordinate of the driving link and the calculated values of the coordinates of movement of the combing element tip are given in the table.

As a result of the made calculations the most optimal dimensions of the offered combing design are determined, which allow to achieve the trajectory of the output link movement (point *C*), maximally repeating the trajectory of the comb tine tip movement at manual combing out the down. In the offered variant the dimensions of the device are the following: driving link *OA*1 = 0,1 m, crank *AB* = 0,3 m, rocker *BO*2 = 0,2 m, the distance between the supports of the stand *O*1*O*2 = 0,4 m, the length of the output link *CB* = 0,3 m (is the length of the combing comb with the tines fixed at the end).

Based on the data in the table, when changing the angular coordinate of the driving link φ1 from 15 to 359º, a curve passing through the points with the coordinates (*xC*; *yC*) was constructed. Check of theoretical calculations has shown the coincidence of the obtained re-

Расчеты размеров четырехзвенника Чебышева
Calculations of the dimensions of the Chebyshev four-bar linkage

Angular parameters, deg.					Coordinates of the output link movement, m	
φ_1	φ_3'	φ_3''	φ_3	φ_2	x_C	y_C
15	2,98	5,99	8,98	1,02	−0,50	0,04
30	5,87	11,95	17,82	2,14	−0,51	0,07
45	8,54	17,83	26,37	3,46	−0,53	0,11
60	10,89	23,58	34,47	5,09	−0,55	0,14
90	14,04	34,45	48,49	9,55	−0,59	0,20
120	13,90	43,85	57,75	15,97	−0,63	0,25
135	12,12	47,66	59,77	19,90	−0,63	0,27
150	9,06	50,60	59,67	24,12	−0,63	0,30
175	1,66	53,06	54,72	31,01	−0,61	0,32
195	−4,88	52,48	47,61	35,35	−0,59	0,32
210	−9,06	50,60	41,54	37,50	−0,56	0,32
225	−12,12	47,66	35,54	38,55	−0,54	0,30
240	−13,90	43,85	29,96	38,43	−0,52	0,29
271	−13,98	34,11	20,13	34,24	−0,49	0,24
300	−10,89	23,58	12,68	25,79	−0,49	0,17
315	−8,54	17,83	9,28	20,08	−0,49	0,14
330	−5,87	11,95	6,08	13,73	−0,50	0,09
359	−0,20	0,40	0,20	0,47	−0,50	0,00

Note. Value of the coefficients: λ01 = 4; λ21 = 3; λ31 = 2.

sults with the desired trajectory of the ridge tine movement (see fig. 3). This movement of the working link allows to optimize the combing area. Besides, the trajectory of the tine movement in the down of animal passes practically along the straight line. According to the values shown in the table and the graph, one can see that the down combing zone is about 0.4 m, which also corresponds to the size of the combing zone in the manual combing method.

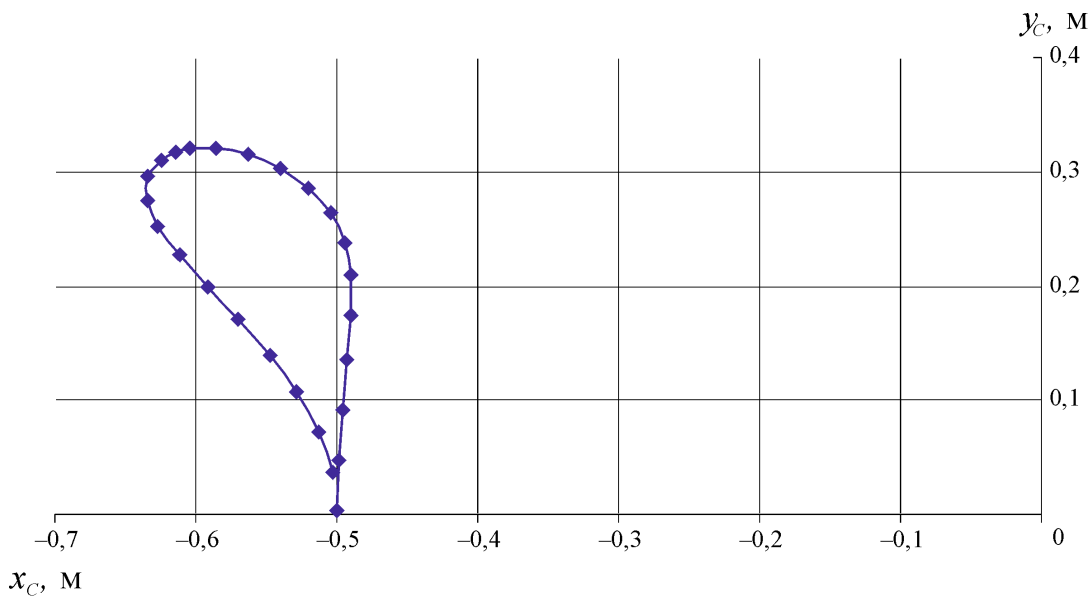

Рис. 3. Траектория движения выходного звена
Fig. 3. The trajectory of the output link

CONCLUSION

The constructed mathematical model of the combing device work based on the Chebyshev articulated linkage mechanism and the analysis of the tine movement allowed us to determine the basic design principle of the mechanical device for combing goat down. As a result of the studies the optimal dimensions of the main links of the device have been established. The introduction of the proposed mechanism will reduce the physical effort and fatigue of the operator, increase productivity by eliminating manual labor and improving the device.

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БАКТЕРИОНОСИТЕЛЬСТВО КЛЕЩЕЙ-ИКСОДИД НА ТЕРРИТОРИИ ЗАБАЙКАЛЬСКОГО КРАЯ

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Представлены результаты микробиологического исследования половозрелых клещей-иксодид рода *Dermacentor*, собранных на территории сельских районов Забайкальского края. Проведено микробиологическое исследование 152 иксодовых клещей. Выявлены четыре микробные культуры разных видов: *Listeria monocytogenes*, *Escherichia coli*, *Salmonella typhi*, *Clostridium botulinum*. Отмечено наличие ассоциаций бактерий разных видовых групп в организме клеща: у 32 особей – *L. monocytogenes*, *E. coli*, *S. typhi*, у 56 – *C. botulinum*, *E. coli*, *S. typhi*, у 6 – *L. monocytogenes*, *E. coli*, у 15 – *C. botulinum*, *E. coli*. Из всех выделенных штаммов микроорганизмов наибольшее количество составляла кишечная палочка: данный микроорганизм высевался из всех клещей. Меньше всего выделено *L. monocytogenes*: из 152 клещей 38 являлись ее переносчиками. Установлена циркуляция возбудителя сальмонеллеза у 123 клещей из 152 обследованных особей. Биологические свойства всех выделенных микробных культур соответствовали их классическим характеристикам. Выделенные из клещей микроорганизмы рода *Clostridium* на питательной среде Китта – Тароцци вызывали равномерное ее помутнение, что свидетельствует о принадлежности данного штамма бактерий к сероварам C, D, E, B. Полученные данные указывают на необходимость ежегодного ветеринарного контроля мест выпаса животных на наличие природных очагов, резервуарами возбудителей которых являются пастбищные клещи. В период массового нападения клещей-иксодид необходимо проведение акарицидных обработок животных репелентными и акарицидными препаратами, что будет способствовать не только повышению их продуктивности, но и позволит профилактировать инфекционные болезни.

Ключевые слова: иксодовые клещи, бактерионосительство, Забайкальский край

BACTERIOCARRIAGE OF IXODID MITES ON THE TRANS-BAIKAL TERRITORY

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The results of a microbiological study of sexually mature ixodid mites of the genus *Dermacentor* collected in the rural areas of the Trans-Baikal Territory are presented. Microbiological examination

of 152 ixodid mites was carried out. Four microbial cultures of different species were identified: *Listeria monocytogenes*, *E. coli*, *Salmonella typhi*, *Clostridium botulinum*. The presence of bacteria associations of different species groups in the mite body was noted: in 32 individuals - *L. monocytogenes*, *E. coli*, *S. typhi*, in 56 - *C. botulinum*, *E. coli*, *S. typhi*, in 6 - *L. monocytogenes*, *E. coli*, in 15 - *C. botulinum*, *E. coli*. Of all the isolated microbial strains, Escherichia coli made up the largest number: this microorganism was isolated from all mites. *L. monocytogenes* appeared to be the least isolated: 38 of 152 mites were its carriers. Salmonellosis pathogen circulation was detected in 123 mites out of 152 examined specimens. The biological properties of all the isolated microbial cultures corresponded to their classical characteristics. Microorganisms of the genus *Clostridium* isolated from the mites on the Kitt-Tarozzi nutrient medium caused uniform turbidity of the nutrient medium, which indicates that this bacterial strain belongs to serovars C, D, E and B. The data obtained indicate the need for annual veterinary control of the grazing areas for the presence of natural foci, the reservoirs of pathogens which are pasture mites. During the period of ixodid mites mass attack it is necessary to carry out acaricide treatments of animals with repellent and acaricide preparations that will not only increase their productivity, but will also allow preventing infectious diseases.

Keywords: ixodid mites, bacteriocarriage, Trans-Baikal Territory

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The authors declare no conflict of interest.

INTRODUCTION

The area of ixodid mites affects most parts of the Russian Federation, including Transbaikal Territory. The area of arable land in the region has decreased fourfold since the USSR era, from 1.2 million ha to 300 thousand ha[1], which caused an increase in the number of biotopes favorable for mites and caused a worsening of the epizootic situation with pyroplasmidosis in domestic farm animals and human vector-borne diseases [1-5]. It is known that ixodid mites are involved in the transfer of pathogens and the maintenance of natural focal infections of various etiologies (viral, bacterial and protozoal) [2, 6-9]. Mites are external parasitic bloodsuckers. They actively participate in the transfer of pathogens and store them. Brucellosis, foot and mouth disease, leptospirosis, tick-borne encephalitis, pyroplasmosis, nuttaliosis, anaplasmosis, rickettsial disease, Lyme disease (borreliosis), relapsing fever, hemorrhagic fever, tularemia, plague, ehrlichiosis are far from being complete list of the diseases which are transmitted by ixodes [10]. The occurrence of these diseases can cause significant economic damage to agriculture and cause epidemics. Research and monitoring of ixodid mites is a topical medical and veterinary issue of theoretical and practical importance [1, 5, 6, 10].

Microbiological monitoring of mites for carriage of infectious agents of various etiologies will allow to predict and prevent the occurrence of diseases in farm animals, thereby reducing the economic damage. Thanks to these researches it will be possible to work out scientifically proved recommendations and plans on the prophylaxis of the disease [11].

Similar work in the territory of the region has not been carried out so far. In the subdivisions of Rospotrebnadzor (Federal Service for the Oversight of Consumer Protection and Welfare) for Transbaikal Territory there was only practical work to ensure the safety of the popu-

[1]Loskutnikov V.G. Ministry of Agriculture: The area of arable land in Transbaikalia has decreased fourfold to 300 thousand hectares since Soviet times: URL: https://www.chita.ru.

lation, which was the reason for the scientific work on this topic.

The purpose of the study is to conduct laboratory tests of ixodid mites to determine whether they are carriers of bacterial pathogens.

The research objectives are to:

– conduct microbiological studies of ixodid mites;

– study the biological properties of the obtained bacterial cultures;

– determine the genus identity of the obtained bacterial strains.

MATERIAL AND METHODS

The material for the study was Dermacentor mites collected manually from animals and in the biotopes by the flag-kilometer method in three districts of the Transbaikal Territory: Chita (n = 60), Krasno-Chikoysky (n = 71), Priargunsky (n = 21). The mites were collected and counted according to the generally accepted methodological guidelines.

The following nutrient media were used for cultivation, identification, and study of the biological properties of bacteria: buffered peptone water, MPA, MPB, AGV, Endo and PAL media.

Biochemical properties of isolated bacterial strains were studied using an indicator paper system. Their reaction with catalase and oxidase was determined. The ability to ferment sugars - glucose, maltose and rhamnose - was checked. To identify microbial cultures by biochemical indices Bergey's identifier was used[2].

Antibiotic sensitivity of the obtained bacteria was determined by the disc-diffusion method using paper disks impregnated with antibiotics: levomycetin, cephalosporin, erythromycin and ampicillin. The work was performed according to MG 4.2.1890-04.

Nonlinear white mice weighing 15-20 g were used for the biological assay. Laboratory animals were kept according to the recommendations of RD-AIC 3.10.07.02-09. When preparing the suspension, the number of cells in it was adjusted to 10 IU using the McFarland turbidity standard.

Laboratory animals were infected intraperitoneally and observed for three days. After animal death an autopsy was performed. Organs with pathological anatomical changes were selected for suspension preparation by the method of limiting dilution to 10^{-8}, after that they were sown on Petri dishes with selective nutrient media.

RESULTS AND DISCUSSION

In the course of laboratory microbiological tests, 38 mites were found to have listeriosis pathogen circulation. Listeria was found in 10 mites from Chita District, 15 mites from Priargunsky District, and 13 mites from Krasno-Chikoysky District.

Biological properties of listeriosis pathogens obtained from mites did not differ from classical culture variants. Gram-positive small coccoid bacilli, sometimes in smears, were arranged in a V shape. Listeria colonies on PAL nutrient media were small (up to 1.5 mm), gray-yellow, round, with smooth edges.

In a biochemical study, the isolated listeria strains were positive for catalase and negative for oxidase. Sugars (glucose, maltose, rhamnose) were fermented with the formation of acid.

Five mice were used for the biological assay, and the infection was performed intraperitoneally. Death occurred on the 2nd-3rd day. Pathological anatomical examination revealed necrotic areas on the heart, kidneys and liver. Then pathological material was collected, placed in a sterile test tube, stored for 4 days for accumulation of listeria in the pathological material. Then, inoculation on selective nutrient medium PAL was performed to isolate and identify listeria on the basis of esculin hydrolysis to esculentin. PAL contains iron ions, which oxidize in the presence of esculetin and cause darkening of the medium around the listeria colony.

In the study of listeria for antibiotic sensitivity, antibiotic discs with a concentration of 2 μg (ampicillin) and 10 μg (gentamicin) were used.

[2]Burgey's bacterial identifier. Edited by J. Hoult, N. Krieg, P. Sneath, J. Staley, and S. Williams.Moscow: Mir. 1997. T. 2: 368 p.

On Petri dishes with Giventale-Vedmina agar medium (AGV), a zone of microbial growth retardation from 10 to 12 mm was observed.

Thus, out of 152 examined mites in 38 specimens the persistence of bacteria of the genus *Listeria*, species *Monocytogenes* was recorded, indicating the role of ixodid mites as a source of infection of animals and humans with leptospirosis.

E. coli was isolated from all 152 mites examined. It should be noted that the species association of lactose-positive and lactose-negative *E. coli* prevailed; no species association of *E. coli* was detected in 10 mites. Three lactose-positive samples and seven lactose-negative samples were detected. According to the data, the absence of the ability to ferment lactose is not a marker of increased pathogenic potential [11].

Cultural and morphological features of *E. coli*: small gram-positive motile bacilli with rounded ends. Spores and capsules were not formed. In the smears, they were arranged singly, randomly.

Cultivation of *E. coli* showed good growth on MPA, MPB, and Endo media. Small, round, grayish-white smooth colonies were formed on MPA. A moderate clouding of MPB was observed, followed by the precipitation of a mucous sludge. Two strains of *E. coli*, lactose-negative and lactose-positive, were obtained on Endo medium.

Biochemical parameters of *E. coli*: it fermented glucose, maltose, mannose, rhamnose, arnitine, sucrose, adonine, sorbitol, and arabinose with acid formation. Tests for catalase were positive and tests for urease were negative.

Antibiotic sensitivity studies showed high sensitivity of *E. coli* to all antibiotics, reflected by a large zone of delayed bacterial growth (more than 20 mm).

In the course of this study, 123 mites were found to have circulating salmonellosis pathogen. There were 48 mites from Chita district, 57 from Krasno-Chikoysky district, and 18 from Priargunsky district.

The isolated bacterial cultures were small gram-negative motile bacilli with rounded ends. Their arrangement was solitary and disorderly. According to a number of biochemical indicators, Salmonella strains fermented glucose, maltose, mannose, rhamnose, and arnitine with the formation of acid. Sucrose, adonine, sorbitol, arabinose, and lactose were not degraded. The bacteria produced hydrogen sulfide, catalase test was positive and urease test was negative. The pathogen was identified as *Salmonella typhi*.

The study of Salmonella antibiotic sensitivity revealed weak sensitivity to three antibacterial agents: levomycetin, cephalosporin, and ampicillin. The average zone of microbial culture growth retardation was 3 mm. Microbial cells were most sensitive to erythromycin: the zone of growth retardation was 16 mm.

Microorganisms of the genus *Clostridium* were also isolated from 71 mites: in Chita district from 18, in Krasno-Chikoysky district from 40, and in Priargunsky district from 13. When biological material from mites was inoculated into Kitt-Tarazzi liquid nutrient medium, a uniform clouding of the nutrient medium was observed.

The liver pieces were not melted, which may indicate that this bacterial strain belongs to serovars C, D, and E. Gram-positive bacillus with subterminal spore location was found in the smears. When stained by Peshkov, the spore stained green. The cells were located chaotically in the smear. The study of biochemical properties showed that the reaction of microorganisms of the genus *Clostridium* with sugars was weak or absent, indicating the low saccharolytic properties of this strain.

In the antibiotic sensitivity study, the average zone of stunting for tetracycline was 12 mm.

CONCLUSIONS

1. The microbiological study of 152 *Dermacentor* vacuum mites collected in the Transbaikal Territory resulted in obtaining four microbial cultures of different species: *L. monocytogenes*, *E. coli*, *S. typhi*, *C. botulinum*. The presence of associations of bacteria of different species groups in the organism of the mite was noted; in 32 specimens the presence of *L. monocytogenes*, *E. coli*, *S. typhi*, in 56 speci-

mens the presence of *C. botulinum*, *E. coli*, *S. typhi*, in 6 specimens the presence of *L. monocytogenes*, *E. coli*, in 15 specimens the presence of *C. botulinum*, *E. coli*.

2. Of all the microbial strains isolated, Escherichia coli was the most abundant: this microorganism was isolated from all the mites. *L. monocytogenes* was the least of all strains: 38 of 152 mites were carriers of it.

3. The data obtained point to the necessity of annual veterinary control of the grazing places for the presence of natural foci, the reservoirs of pathogenic agents of which are pasture ticks. It is necessary to carry out acaricide treatments of animals with repellent and acaricide preparations during mass attack of ixodid mites.

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ПРАВИЛА ДЛЯ АВТОРОВ

Правила для авторов составлены на основе этических принципов, общих для членов научного сообщества, и правил публикации в международных и отечественных научных периодических изданиях, а также в соответствии с требованиями ВАК для периодических изданий, включенных в Перечень российских рецензируемых научных журналов, в которых должны быть опубликованы основные научные результаты диссертаций на соискание ученой степени доктора и кандидата наук.

Журнал публикует оригинальные статьи по фундаментальным и прикладным проблемам по направлениям:

- общее земледелие и растениеводство;
- селекция, семеноводство и биотехнология растений;
- агрохимия, агропочвоведение, защита и карантин растений;
- кормопроизводство;
- инфекционные болезни и иммунология животных;
- частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства;
- разведение, селекция, генетика и биотехнология животных;
- технологии, машины и оборудование для агропромышленного комплекса;
- пищевые системы.

Статья, направляемая в редакцию, должна соответствовать тематическим разделам журнала «Сибирский вестник сельскохозяйственной науки»:

Наименование рубрики	**Шифр и наименование научной специальности в соответствии с Номенклатурой научных специальностей, по которым присуждаются ученые степени**
Земледелие и химизация	4.1.1. Общее земледелие и растениеводство 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Растениеводство и селекция	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений
Защита растений	4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Кормопроизводство	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Зоотехния и ветеринария	4.2.3. Инфекционные болезни и иммунология животных 4.2.4. Частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства 4.2.5. Разведение, селекция, генетика и биотехнология животных
Механизация, автоматизация, моделирование и информационное обеспечение	4.3.1. Технологии, машины и оборудование для агропромышленного комплекса
Переработка сельскохозяйственной продукции	4.3.3. Пищевые системы
Проблемы. Суждения Научные связи Из истории сельскохозяйственной науки Краткие сообщения Из диссертационных работ	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений 4.2.3. Инфекционные болезни и иммунология животных 4.2.4. Частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства 4.2.5. Разведение, селекция, генетика и биотехнология животных 4.3.1. Технологии, машины и оборудование для агропромышленного комплекса 4.3.3. Пищевые системы

В журнале также публикуются обзоры, краткие сообщения, хроника, рецензии, книжные обозрения, материалы по истории сельскохозяйственной науки и деятельности учреждений и ученых.

Число публикаций одного автора в номере журнала не должно превышать двух, при этом вторая статья допустима лишь в соавторстве.

К рассмотрению принимаются материалы от различных категорий исследователей, аспирантов, докторантов, специалистов и экспертов в соответствующих областях знаний.

Все статьи рецензируются и имеют зарегистрированный в системе CrossRef индекс DOI.

Публикации для авторов **бесплатны**.

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РЕКОМЕНДАЦИИ АВТОРУ ДО ПОДАЧИ СТАТЬИ

Представление статьи в журнал «Сибирский вестник сельскохозяйственной науки» подразумевает, что:

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3. Нерецензируемые материалы (материалы научной хроники, рецензии, книжные обозрения, материалы по истории сельскохозяйственной науки и деятельности учреждений и ученых) направляются на e-mail: **sibvestnik@sfsca.ru** и регистрируются ответственным секретарем.

ПОРЯДОК ОФОРМЛЕНИЯ СТАТЬИ

Текст рукописи оформляется шрифтом Times New Roman, кеглем 14 с интервалом 1,5, все поля 2,0 см, нумерация страниц внизу. Объем статьи не более 15 страниц (включая таблицы, иллюстрации и библиографию); статей, размещаемых в рубриках «Из диссертационных работ» и «Краткие сообщения», – не более 7 страниц.

Структура оформления статьи:

1. **УДК**
2. **Заголовок статьи на русском и английском языках (не более 70 знаков).**
3. **Фамилии и инициалы авторов, полное официальное название научного учреждения, в котором проведены исследования на русском и английском языках.**

Если в подготовке статьи принимали участие авторы из разных учреждений, необходимо указать принадлежность каждого автора к конкретному учреждению с помощью надстрочного индекса.

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6. **Информация о конфликте интересов либо его отсутствии.** Автор обязан уведомить редактора о реальном или потенциальном конфликте интересов, включив информацию о конфликте интересов в соответствующий раздел статьи. Если конфликта интересов нет, автор должен также сообщить об этом.

Пример формулировки: «Автор заявляет об отсутствии конфликта интересов».

7. **Благодарности на русском и английском языках.** В этом разделе указываются все источники финансирования исследования, а также благодарности людям, которые участвовали в работе над статьей, но не являются ее авторами.
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ВВЕДЕНИЕ (постановка проблемы, цели, задачи исследования)

МАТЕРИАЛ И МЕТОДЫ (условия, методы (методика) исследований, описание объекта, место и время проведения)

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

ЗАКЛЮЧЕНИЕ или **ВЫВОДЫ**

СПИСОК ЛИТЕРАТУРЫ. Количество источников не менее 15. В список литературы включаются только рецензируемые источники: статьи из научных журналов и монографии. Самоцитирование не более 10% от общего количества. Библиографический список должен быть оформлен в виде общего списка в порядке упоминания в тексте, желательны ссылки на источники 2–3-летнего срока давности. Правила оформления списка литературы – в соответствии с ГОСТ Р 7.05–2008 (требования и правила составления библиографической ссылки). В тексте ссылка на источник отмечается порядковой цифрой в квадратных скобках, например [1]. Литература в списке дается на тех языках, на которых она издана. В библиографическое описание публикации необходимо вносить всех авторов, не сокращая их одним, тремя и т.п. Недопустимо сокращение названий статей, журналов, издательств.

Если необходимо сослаться на авторефераты, диссертации, сборники статей, учебники, рекомендации, учебные пособия, ГОСТы, информацию с сайтов, статистические отчеты, статьи в общественно-политических газетах и прочее, то такую информацию следует оформить в *сноску* в конце страницы. Сноски нумеруются арабскими цифрами, размещаются постранично сквозной нумерацией.

Внимание! Теоретические, обзорные и проблемные статьи могут иметь произвольную структуру, но обязательно должны содержать реферат, ключевые слова, список литературы.

ПРИМЕРЫ ОФОРМЛЕНИЯ СПИСКА ЛИТЕРАТУРЫ, REFERENCES И СНОСОК

СПИСОК ЛИТЕРАТУРЫ:

Монография

Климова Э.В. Полевые культуры Забайкалья: монография. Чита: Поиск, 2001. 392 с.

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Холмов В.Г. Минимальная обработка кулисного пара под яровую пшеницу при интенсификации земледелия в южной лесостепи Западной Сибири // Ресурсосберегающие системы обработки почвы. М.: Агропромиздат, 1990. С. 230–235.

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REFERENCES:

Составляется в том же порядке, что и русскоязычный вариант, по следующим правилам:

Фамилии И.О. авторов в устоявшемся способе транслитерации, англоязычное название статьи, *транслитерация названия русскоязычного источника (например через сайт: https://antropophob.ru/translit-bsi) = англоязычное название источника.* Далее оформление для монографии: город, англоязычное название издательства, год, количество страниц; для журнала: год, номер, страницы). (In Russian).

Пример: Avtor A.A., Avtor B.B., Avtor C.C. Title of article.

Транслитерация авторов. Англоязычное название статьи

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

Транслитерация источника = Англоязычное название источника

Монография

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

Часть книги

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

Периодическое издание

Pakul A.L., Lapshinov N.A., Bozhanova G.V., Pakul V.N. Technological grain qualities of spring common wheat depending on the system of soil tillage. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2018, vol. 48, no. 4, pp. 27–35. (In Russian). DOI: 10.26898/0370-8799-2018-4-4.

СНОСКИ:

Цитируемый текст[1].

[1]*Климова Э.В., Андреева О.Т., Темникова Г.П.* Пути стабилизации кормопроизводства Забайкалья // Проблемы и перспективы совершенствования зональных систем земледелия в современных условиях: материалы науч.-практ. конф. (Чита, 16–17 октября 2008 г.). Чита, 2009. С. 36–39.

Цифровой идентификатор Digital Object Identifier – DOI (когда он есть у цитируемого материала) необходимо указывать в конце библиографической ссылки.

Пример:

Chu T., Starek M.J., Brewer M.J., Murray S.C., Pruter L.S. Assessing lodging severity over an experimental maize (Zea mays L.) field using UAS images // Remote Sensing. 2017. Vol. 9. P. 923. DOI: 10.3390/rs9090923.

Наличие DOI статьи следует проверять на сайте http://search.crossref.org/ или https://www.citethisforme.com. Для этого нужно ввести в поисковую строку название статьи на английском языке.

РИСУНКИ, ТАБЛИЦЫ, СКРИНШОТЫ И ФОТОГРАФИИ

Рисунки должны быть хорошего качества, пригодные для печати. Все рисунки должны иметь подрисуночные подписи. Подрисуночную подпись необходимо перевести на английский язык. Рисунки нумеруются арабскими цифрами по порядку следования в тексте. Если рисунок в тексте один, то он не нумеруется. Отсылки на рисунки оформляются следующим образом: «На рис. 3 указано, что …» или «Указано, что … (см. рис. 3)». Подрисуночная

подпись включает порядковый номер рисунка и его название. «Рис. 2. Описание жизненно важных процессов». Перевод подрисуночной подписи следует располагать после подрисуночной подписи на русском языке.

Таблицы должны быть хорошего качества, пригодные для печати. Предпочтительны таблицы, пригодные для редактирования, а не отсканированные или в виде рисунков. Все таблицы должны иметь заголовки. Название таблицы должно быть переведено на английский язык. Таблицы нумеруются арабскими цифрами по порядку следования в тексте. Если таблица в тексте одна, то она не нумеруется. Отсылки на таблицы оформляются следующим образом: «В табл. 3 указано, что …» или «Указано, что … (см. табл. 3)». Заголовок таблицы включает порядковый номер таблицы и ее название: «Табл. 2. Описание жизненно важных процессов». Перевод заголовка таблицы следует располагать после заголовка таблицы на русском языке.

Фотографии, скриншоты и другие нерисованные иллюстрации необходимо загружать отдельно в виде файлов формата *.jpeg (*.doc и *.docx – в случае, если на изображение нанесены дополнительные пометки). Разрешение изображения должно быть >300 dpi. Файлам изображений необходимо присвоить название, соответствующее номеру рисунка в тексте. В описании файла следует отдельно привести подрисуночную подпись, которая должна соответствовать названию фотографии, помещаемой в текст.

Следует обратить внимание на написание формул в статье. Во избежание путаницы необходимо греческие (α, β, π и др.), русские (А, а, Б, б и др.) буквы и цифры писать прямым шрифтом, латинские – курсивным (*W*, *Z*, *m*, *n* и др.). Математические знаки и символы нужно писать также прямым шрифтом. Необходимо четко указывать верхние и нижние надстрочные символы (W^1, F_1 и др.).

ВЗАИМОДЕЙСТВИЕ МЕЖДУ ЖУРНАЛОМ И АВТОРОМ

Редакция просит авторов при подготовке статей руководствоваться изложенными выше правилами.

Все поступающие в журнал «Сибирский вестник сельскохозяйственной науки» статьи проходят предварительную проверку на соответствие формальным требованиям. На этом этапе редакция оставляет за собой право:

- принять статью к рассмотрению;
- вернуть статью автору (авторам) на доработку с просьбой устранить ошибки или добавить недостающие данные;
- вернуть статью автору (авторам) без рассмотрения, оформленную не по требованиям журнала;
- отклонить статью из-за несоответствия ее целям журнала, отсутствия оригинальности, малой научной ценности.

Переписка с авторами рукописи ведется через контактное лицо, указанное в рукописи.

Все научные статьи, поступившие в редакцию журнала «Сибирский вестник сельскохозяйственной науки», проходят обязательное двухстороннее «слепое» рецензирование (double-blind – автор и рецензент не знают друг о друге). Рукописи направляются по профилю научного исследования на рецензию членам редакционной коллегии.

В спорных случаях редактор может привлечь к процессу рецензирования нескольких специалистов, а также главного редактора. При положительном заключении рецензента статья передается редактору для подготовки к печати.

При принятии решения о доработке статьи замечания и комментарии рецензента передаются автору. Автору дается 2 месяца на устранения замечаний. Если в течение этого срока автор не уведомил редакцию о планируемых действиях, статья снимается с очереди публикации.

При принятии решения об отказе в публикации статьи автору отправляется соответствующее решение редакции.

Ответственному (контактному) автору принятой к публикации статьи направляется финальная версия верстки, которую он обязан проверить.

ПОРЯДОК ПЕРЕСМОТРА РЕШЕНИЙ РЕДАКТОРА/РЕЦЕНЗЕНТА

Если автор не согласен с заключением рецензента и/или редактора или отдельными замечаниями, он может оспорить принятое решение. Для этого автору необходимо:

- исправить рукопись статьи согласно обоснованным комментариям рецензентов и редакторов;
- ясно изложить свою позицию по рассматриваемому вопросу.

Редакторы содействуют повторной подаче рукописей, которые потенциально могли бы быть приняты, однако были отклонены из-за необходимости внесения существенных изменений или сбора дополнительных данных, и готовы подробно объяснить, что требуется исправить в рукописи для того, чтобы она была принята к публикации.

ДЕЙСТВИЯ РЕДАКЦИИ В СЛУЧАЕ ОБНАРУЖЕНИЯ ПЛАГИАТА, ФАБРИКАЦИИ ИЛИ ФАЛЬСИФИКАЦИИ ДАННЫХ

Редакция научного журнала «Сибирский вестник сельскохозяйственной науки» в своей работе руководствуется традиционными этическими принципами научной периодики и сводом принципов «Кодекса этики научных публикаций», разработанным и утвержденным Комитетом по этике научных публикаций, требуя соблюдения этих правил от всех участников издательского процесса.

ИСПРАВЛЕНИЕ ОШИБОК И ОТЗЫВ СТАТЬИ

В случае обнаружения в тексте статьи ошибок, влияющих на ее восприятие, но не искажающих изложенные результаты исследования, они могут быть исправлены путем замены pdf-файла статьи. В случае обнаружения в тексте статьи ошибок, искажающих результаты исследования, либо в случае плагиата, обнаружения недобросовестного поведения автора (авторов), связанного с фальсификацией и/или фабрикацией данных, статья может быть отозвана. Инициатором отзыва статьи может быть редакция, автор, организация, частное лицо. Отозванная статья помечается знаком «Статья отозвана», на странице статьи размещается информация о причине отзыва статьи. Информация об отзыве статьи направляется в базы данных, в которых индексируется журнал.

УВАЖАЕМЫЕ ПОДПИСЧИКИ!

Подписку на журнал «Сибирский вестник сельскохозяйственной науки»
(как на годовой комплект, так и на отдельные номера)
можно оформить одним из следующих способов:

– в агентстве подписки ГК «Урал-Пресс» по индексу 014973. Ссылка на издание https://www.ural-press.ru/catalog/97210/8707659/?sphrase_id=392975. В разделе контакты зайти по ссылке http://ural-press.ru/contact/, где можно выбрать филиал по месту жительства;
– в редакции журнала (телефон 7-383-348-37-62; e-mail: sibvestnik@sfsca.ru).

Полнотекстовая версия журнала
«Сибирский вестник сельскохозяйственной науки»
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