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SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

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OUR JUBILJARS

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УМЕРЕННО ОПАСНЫЕ МИКРОЭЛЕМЕНТЫ В ПОЧВАХ ЗАСОЛЕННЫХ АГРОЛАНДШАФТОВ БАРАБИНСКОЙ РАВНИНЫ

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При освоении адаптивно-ландшафтных систем земледелия особое внимание уделяется изучению эколого-токсикологического и санитарно-гигиенического состояния используемой территории. Особенно это важно для засоленных агроландшафтов, которые широко распространены в Барабинской равнине (Барабе). Исследования проведены в северо-восточной части Барабы в пределах Новосибирской области. Изучены почвы элювиальной (лугово-черноземной), транзитной (черноземно-луговой) и аккумулятивной (солонец глубокий) зон катены. Почвы различались по физико-химическим свойствам и микроэлементному составу. В профиле почв от элювиальной к аккумулятивной зоне увеличивалась щелочность, уменьшилось содержание гумуса и изменялся гранулометрический состав. Эти показатели влияют на микроэлементный состав. Определено содержание умеренно опасных микроэлементов (второго класса опасности): хрома, никеля, кобальта и молибдена. Установлено, что максимальное содержание валового хрома приходится на профиль лугово-черноземной почвы в элювиальной позиции. В пахотном горизонте подвижного хрома менее 0,00001 мг/кг, что не попадает в диапазон определения прибора. Отмечено некоторое передвижение подвижных форм хрома с элювиальной позиции в аккумулятивную. Максимальное содержание валового никеля и кобальта обнаружено в профиле лугово-черноземной почвы, но оно находится в количестве значительно ниже ПДК. По профилю почв валовое содержание никеля и кобальта изменяется незначительно, что свидетельствует об их слабой подвижности. Валовое содержание молибдена в почвах находится в пределах кларка и примерно одинаково по всей глубине. Установлено, что в почвах засоленных агроландшафтов Барабы по катене содержание умеренно опасных микроэлементов никеля и кобальта ниже ПДК и не представляет опасности с эколого-токсикологической точки зрения. Содержание валового хрома и молибдена находится на грани ПДК, поэтому в определенных случаях может возникнуть напряженность эколого-токсикологической обстановки территории. На это следует обращать внимание при сельскохозяйственном использовании засоленных агроландшафтов.

Ключевые слова: микроэлементы, хром, никель, кобальт, молибден, катена, засоленная почва

MODERATELY HAZARDOUS MICROELEMENTS IN THE SOILS OF SALINE AGROLANDSCAPES OF THE BARABA PLAIN

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When developing adaptive-landscape farming systems, special attention is paid to the study of the ecological, toxicological and sanitary-hygienic state of the territory used. This is especially important for saline agro-landscapes, which are widespread in the Barabinskaya plain (Baraba). The studies were conducted in the northeastern part of the Baraba within the Novosibirsk Region. The soils of the eluvial (meadow-chernozem), transit (chernozem-meadow), and accumulative (deep solonetz) zones of the

catena were studied. The soils differed in physicochemical properties and microelement composition. In the soil profile from the eluvial to accumulative zone, alkalinity increased, humus content decreased, and the granulometric composition changed. These indicators affect the microelement composition. The content of moderately hazardous trace elements (hazard class 2): chromium (Cr), nickel (Ni), cobalt (Co) and molybdenum (Mo) were determined. It was found that the maximum content of total chromium falls on the profile of meadow-chernozem soil in the eluvial position. In the arable horizon there is less than 0.00001 mg/kg of mobile chromium, which does not fall within the detection range of the device. Some movement of mobile forms of chromium from the eluvial to accumulative position was noted. The maximum content of total nickel and cobalt was found in the profile of meadow-chernozem soil, but it is in amounts well below the LOC. The total content of nickel and cobalt varies insignificantly across the soil profile, indicating their low mobility. The total content of Mo in soils is within the clarke range and is approximately the same over the entire depth. It was found that the content of moderately hazardous trace elements of nickel and cobalt in the soils of saline agro-landscapes of Baraba by catena is below the LOC and cannot be a hazard from the ecological-toxicological point of view. The content of total chromium and molybdenum is on the verge of the LOC and therefore, in certain cases, tension in the ecological and toxicological situation of the territory may arise. This should be taken into account in the agricultural use of saline agrolandscapes.

Keywords: microelements, chromium, nickel, cobalt, molybdenum, catena, saline soil.

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INTRODUCTION

The development of adaptive-landscape farming systems and precision agriculture required the development of new, more detailed approaches to the use of soil cover of territories. These approaches should include a comprehensive study of the soil properties of a particular agrolandscape. Special attention should be paid to the microelement composition, as it determines both the fertility and the ecological and hygienic conditions of the agrolandscape.

Currently, agroecological zoning of agrolandscapes has been developed for the forest-steppe zone using the example of the Novosibirsk region[1]. In particular, it has been found that the Barabinsk plain (Baraba), which occupies about 65.5%, or 11.7 million ha of the Novosibirsk region, is dominated by saline agrolandscapes, represented by semihydromorphic and hydromorphic analogues of zonal soils (chernozems) – meadow-chernozem, black-meadow and meadow soils of various degrees

[1]Dobrotvorskaya N.I., Semendyaeva N.V., Ponko V.A., Ivanova M.I. Methodology and methods for assessing the ecological and resource potential of agrolandscapes in the Western Siberia: a methodological handbook. Novosibirsk: SFSCA RAS, 2018. 99 p.

of salinity and alkalinity in complex with saline soil, alkaline soil and solod soil.

In the study of the properties of saline soils a special place is given to trace elements - heavy metals and metalloids. They are extremely necessary in small quantities for plants, living organisms, as well as humans, because they are part of enzymes, vitamins, lipids, etc. Increased and decreased content of trace elements can cause various diseases.

The aim of the study was to study the content of moderately hazardous trace elements - chromium, nickel, cobalt and molybdenum (the second class of danger)[2] - in the soils of the katena saline agrolandscape of the north-eastern part of Baraba within the Novosibirsk region.

Research objectives:

– to study the morphological and physicochemical properties of soils by catena (eluvial, transit and accumulative positions);

– to determine the content and character of movement of moderately dangerous microelements in soils;

– to give an ecological and hygienic assessment of the content of moderately dangerous trace elements in soils of saline agro-landscapes of Baraba for animals and humans.

MATERIAL AND METHODS

The studies were carried out on the territory of JSC "Bolshenikolskoye", Chulymsky District, Novosibirsk Region. This territory is a two-stage lake-alluvial plain. Its northeastern part, where the research was conducted, belongs to the high structural-geomorphological surface, and the southwestern part to the low one.

The relief of the northeastern part of this area is represented by an alternation of ancient interfluves and runoff gullies stretching from northeast to southwest.

The interfluves are flat, elevated above the gullies by only 5-15 m. In some places, there are blurred low ridges. Small hollows in gullies can be occupied by lakes and bogs. The microrelief is knob and kettle, which facilitates redistribution of moisture and easily soluble salts from ridges to inter-ridge depressions[3].

Annual precipitation varies from 225 to 350-400 mm. Hydrothermal coefficient varies from 0.6-0.8 to 1.0-1.2. Baraba is characterized by climate cyclicity, which has a significant impact on soil composition and properties, especially on redistribution of easily soluble salts. During humid periods there is some desalinization of soil profiles and strengthening of reductive processes, in droughty periods - opposite phenomena are observed.

A characteristic feature of the vegetation cover of Baraba is the change of forest vegetation to steppe vegetation. Park-type birch knolls alternate with steppe meadows. Steppification of the territory leads to desiccation of forestland and salinization of the soil cover. Periodic over-moistening and elevation of saline groundwater contribute to development of sod formation process and formation of meadow-chernozem, chernozem-meadow and meadow soils of different degrees of gleying, salinization, as well as development of soils of halogen process of soil formation - saline soil, alkaline soil and solod soil.

In the northeastern part of Baraba in the wide valley of the Karasuk River, soil sections were laid along the catena (eluvial, transitional, and accumulative positions). In them, soil samples were selected according to genetic horizons, in which the following types of analyses were performed: granulometric composition according to Kachinsky, humus according to Tyurin, pH value according to potentiometric analysis[4]. Determination of gross and mobile forms of trace elements was carried out by atomic-emission spectroscopy on DAEP device (double-beam atomic-emission plasma torch) (see footnote 4). The mobile forms of chromium, nickel, and cobalt compounds were extracted from soils with acetate-ammonium buffer solution with pH 4.8. Statistical processing of the obtained data was performed using the Excel software package.

[2]GOST 17.4.1.02-83. Nature Conservation. Soils. Classification of Chemical Elements for Pollution Control. Moscow, 1983.12 p.

[3]Semendyaeva N.V., Galeeva L.P., Marmulev A.N. Soils of the Novosibirsk region and their agricultural use: a textbook. Novosibirsk, 2010. 187 p.

[4]Practical agrochemistry: textbook; 2nd ed. / Ed. by V.G. Mineev. Moscow: Publishing house of the Moscow State University, 2001. 689 p.

RESULTS AND DISCUSSION

When studying the ecotoxicity of trace elements in soil, it is necessary to know the pH value, humus content, and granulometric composition, since these parameters determine the geochemical properties of elements and their compounds. The characteristic of these properties of soils of katena is presented in table 1.

In the eluvial position, zonal meadow-chernozem soil has a neutral pH (6.6-6.7) up to a depth of 80 cm, and then it is alkaline. In the transitional position, the meadow-chernozem soil is alkaline throughout the profile, and alkalinity increases with depth. In the accumulative - deep solonetz - soil is strongly alkaline: in the horizon A (0-20 cm) - 9.8, then the pH is 10 or more. The content of humus is high in the A horizons of eluvial and transitional soils - 9.7 and 10.8%, respectively. In accumulative - deep solonetz - the content of humus is reduced to 5%, with depth it sharply decreases. Granulometric composition is different: in meadow-chernozem soil of eluvial position in A horizon it is medium-loamy, with depth it is heavy-loamy. In the transitional position the granulometric composition of the meadow-chernozem soil is loamy in the A horizon, then it gets heavier to light loamy and then it gets further heavier. It should be noted that such a diverse granulometric composition is characteristic of soils formed in floodplains. A similar situation is noted in the accumulative zone, but here the granulometric composition is heavier, from mid-loamy to light loamy.

The gross content of moderately hazardous chemical trace elements is presented in Table 2.

Chromium is a biogenic element that is constantly present in plant and animal cells. It participates in protein synthesis in plants and increases chlorophyll content in leaves. But chromium is a highly toxic trace element: in small amounts it is a plant stimulant, in larger amounts it is an inhibitor. In excessive amounts, chromium inhibits plant development; in very high concentrations, it causes plant death.

The phytotoxicity of chromium depends on its valence, which determines its toxicity

Табл. 1. Физико-химические свойства почв катены засоленных агроландшафтов Барабинской равнины

Table. 1. Physical and chemical properties of catena soils in saline agricultural landscapes of the Baraba plain

Geomorphological position, soil crossover number, soil	Horizon, sampling depth, cm	pH_{H_2O}	Humus, %	Physical clay, particles < 0,01%	Short name by granulometric composition
Eluvial, soil crossover No. 1, meadow-chernozem moderately deep middle-loamy	$A_{пах}$ 0–18	6,62	9,67	36,5	Middle loamy
	A_1 25–35	6,57	7,74	31,1	»
	AB 50–60	6,26	1,29	53,5	Heavy loamy
	B_1 70–80	6,71	Not defined	53,9	»
	$B_к$ 110–120	8,40	» »	56,3	»
Transit, soil crossover No. 2, meadow-chernozem saline loamy sand	$A_д$ 0–10	7,90	10,75	14,0	Loamy sand
	A_1 10–24	8,20	4,51	8,8	Sandy
	AB 30–40	8,30	1,00	21,4	Light loamy
	B_q 50–60	8,44	0,55	22,6	»
	A_{error} 80–90	8,91	0,88	53,3	Heavy loamy
	B_{error} 100-110	9,13	0,59	56,1	»
Accumulative, soil crossover No. 3, deep solonchak slightly saline heavy loamy	A 0–20	9,8	5,16	60,6	Moderately clayey
	B_1 20–30	10,12	2,58	60,2	»
	B_2 30–50	10,16	0,86	41,2	Light clayey
	B_3 50–60	10,00	Not defined	41,2	»
	B_4 70–80	10,04	» »	54,6	Moderately clayey

in the soil and its availability to plants. Cr^{6+} is most accessible to plants. It is unstable under normal soil conditions. Cr^{3+} usually prevails in soils, which compounds are weakly soluble in an acidic environment [1]. In an alkaline environment, Cr^{3+} is oxidized to Cr^{6+} to form soluble chromates. Trivalent chromium is well absorbed by soil, so it has little toxicity.

In soil, the MAC of Cr^{3+} is 100 mg/kg, Cr^{6+} is 0.05 mg/kg [2]. Chromium clark in the Earth's crust is 200 mg/kg [3], but its gross content in the soils of the world varies widely [4]. In the process of detailed study clark chromium changed mainly in the direction of reduction [5]. It has been found that the gross chromium content in soils increases from rural settlements (50-58 mg/kg) to cities with developed industrial industry (90-100 mg/kg). Excess chromium sharply reduces the biological activity of soils.

In the soils of the studied catena in the eluvial position the gross chromium content in the arable horizon of meadow-chernozem soil was 79.5 mg/kg, mobile - less than 0.00001 mg/kg, which is below the detection range of the instrument. With depth, the content of gross chromium increased to 141 mg/kg. Its noticeable movement along the catena was not found, in the transit zone the amount varied with depth from 51 to 92 mg/kg. In the accumulative zone there is slightly more gross chromium than in the transit zone, but lower

Табл. 2. Профильное распределение валового содержания умеренно опасных микроэлементов в почвах засоленных агроландшафтов Барабы

Table. 2. Profile distribution of the total content of moderately hazardous microelements in the soils of saline agricultural landscapes of the Baraba plain

Geomorphological position of the soil crossover, soil	Horizon, sampling depth, cm	Trace elements, mg/kg soil					
		Chromium		Nickel		Cobalt	Molybdenum
		gross	mobile	gross	mobile	gross	gross
Eluvial, soil crossover No. 1, meadow-chernozem moderately deep middle-loamy	$A_{пах}$ 0–18	79,5	0,0	50,1	0,02	14,6	1,24
	A_1 25–35	109	«0,1	52,1	0,03	17,6	2,32
	AB 50-60	107	0,12	66,7	0,04	16,3	2,5
	B_1 70–80	141	0,12	58,3	0,04	13,4	2,03
	$B_к$ 110–120	102	0,15	51,9	0,04	10,9	2,31
Transit, soil crossover No. 2, meadow-chernozem saline loamy sand	$A_д$ 0–10	51,0	0,14	50,5	«0.01	15,4	3,85
	A_1 10–24	66,0	0,14	58,7	0,01	13,3	2,77
	AB 30–40	48,2	0,15	36,4	0,01	7,4	1,83
	B_q 50–60	50,8	0,18	32,9	0,01	7,0	2,22
	$A_{погр}$ 80–90	92,0	0,13	52,1	0,02	15,6	1,84
	$B_{погр}$ 100-110	59,8	0,13	47,1	0,03	11,8	1,88
Accumulative, soil crossover No. 3, deep solonchak slightly saline heavy loamy	A 0–20	74,4	0,32	44,2	0,060	9,9	2,25
	B_1 20–30	56,7	0,31	47,4	0,040	10,5	1,31
	B_2 30–50	77,1	0,13	43,6	0,020	10,5	2,79
	B_3 50–60	83,4	0,21	44,4	0,014	10,5	1,85
	B_4 70–80	87,4	0,17	40,1	0,014	8,5	2,02
Clarke [3]		200		40		10	2,0
MAC[5]		100		50		50	5,0

[5]The list of Maximum Permissible Concentrations (MPC) and Approximately Permissible Amounts (APC) of chemical substances in the soil. Special edition. Moscow: Goskomsanepidnadzor of Russia Publishing House. 1991. 18 p.

than in the eluvial. There was a tendency of insignificant movement of mobile chromium from the eluvial to accumulative zone, which, in our opinion, is associated with the movement of silty particles and humus with surface water flows.

The results obtained on the content of gross chromium in the soils of saline agro-landscapes of Baraba indicate that its movement along the catena is insignificant. However, the mobility of chromium in the upper humus horizons increases from the eluvial position through the transitional to accumulative position due to an increase in pH and the movement of silty particles with surface water. It is cumulated in the accumulative zone. The content of both gross and mobile chromium in the soils of the catena is below the MAC and does not contribute to environmental pollution.

Nickel in trace amounts is essential for plants and living organisms. It accelerates plant emergence from dormancy, promotes nitrogen movement and seed germination, and affects urease activity. Nickel stimulates photosynthesis, promotes the formation of the spiral structure of nucleic acids, and affects the absorptive capacity of plant roots. However, its increased content in soils inhibits plant growth and reduces the amount of chlorophyll in the leaves [6].

Nickel clark in soils equals 40 mg/kg. TAC (tentative allowable concentration) of its gross content in sandy and sandy loam soils is 20 mg/kg, in loamy and clayey (acidic) soils - 40, loamy and clayey (neutral) soils - 80 mg/kg. The TAC of the exchangeable form (acetate-ammonium buffer, pH - 4.8) is 4 mg/kg of soil [7]. In soils, nickel, as a rule, is concentrated in the silty fraction which is enriched in montmorillonite. Nickel forms soluble chelate compounds with organic matter. It has been established that nickel migrates, although weakly, along the soil profile in cationic form in the form of true solutions, compounds in colloidal form, and in the form of mechanical suspensions [7]. According to S.V. Lukin [1], the gross nickel content in the chernozems of the Belgorod region is about 25 mg/kg and does not change reliably with depth. In the Novosibirsk region, the gross nickel content in zonal soils is higher, from 32 mg/kg of soil in humus horizons to 43-45 mg/kg and more in saline landscapes [7].

In particular, the soil profile of the studied catena contains the greatest amount of bulk nickel in the eluvial position: in the humus layer - 50.1-52.1 mg/kg of soil; in the AB and B horizons it increases to 66.7-58.3, at a depth of 110 cm it decreases again to 52 mg/kg (see Table 2). In the transit zone, its content in the humus layer of soil is about the same as in the eluvial zone, and decreases with depth. In the accumulative zone, the gross nickel content tends to increase as compared to the transit zone. The gross nickel content in the saline agrolandscape soils is slightly higher than the clark, but significantly lower than the MAC.

The content of mobile forms of nickel is the highest in the meadow-chernozem soil. It is approximately the same throughout the entire profile, only in the A horizon it is slightly lower. In the accumulative position, more mobile nickel was found in the upper humus horizons, which indicates its movement from the eluvial zone through the transit zone, as well as some cumulation in the accumulative zone.

Thus, in the studied saline agro-landscape of Baraba no deficiency or excess of nickel was found. However, its accumulation in the accumulative position is possible due to the movement of nickel compounds with surface water, as indicated by the studies of V.B. Ilyin and A.I. Syso [7]. Nickel is geochemically related to cobalt, since their atomic masses are close [1].

Cobalt takes an active part in physiological processes of plant and living organisms. It significantly enhances nitrogen-fixing ability of microorganisms, synthesis of chlorophyll, proteins, and carbohydrates. It promotes the formation of vitamin B_{12}, extremely necessary for living organisms[6] [8]. Clark cobalt is equal to 10 mg/kg [3, 8, 9]. In the soil cover, its distribution depends on the composition of the parent rock, in the soil profile - on the content of physical clay, silt fraction, iron oxides and organic matter, as these indicators are able to fix and accumulate cobalt. It has been estab-

lished that the proportion of substances capable of fixing cobalt in soils into immobile and low-mobile compounds is 95% of its gross content. In natural environments, cobalt can be in two oxidation states, Co^{2+} and Co^{3+}, as well as in the form of the complex compound Co $(OH)^3$-. Co^{2+} and Co^{3}+ ions are almost completely fixed by the soil absorbing complex, in the soil profile more mobile are complex compounds Co $(OH)^7$ (see footnotes 2-6).

The average content of cobalt in plants is 0.01-0.6 mg/kg of dry matter. In leguminous plants there is more of it than in cereals [10]. When the content of cobalt in soils is less than 5 mg/kg, its deficiency in herbaceous vegetation is noted. In this case, animals begin to show signs of avitaminosis, the formation of hemoglobin, nucleic acids, and proteins slows down, and endemic goiter appears. The critical level of cobalt content in plants for normal animal development is 0.08-0.1 mg/kg of plant dry weight [3, 11]. External cobalt deficiency in plants manifests itself similarly to nitrogen deficiency - leaf chlorosis, slowed plant growth and short development cycle.

Under natural conditions, an excess of cobalt in soils is rare. It usually accumulates in the edges and tips of leaves; they turn white and die off. Excess cobalt has a negative effect on animals. Its maximum allowable concentration in grasses should not exceed 60 mg/kg dry matter.

Cobalt toxicity is manifested by a decrease in vitamin B_{12} content and lack of fruiting.

According to V.B. Ilyin and A.I. Syso, the soils of the Novosibirsk region in Baraba and Priob'ye are characterized by high gross content of trace elements, which is associated with their heavy granulometric composition and high humus content, especially in meadow-chernozem soils and in saline (solonets and solonchaks). In particular, they found that the soils of Baraba are characterized by increased and high content of cobalt [7].

In the studied soils of katena the highest content of gross cobalt is concentrated in meadow-chernozem soil of eluvial position. Its maximum is in the A and AB horizons and is 17.6-16.3 mg/kg of soil, respectively (see Table 2). In the A_{nax} horizon, the content of gross cobalt is somewhat lower than in the A_1 horizon, which is probably associated with its movement to the transit zone with water flows containing mud particles and humus. According to the regulations (see footnote 5), this content of cobalt in the soil is high and very high (10-15 and 15-22 mg/kg). In the lower horizons it decreases to 13-10 mg/kg. In the transit zone of chernozem-meadow soil in the upper humus horizons, the content of cobalt, despite the light granulometric composition, is high - 15.4-13.3 mg/kg. This is associated with its movement from the upper positions to the lower ones, where a significant part of cobalt is absorbed, most likely, by soil organic matter. In the AB and Bq horizons, the amount of bulk cobalt decreases sharply to 7 mg/kg of dry soil. In the buried soil, its content increases again and approaches the content in the upper horizons. This phenomenon indicates weak movement of cobalt along the catena. It is practically all fixed in the upper soil horizons of the transit zone. In the accumulative zone, the gross content of cobalt throughout the profile of deep solonetz is distributed approximately equally. Its accumulation at any depth was not detected, although the gross amount of cobalt according to the grading is high. As noted earlier, in an alkaline environment mobility of cobalt decreases sharply, as evidenced by our data. Mobile cobalt in the studied soils is less than 0.00001 mg/kg, except for deep solonetz A horizon (0.0118 mg/kg).

Thus, all soils of the catenas of saline agrolandscapes of the Barabinsk plain contain increased and high content of gross cobalt. Despite its high content, it is not an environmental pollutant (MPC = 50 mg/kg) and does not currently aggravate the sanitary and hygienic situation in saline agrolandscapes.

[6]Protopopova L.G. The behavior of cobalt in the soil-plant system and the effectiveness of cobalt fertilizers in the Altai plains and foothills: Ph. D in Agr. 2002, 232 p.

[7]Bityutsky N.P. Micronutrients and the Plant: Textbook. St. Petersburg: Publishing house of St. Petersburg State University, 1999. 232 p.

In soils, the content of gross molybdenum is in the range 0.013-17 mg/kg, the average value (clark) is 2 mg/kg [3, 12]. S.F. Spitsina et al. [13] found that the soils of the Altai region is characterized by low gross molybdenum content (0.1-1.2 mg/kg), which is associated with its low gross content in the soil-forming rocks (0.2-1.4 mg/kg soil). In the upper humus horizons gross molybdenum is more due to biogenic accumulation [13]. According to V.B. Ilyin et al. [14], the concentration of molybdenum in the south of Western Siberia is much higher and averages about 4.3 mg/kg. Consequently, the soils here are characterized by a high content of this element, whereas the soils of Altai Krai require the application of molybdenum-containing microfertilizers.

The average content of molybdenum in plants ranges from 0.0005-0.002%. Molybdenum is an important and essential chemical element for plants and living organisms, it is a part of enzymes responsible for nitrogen metabolism, it improves phosphorus absorption by plants, it is a part of nitrogenase, which ensures growth and development of legumes and vegetable crops. During vegetation, molybdenum accumulates in the young organs of plants, and at the end of the growing season it is concentrated in the seeds. The availability of molybdenum to plants depends on pH value. In acidic soils its compounds are insoluble, in alkaline soils they are available to plants. It has been established that a significant part of molybdenum in soil is associated with organic matter and aqueous iron oxides [7].

As evidenced by our data (see Table 2), the content of molybdenum in the soils of the studied catenary in all geomorphological positions is within the clark - about 2 mg/kg of dry soil. Only a small accumulation of it in the upper humus layer due to the increased content of organic matter in it was noted [13]. Our data slightly differ from those of V.B. Ilyin et al. [14, 15], which is explained by the high alkalinity of soils in saline agricultural landscapes (up to 10 and more), in which molybdenum compounds become mobile.

A. Azarenko [16] in the study of mobile forms of trace elements in the soils of the Omsk Irtysh Land region found that the largest amount of mobile molybdenum is in alkaline soils. Then come chernozems, the smallest amount of this element is in sod-podzolic soils. As noted by the author, in the profile of chernozems and meadow-chernozem soils there is an accumulation of this element in the upper humus horizons, a decrease in the horizons B and Bk, then its content increases again due to the solubility of this element in an alkaline environment.

Thus, the gross content of molybdenum in the soils of saline agro-landscapes of the northeastern part of the Baraba within the Novosibirsk region is within the Earth clark. Its greatest amount is in the humus layer, in which molybdenum is fixed by soil organic matter. According to the approved sanitary and hygienic standards, its content in soils of the katena is not dangerous for animal and human health.

Statistical processing of the material.

Using the correlation analysis of microelement composition and physicochemical properties of soils a direct relationship between the concentration of humus and the gross content of cobalt has been revealed. In the eluvial and transitional positions the correlation coefficient was 0.55, in the accumulative position the correlation relation is weaker ($r = 0.18$). Inverse correlation between the concentration of humus and gross chromium content was recorded on the catena. In the eluvial zone, the correlation coefficient is 0.65, in the transit zone - 0.25, and in the accumulative zone - 0.53. In addition, a close correlation between the content of physical clay (particles < 0.01%) and mobile nickel was detected in all positions. The correlation coefficient varied from 0.83 in the eluvial zone to 0.92 in the transitional zone and 0.74 in the accumulative zone.

CONCLUSIONS

1. The studied area of the northeastern part of the Barabinsk plain within the Novosibirsk region is typical for this geomorphological position, which allows the obtained results of research to be transferred with high probability to the adjacent territories. The character-

istic feature of the territory under study is the presence of meadow-chernozem soils in the eluvial zone of the catena, and of chernozem-meadow soils of various degrees of alkalinity and salinity in the transitional zone. In accumulative zone, alkaline, meadow-marsh and even marsh soils of different degree of alkalinity and salinity can be formed.

2. The physicochemical properties of soils of the catena change from the eluvial to accumulative zone as follows: pH in the soil profile increases from the eluvial position to the accumulative position. Whereas in meadow-chernozem soil it is neutral (alkaline in the parent rock), in deep solonetz it is strongly alkaline (pH 10 and more). The humus content in the A horizons is high, while in the B horizons it decreases sharply.

3. The granulometric composition of soils by genetic horizons changes significantly, which is typical for soils formed on alluvial deposits. It largely determines the elemental composition of soils.

4. In the eluvial position of the catena in the profile of meadow-chernozem soils, the minimum content of gross chromium falls on the A_{nax} horizon - 79.5 mg/kg dry soil. Deeper in the profile it increases to 102-141 mg/kg and is within the limits above the MAC. Some movement of chromium along the profile takes place.

5. The maximum amount of gross nickel and cobalt also falls on the profile of meadow-chernozem soil, but it is within the limits well below the MAC. From the eluvial to accumulative position, the gross content of these elements decreases. Their quantity along the profile of soils varies weakly, indicating their weak mobility. The total content of molybdenum in the studied soils is within the clark and approximately the same throughout the depth.

6. In the studied saline agrolandscapes, the content of nickel and cobalt in the soils by catena is below the MAC and poses no danger from the ecological-toxicological point of view. The gross contents of chromium and molybdenum are within the MAC and in certain cases can cause tension of the ecological-toxicological situation of the territory. This should be taken into account in the agricultural use of saline agrolandscapes.

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ИЗМЕНЕНИЕ БИОХИМИЧЕСКИХ ПОКАЗАТЕЛЕЙ СОИ В ЗАВИСИМОСТИ ОТ УСЛОВИЙ ВЫРАЩИВАНИЯ

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Представлены результаты анализа изменений биохимических показателей сои в зависимости от условий выращивания. Объектом исследования служили образцы сои (*Glycine max* (L.) Merr) сорта Лидия и дикой сои (*Glycine soja* Sieb. & Zucc.) формы КА-1344, выращенные на естественных почвах (контрольной и с повышенным содержанием тяжелых металлов). Анализ проводили в листьях, стеблях, корнях, цветках и семенах культурной и дикой сои в фазу первого тройчатого листа, цветения и плодоношения. Содержание малонового диальдегида и удельной активности кислой фосфатазы определяли спектрофотометрическим методом, активность пероксидазы – колориметрическим, содержание цинка, меди и свинца – атомно-абсорбционным. Электрофоретические спектры кислой фосфатазы выявляли методом электрофореза на колонках 7,5%-го полиакриламидного геля. Выявление на геле зон с ферментативной активностью проводили соответствующими гистохимическими методами. Установлено, что выращивание сои на почве с повышенным содержанием цинка, меди и свинца приводит к их накоплению в ее органах. Наибольшее содержание исследуемых металлов установлено в корнях. Выращивание сои на почве с повышенным содержанием цинка, меди и свинца привело к увеличению удельной активности пероксидазы в ее органах. При этом содержание малонового диальдегида у культурной сои достоверно увеличивалось лишь в стеблях в фазу первого тройчатого листа и в корнях в фазу цветения, у дикой сои – в листьях, стеблях и корнях в фазу первого тройчатого листа и в стеблях в фазу цветения. Выявлено, что максимальной удельной активностью кислой фосфатазы обладают цветки. Культурная соя в условиях повышенного содержания цинка, меди и свинца в почве характеризовалась увеличением удельной активности кислой фосфатазы и появлением новых множественных форм. Для дикой сои в целом отмечено снижение удельной активности кислой фосфатазы и увеличение числа множественных форм фермента.

Ключевые слова: соя, *Glycine max*, *Glycine soja*, адаптация, тяжелые металлы, малоновый диальдегид, пероксидаза, кислая фосфатаза

CHANGES IN THE BIOCHEMICAL PARAMETERS OF SOYBEANS DEPENDING ON THE GROWING CONDITIONS

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The results of the analysis of changes in biochemical parameters of soybeans depending on growing conditions are presented. The object of the study was samples of soybean (*Glycine max*

(L.) Merr) of the Lydia variety and wild soybean (*Glycine soja* Sieb. & Zucc.) forms of KA-1344 grown on natural soils (control and with a high content of heavy metals). The analysis was carried out in leaves, stems, roots, flowers and seeds of cultivated and wild soybeans in the phase of the first triple leaf, flowering and fruiting. The content of malonic dialdehyde and the specific activity of acid phosphatase were determined by spectrophotometric method, the activity of peroxidase – by colorimetric method, the content of zinc, copper and lead – by atomic absorption. Electrophoretic spectra of acid phosphatase were detected by electrophoresis on columns of 7.5% polyacrylamide gel. Identification of zones with enzymatic activity on the gel was carried out by appropriate histochemical methods. It has been established that the cultivation of soybeans on soil with a high content of zinc, copper and lead leads to their accumulation in the organs of soybeans. The highest content of the studied metals is found in the roots. Growing soybeans on soil with a high content of zinc, copper and lead led to an increase in the specific activity of peroxidase in its organs. At the same time, the content of malonic dialdehyde in cultivated soybeans significantly increased only in stems during the phase of the first triple leaf and in roots during the flowering phase, and in wild soybeans in leaves, stems and roots during the phase of the first triple leaf and in stems during the flowering phase. It has been revealed that the flowers have the maximum specific activity of acid phosphatase. Cultivated soybeans, under conditions of increased zinc, copper and lead content in the soil, were characterized by an increase in the specific activity of acid phosphatase and the appearance of new multiple forms. For wild soybeans, in general, there was a decrease in the specific activity of acid phosphatase and an increase in the number of multiple forms of the enzyme.

Key words: soya, *Glycine max, Glycine soja,* adaptation, heavy metals, malonic dialdehyde, peroxidase, acid phosphatase

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INTRODUCTION

Currently, one of the global environmental problems of our time is pollution of the environment with heavy metals [1]. To solve this problem different measures are taken, including monitoring studies of the state of various objects of the environment. Significant interest is represented by research of composition and intensity of influence of the chemical pollution of environment on the state of plants growing in different ecological and geographical conditions [2].

The influx of heavy metals in plants is determined by a complex of factors, the most important of which are soil properties and dynamics of soil processes, the concentration of elements in the environment and their physiological significance for plants, the physiological characteristics of plants, etc. For each plant a characteristic pattern of distribution of elements in organs and tissues is formed[1,2].

Excessive levels of chemical elements have depressing and even toxic effects on plants. There is a statement that there are no toxic metals, there are toxic concentrations. Consequently, trace elements and heavy metals are concepts referring to the same elements, characterizing their concentration in different

[1]Janadeleh H., Kardani M., Salemi M. Study of heavy metals effects on plants // Third International Symposium on Environmental and Water Resources, Engineering. Tehran, Iran, 2–3 June 2015.

[2]Loginova A.S., Otradnova M.I., Shilova N.A., Rogacheva S.M. Assessment of the safety of plant crops with soil contamination by heavy metals // Technogenic and natural safety: Proceedings of the IV All-Russian scientific and practical conference (Saratov, 19-21 April 2017). Saratov: LLC "Amirit", 2017. Pp. 69-72.

environments [3]. The effect of heavy metals on a plant may differ at various stages of its development. Oxidative stress caused by the action of heavy metals is one of the main ones adversely affecting crops [4].

The enzyme system can serve as an indicator of plant resistance. A well-studied enzyme is peroxidase (ACP 1.11.1.X), which plays an important role in the plant immune defense system [5]. Acid phosphatase (ACP 3.1.3.2) is of considerable interest since it is the most important enzyme of the main metabolic pathways of living systems and has not been sufficiently studied for plants [6, 7].

The aim of the study was to investigate the change in biochemical parameters in the organs of cultivated and wild soybean during ontogenesis depending on the growing conditions.

MATERIAL AND METHODS

The material for the study was samples of soybean variety Lydia and wild soybean form KA-1344. We previously analyzed soils in soybean growing areas [8]. For this study, natural soils in the background point (control) and with increased content of heavy metals (experiment) were selected (see Table 1).

Soybean samples were grown in a greenhouse at 18-28 ºC. Before planting in selected soil, seeds were surface sterilized with 70% ethyl alcohol solution, washed with distilled water, then planted in darkened vessels with soil. The analysis was performed in leaves, stems, and roots at the stage of the first triple leaf, in leaves, stems, roots, and flowers at the flowering stage, and in seeds at the fruiting stage.

For biochemical analysis, extracts of soluble soybean proteins were prepared[3]. Protein in the extracts was determined by the Lowry method [9], the specific activity of acid phosphatase by spectrophotometric method with p-nitrophenyl phosphate as a substrate. Specific activity was expressed in units per 1 mg of protein. Multiple forms of the enzyme were detected by electrophoresis in 7.5% PAAG, followed by staining of the zones with appropriate histochemical methods (see footnote 3). The standard criterion for characterizing multiple forms of enzymes is their relative electrophoretic mobility (Rf). Previously, 13 forms of acid phosphatase with Rf from 0.04 to 0.75 were identified [10].

The content of malondialdehyde (MDA) and specific activity of peroxidase were used as markers of oxidative stress. Specific peroxidase activity was determined by Boyarkin's photometric method according to modification by Mokronosov on photoelectric concentration colorimeter KFK-2 (Russia) by the change in optical density (see footnote 3). Benzidine hydrochloride (Interkhim, Russia) was used as a substrate. MDA content was determined by reaction with thiobarbituric acid, which at high temperature and acidic pH proceeds with the formation of a colored trimethine complex[4]. The contents of zinc, copper, and lead were determined by atomic absorption method on spectrophotometer KVANT.Z (Russia).

Табл. 1. Характеристика почв для исследований
Table 1. Characteristics of soils for research

Soil	Humus, %	pH	Content, mg/kg				
			Water-soluble forms of phosphate ions converted to P_2O_5	Water-soluble forms of potassium ions	Labile forms		
					zinc	lead	copper
Control	4,2 ± 0,6	5,1 ± 0,2	9,2 ± 1,4	3,1 ± 0,5	<1,0	<0,5	<1,0
Experiment	4,6 ± 0,7	5,0 ± 0,2	15,7 ± 2,4	7,3 ± 1,2	20,2 ± 6,1	0,9 ± 0,3	2,4 ± 0,7

[3]Ivachenko L.E., Kashina V.A., Mascaltsova V.I., Razantsvey V.I., Stasiuk E.M., Trofimtsova I.A. Methods for studying the polymorphism of soybean. Blagoveshchensk: Publishing house of BSPU, 2008. 138 p.

[4]Rogozhin V.V., Rogozhina T.V. Practicum on physiology and biochemistry of plants: a textbook. SPb.: GIORD, 2013. 352 p.

Statistical processing of the obtained data was performed using Microsoft Excel software. Plant material was analyzed in two biological and three analytical replications (6 replications in total). The results were expressed as the mean (n = 6) ± standard deviation; the differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

Currently, increased attention is paid to the accumulation and distribution of heavy metals in plant organs, as well as their effect on the main physiological processes and productivity. The typical distribution of metals in plant organs is as follows (in descending order): root > aboveground mass > generative organs [11]. The ability to accumulate metals varies not only between species, but also between varieties and genotypes. Accumulation of heavy metals in reproductive organs and seeds is less intense [12]. This is of great biological importance related to the preservation of reproductive ability and seed productivity.

During the conducted analysis, soybean organs were distributed according to their ability to accumulate zinc (in descending order): roots > seeds > leaves = flowers > stems (see Fig. 1, a). It is noted in the literature that, in general, zinc is distributed among different plant organs as follows: roots > leaves > stems > trunk (stem)5. An increase in zinc concentration in all organs of soybean plants under conditions of high content of heavy metals in soil was observed. The maximum was recorded in soybean roots, from 37.65 to 56.02 mg/kg.

The distribution of copper by soybean organs is as follows (in descending order): roots > flowers = leaves > seeds > stems (see Fig. 1, b). The content of copper in the samples grown on the experimental soil is higher than in the control. The maximum accumulation of copper was recorded in soybean roots, from 18.83 to 28.97 mg/kg.

Lead accumulation capacity (in descending order): roots > leaves = stems > flowers = seeds (see Fig. 1, c). Most researchers who have studied the distribution of lead in the organs of various plant species report the predominant accumulation of the element in roots [13]. We also noted this pattern: lead accumulation during cultivation on experimental soil occurs in all organs of soybean. The concentration of lead in the roots of soybean grown on experimental soil was higher by more than 2.5 times relative to the control. The minimum concentration of

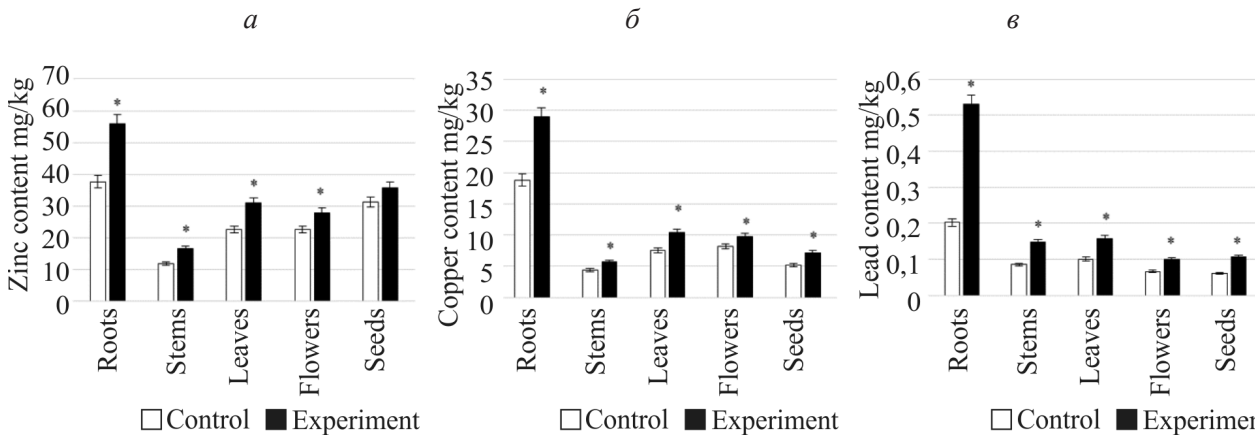

Рис. 1. Содержание цинка (*а*), меди (*б*) и свинца (*в*) в органах сои (среднее) в зависимости от агрофона. Здесь и в рис. 2–5 различия с контролем достоверны при $p \leq 0,05$

Fig. 1. The content of zinc *(a)*, copper (*b*) and lead (*c*) in soybean organs (average) depending on the agricultural background

*Here and in Figs. 2-5 differences with control are significant at $p \leq 0.05$

[4]*Rogozhin V.V., Rogozhina T.V.* Practicum on physiology and biochemistry of plants: a textbook. SPb.: GIORD, 2013. 352 p.
[5]*Kabata-Pendias A.* Trace elements in soils and plants. L.: CRC Press, 2011. 505 p.

lead was established in the generative organs of soybean, which indicates the protective mechanisms that prevent the accumulation of heavy metals in the seeds of plants.

Accumulation of heavy metals leads to increased oxidative stress, markers of which are MDA content and peroxidase test. The analysis showed a significant increase in specific peroxidase activity in most organs of cultivated and wild soybean (see Fig. 2).

MDA content in cultivated soybean significantly increased in the stems at the first triplet leaf phase and in the roots at the flowering phase; in wild soybean, it increased in the leaves, stems, and roots at the first triplet leaf phase and in the stems at the flowering phase (see Fig. 3).

In the course of the studies, it was found that soybean flowers were characterized by maximum specific activity and high heterogeneity of acid phosphatase (see Fig. 4, A). When growing cultivated and wild soybean on control soil, six and five forms, respectively, were detected in the flowers. Growing soybean on experimental soil resulted in an increase in the specific activity of acid phosphatase in flowers of cultivated soybean and a decrease in wild soybean. At the same time, the number of forms of the enzyme increased for wild soybean (a new form of KF10 was noted) and remained stable for cultivated soybean (see Fig. 4, B). A significant increase in specific activity of acid phosphatase in leaves (1.7 and 1.4-fold) and roots of cultivated soybean (1.4 and 1.6-fold) during the first triple leaf phase and flowering, respectively, was observed. The number of forms of the enzyme also increased: a new form of KF5 (first triplet leaf) was detected in roots, KF10 in leaves, and KF9 in roots (flowering). Seeds were characterized by minimal activity. Cultivation of cultivated soybean on experimental soil led to an increase in specific activity and a number of multiple forms of acid phosphatase in seeds; a new form of the enzyme, KF4, was noted (see Fig. 4, B).

For wild soybean, a decrease in the specific activity of acid phosphatase in leaves, stems, and roots during the phase of the first triplet leaf was noted by 1.1; 2.5 and 1.8 times, respectively, and in flowers by 1.2 times. New forms of the enzyme in leaves (KF12), roots (KF6, KF10) and flowers (KF10) were revealed. An increase in the specific activity of the enzyme was observed in leaves and stems of wild soybean during the flowering phase by 1.5 and 2.6 times, respectively, and in seeds, which correlates with the appearance of a new form of the enzyme in leaves and seeds (KF5) (see Fig. 5).

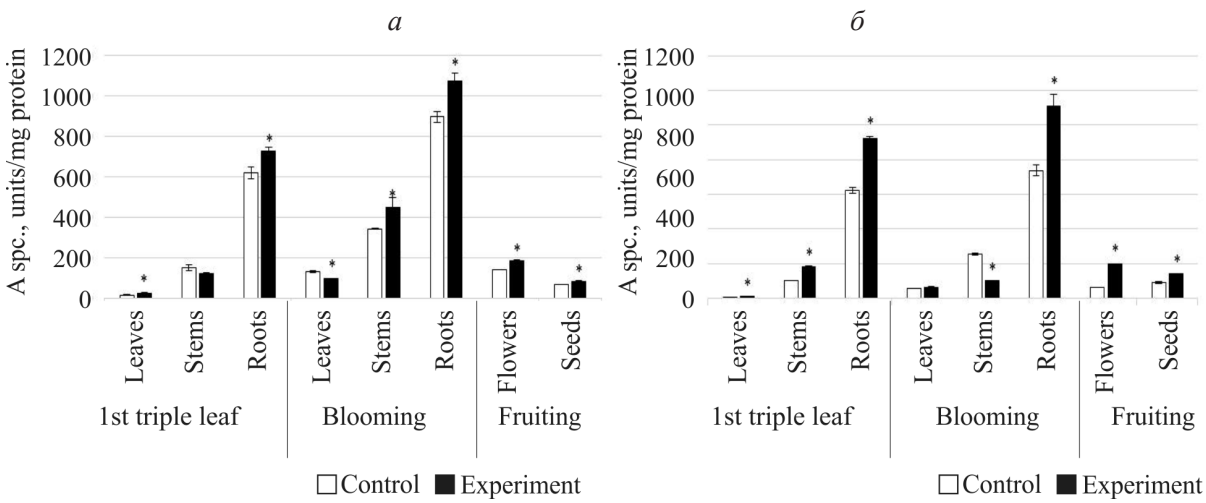

Рис. 2. Удельная активность пероксидазы в различных органах культурной (*а*) и дикой сои (*б*) в фазу первого тройчатого листа, цветения и плодоношения

Fig. 2. Specific activity of peroxidase in various organs of cultivated (*a*) and wild soybean (*b*) in the phase of the first trifoliate leaf, flowering and fruiting

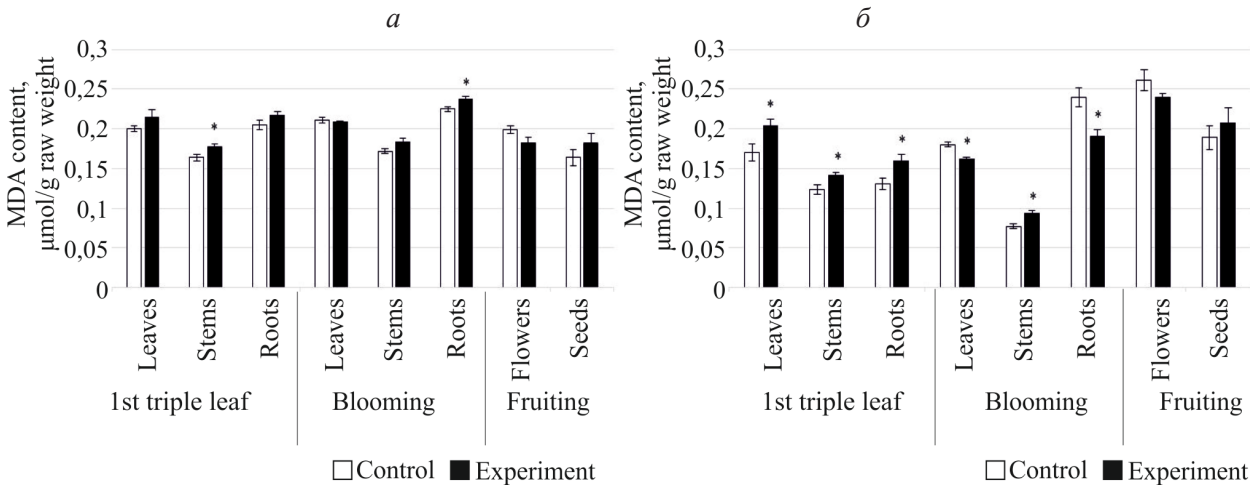

Рис. 3. Содержание МДА в различных органах культурной (*а*) и дикой сои (*б*) в фазу первого тройчатого листа, цветения и плодоношения

Fig. 3. The content of MDA in various organs of cultivated (*a*) and wild (*б*) soybeans in the phase of the first trifoliate leaf, flowering and fruiting

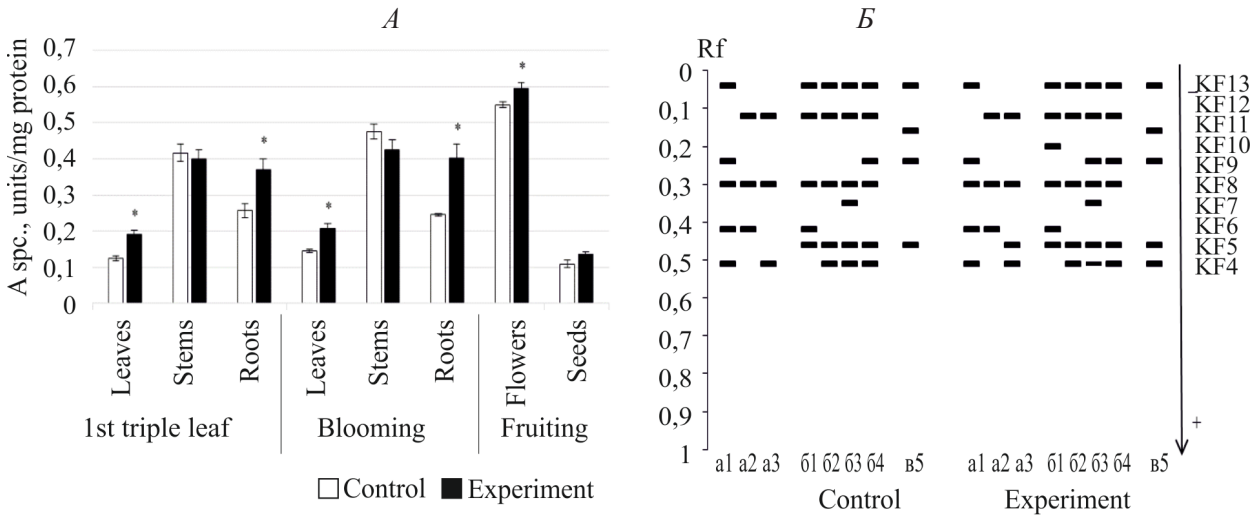

Рис. 4. Удельная активность (*А*) и схемы энзимограмм (*Б*) кислой фосфатазы в различных органах культурной сои в фазу первого тройчатого листа (а), цветения (б) и плодоношения (в):
1 – листья; 2 – стебли; 3 – корни; 4 – цветки; 5 – семена. Стрелка указывает направление электрофореза (от катода к аноду). Справа указана нумерация выявленных форм фермента

Fig. 4. Specific activity (*A*) and enzyme diagrams (*B*) of acid phosphatase in various organs of cultivated soybean in the phase of the first trifoliate leaf (a), flowering (b) and fruiting (c):
1 – leaves; 2 – stems; 3 – roots; 4 – flowers; 5 – seeds. The arrow indicates the direction of electrophoresis (from the cathode to the anode). On the right is the numbering of the identified forms of the enzyme

CONCLUSION

It was found that the cultivation of soybean on soil with high content of zinc, copper and lead leads to their accumulation in soybean organs. The highest content of the studied metals was found in the roots. When growing cultivated and wild soybean on the soil with increased content of heavy metals, an increase in specific activity of peroxidase in most organs of cultivated and wild soybean was observed. The MDA content in cultivated soybean increased significantly only in the stems at the phase of the first triple leaf and in the roots at the flowering phase; in

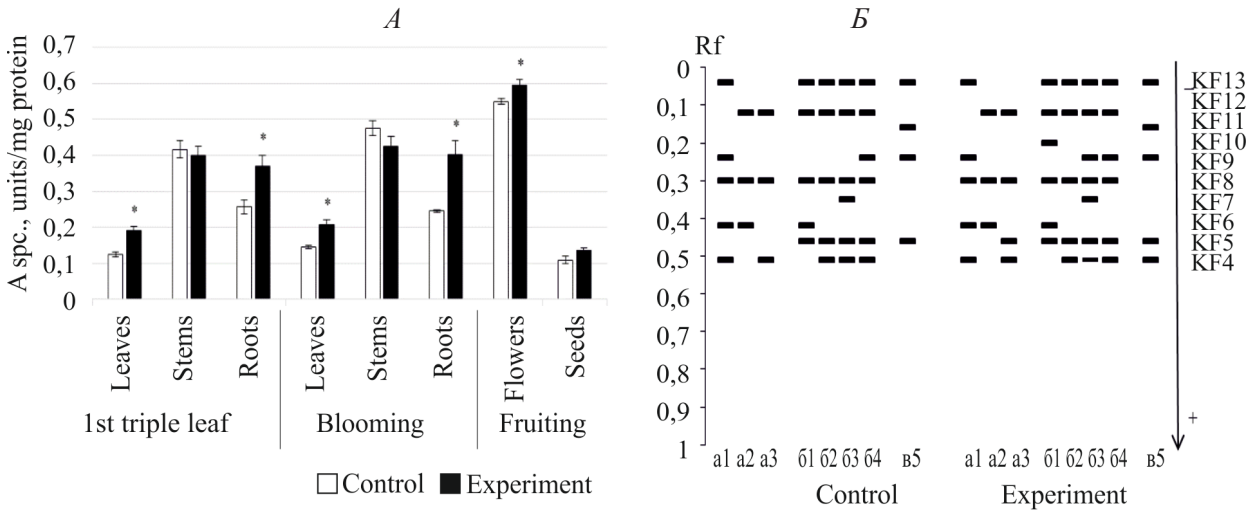

Рис. 5. Удельная активность (*А*) и схемы энзимограмм (*Б*) кислой фосфатазы в различных органах дикой сои в фазу первого тройчатого листа (а), цветения (б) и плодоношения (в):
1 – листья, 2 – стебли, 3 – корни, 4 – цветки, 5 – семена. Стрелка указывает направление электрофореза (от катода к аноду). Справа указана нумерация выявленных форм фермента.

Fig. 5. Specific activity (*A*) and schemes of enzymograms (*B*) of acid phosphatase in various organs of wild soybean in the phase of the first trifoliate leaf (a), flowering (b) and fruiting (c):
1 – leaves, 2 – stems, 3 – roots, 4 – flowers, 5 – seeds. The arrow indicates the direction of electrophoresis (from the cathode to the anode). On the right is the numbering of the identified forms of the enzyme.

wild soybean, it increased significantly in the leaves, stems, and roots at the phase of the first triple leaf and in the stems at the flowering phase. Analysis of the specific activity of acid phosphatase showed that the greatest activity of the enzyme was in the flowers, which is most likely due to the participation of acid phosphatase in the mobilization of phosphate, which is required in the processes occurring at the flowering phase. In cultivated soybean plants with increased content of zinc, copper and lead in the soil, the specific activity of acid phosphatase increased and new multiple forms appeared: in leaves - KF10, in roots - KF5 and KF9 and in seeds - KF4. For wild soybean, a decrease in the specific activity of acid phosphatase and an increase in the number of multiple forms of the enzyme in leaves - KF5 and KF12, roots - KF6 and KF10, flowers - KF10, seeds - KF5 were generally observed.

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СРАВНЕНИЕ МЕТОДОВ ОЦЕНКИ ТЕХНОЛОГИЧЕСКОГО КАЧЕСТВА ЛЬНОВОЛОКНИСТОЙ ПРОДУКЦИИ

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Представлены результаты сравнительного анализа оценки технологического качества льнотресты по основным признакам: выходу и номеру длинного и короткого волокна, содержанию и общему выходу волокна, определенных различными методами по нормативной документации. Исследования проведены в 2001–2021 гг. в льносеющих регионах России: Тверской, Смоленской, Вологодской, Костромской областях. Установлено, что от выбранного метода оценки зависит информационная ценность полученных результатов. Абсолютные отклонения среднего уровня значений признаков, определенных различными методами, составляют для выхода длинного волокна 3,55–9,05%, его номера – 0,00–1,64 N, выхода короткого волокна – 0,20–11,60%, его номера – 0,40–2,75 N, содержания и общего выхода волокна 0,40–10,80%. Относительные отклонения для тех же признаков соответственно равны 24,0–44,5%; 0,00–13,60; 1,80–51,60; 1,30–44,40; 1,00–32,00%. На приведенном примере показан возможный разброс в оценке интегрального технологического качества льнотресты (от номера 1,25 до 2,00 N) и стоимости (19%) произведенной из нее продукции (длинного и короткого волокна) при условии определения по двум вариантам. Первый вариант предусматривал определение выхода длинного волокна на лабораторном мяльно-трепальном станке СМТ-200М, номера длинного волокна – по изменению № 4 ГОСТ 10330–76, выхода короткого волокна – по методике технологической оценки качества льнотресты на мяльно-трепальной машине ТЛ-40, номера короткого волокна – по ГОСТ 9394–76. Второй вариант заключался в нахождении выхода длинного и короткого волокна в производственных условиях на мяльно-трепальном агрегате, органолептической оценке номера длинного волокна и определении номера короткого волокна расчетным путем. Сделано заключение о необходимости приведения уровня значений указанных признаков, определенных различными методами к единому уровню с целью повышения информационной ценности оценки технологического качества льносырья.

Ключевые слова: технологическое качество, выход и номер длинного и короткого льноволокна, общий выход и содержание льноволокна, методы оценки, уровень значений, информационная ценность

COMPARISON OF METHODS FOR ASSESSING THE TECHNOLOGICAL QUALITY OF FLAX FIBER PRODUCTS

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The paper presents the results of a comparative analysis of technological quality assessment of flax fiber by the main features: the yield and number of long and short fiber, the content and total fiber yield, determined by different methods of regulatory documentation. The research took place in 2001–2021 in the flax–growing regions of Russia: Tver, Smolensk, Vologda, Kostroma regions. It is established that the information value of the obtained results depends on the chosen evaluation method. The absolute deviations of the average level of the values of the signs determined by various methods are 3.55 - 9.05% for the output of a long fiber, its numbers are 0.00 - 1.64 N, the output of a short fiber is 0.20 - 11.60%, its numbers are 0.40 - 2.75 N, the content and total fiber output are 0.40–10,8%; relative deviations are for the same signs, respectively equal, 24,0–44,5%, 0,00–13,60%, 1,80–51,60,%, 1,30–44,40%, 1,00–32,00%. The given example shows a possible variation

in the assessment of the integral technological quality of flax (from number 1.25 to number 2.00) and the cost of the products produced from it (long and short fiber) (19%), subject to determination by the following two options. The first option provided for the determination of the output of a long fiber on a laboratory ribboner CMT-200M, the numbers of a long fiber - according to the change N4 GOST 10330–76, the output of a short fiber according to the method of technological evaluation of the quality of flax on the ribboner TL-40, the numbers of a short fiber according to GOST 9394-76. The second option was to find the output of long and short fibers in production conditions on a ribboner, organoleptic evaluation of the number of the long fiber and determination of the number of the short fiber by calculation. It is concluded that it is necessary to bring the level of values of these signs determined by various methods to a single level in order to increase the informational value of assessing the technological quality of flax raw materials.

Keywords: technological quality, yield and number of long and short flax fiber, total yield and content of flax fiber, evaluation methods, value level, information value

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INTRODUCTION

Timely and reliable information about the quality of flax fiber production along the whole technological line from variety breeding to processing at flax processing plants is one of the components of increasing efficiency of flax fiber production[1] [1, 2]. The problem of improving the quality of flax products is inextricably linked to the assessment of the level of its integral quality, as well as the main attributes that condition it, the objective features that are observed during the creation, consumption and operation. Planning, attestation, control, variety creation, selection of the best product variant, analysis of changes in individual quality parameters are the links of technological cycle, each of which requires assessment of product quality level with sufficient accuracy according to the current regulatory documentation [3].

Technological quality of fiber raw material of fiber flax varieties depends on a combination of the following features: yield and quality of long and short fiber to obtain the maximum total yield, produced from flax straw of different quality by traditional processing technology in production conditions [4, 5]. These basic characteristics ensure the level of processing and use of raw materials as intended. However, at present different methods are used to determine the characteristics of flax raw material, the implementation of which leads to different levels of values of the same indicator[2] [6, 7]. One of

[1]Trukhachev V.I., Belopukhov S.L., Dmitrievskaya I.I., Baybekov R.F., Zharkikh O.A. Quality and Safety Indicators of Flax fiber // Database Registration Certificate 2021621161. 01. 06. 2021. Application № 2021620776 dated 22.04.2021.

[2]Romanov V.A., Rozhmina T.A., Kovalev M.M., Belopukhov S.S. Method of the technological value evaluation of fiber flax stems // Patent for invention RU 259755 C1, 10.09.2016. Application № 2015108332/12 dated 10.03.2015.

the important signs of technological quality - the yield of long fiber from flax straw of different quality - can be determined by the following methods currently used [8-12].

– after processing flax straw on the CMT 200M laboratory ribboner according to GOST 24383-89 Flax straw.

Requirements for harvesting:

– on methods of technological evaluation of flax raw material quality after processing on flax pulling machine TL-40;

– after processing on a flax pulling machine under production conditions.

Six methods can be used to estimate the long fiber number.

To ensure that the information obtained in the course of evaluation, relating to the determination of one or another quality trait, has the necessary value, it must be timely, reliable and comparable [13, 14]. Comparability of evaluation results is one of the significant factors influencing the correctness of breeders' conclusions about the advantages of a new variety in fiber yield and quality over varieties created earlier, provided that these traits are determined by different methods.

In addition, the correct orientation of producer and consumer products also depends on timely, reliable and comparable information about its level of quality. Such information will also make it possible to make informed decisions aimed at improving the production activities of agricultural enterprises.

The aim of the research is to analyze the information value of assessing the technological quality of flax fiber products using the existing methods, to develop proposals for improving metrological expertise in determining the main quality attributes using different methods.

MATERIAL AND METHODS

The studies were conducted at the All-Russian Flax Research Institute (a separate subdivision of the Research Institute of Flax of the Federal Scientific Center of Bast Crops) and flax-growing regions of Russia in 2000-2021 according to the scheme shown in Fig. 1.

The formation of flax straw batches of different quality of 30 fiber flax varieties of domestic and foreign selection was carried out in the period of harvesting in the conditions of flax-growing farms and flax-processing enterprises of Smolensk, Tver, Kostroma, Pskov and Vologda regions. When carrying out these works, a special methodological program[3] [1, 15] was used, which provided for control developments in accordance with the Rules of technical operation of flax-processing plants. At optimal modes of production equipment operation, depending on the quality of initial flax raw material, flax straw was processed according to the traditional technology with obtaining long and short fiber. The evaluation of features determining the quality of flax fiber products was carried out according to the current normative documentation[4-8].

The following laboratory and production equipment was used: ribboner CMT-200M, decorticator LM-3, motorized decorticator ML-5, shive separation unit PC-2M, tensile testing machine RMP-1, dynamometer DKV-60, electronic scales VLKT-500, flexometer GV-3, quadrant Po-2, moisture meter VLS, desiccators SSh-2, US-4, standard samples of fiber color, OBA device to determine separability, drier for flax straw SKP-10LU, ribboner MTA, flax

[3]The Decree of the Ministry of Agriculture of the Russian Federation № 23 - p of March 10, 2016. "Procedure for determining the norms of conversion of flax and hemp trusts into fiber" (As amended by the Russian Federation Government Decree No. 450 of 12.06.2008). 7 p.

[4]GOST 24383-89 Retted straw. Conservation requirements. Official edition. Moscow: Publishing house of standards. 1990. 17 p.

[5]GOST 10330-76 Scutched flax. Technical conditions. Official edition. Moscow: Publishing house of standards. 1982. 11 p.

[6]Amendment № 4 GOST 10330-76 Scutched flax. Technical conditions. Moscow: Approved and put into effect by the Decree of the USSR State Standards Committee of 28.06.88 № 2441 1989. 11p.

[7]GOST 9394-76 Short flax fiber. Technical conditions. Official edition. Moscow: Publishing house of standards. 1981. 7 p.

[8]Methodical guidelines for technological assessment of flax straw and experiments on primary flax processing. Torzhok: VNIIL. 1972. 58 p.

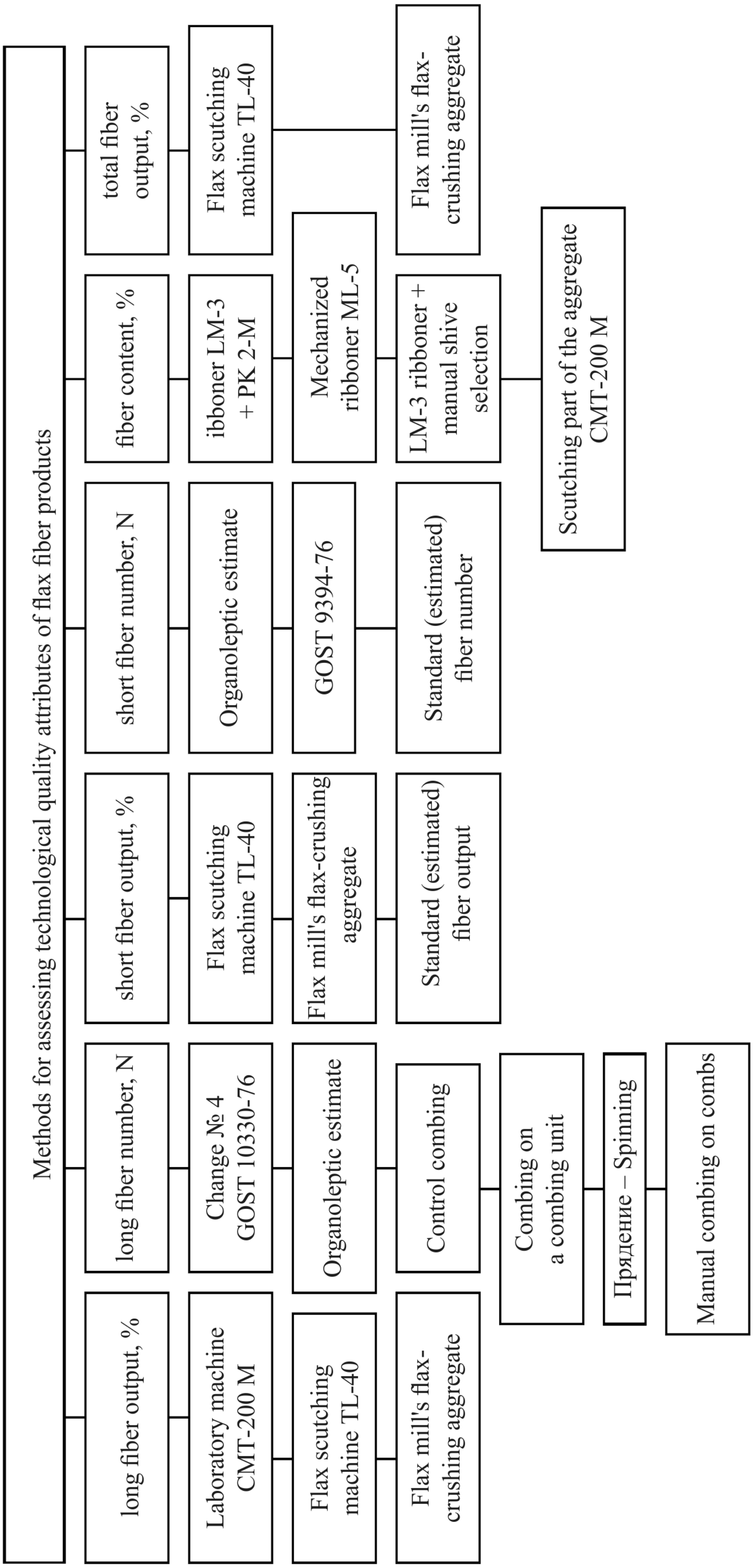

Рис.1. Схема определения признаков технологического качества льноволокнистой продукции
Fig.1. Scheme for determining the signs of technological quality of flax fiber products

scutching machine TL-40 and TL-4-2, dryer for short fiber SKP-10KU, tow opener KPAL, carding machine Ch-302-L, spinning machines.

The obtained results were processed using methods of mathematical statistics. The distribution of the trait values was checked for compliance with the law of normal distribution using the "plus-minus three sigmas" rule and taking into account the excesses. Significance of differences was determined by pairwise comparisons in equal and unequal samples using Student's test [13, 14, 16].

RESULTS AND DISCUSSION

A comparative assessment of the level of values of the main attributes of technological quality of flax straw by the currently used methods was carried out for 20 different samples consisting of different numbers of batches - from 15 to 256.

Fig. 2 shows the level of long fiber yields determined by the different methods. The average yield of long fiber from grass-retting flax straw established by the three methods differs by 3.55-9.05% absolute or 24.00-44.50% relative units.

Statistical processing by the method of pairwise comparisons of data of equal samples confirmed the significance of differences between the average values of long fiber yield found by different methods at 95% probability (see Table 1).

In order to determine the reliability and comparability of the results of estimation of the average level of values of long fiber number, fiber content, total fiber yield, yield and number of the short fiber by existing methods, a comparative analysis of 15 samples consisting of different number of batches was conducted. Earlier studies [3, 6, 9, 10, 11, 15] proved that the experimental values of characteristics in random samples are distributed according to the normal law, since randomly selected samples do not deviate from the general average by a value exceeding the standard deviation by 3 times. Due to the fact that in most cases the number of pairs of compared values did not exceed 30, we used the parametric Student's test to deter-

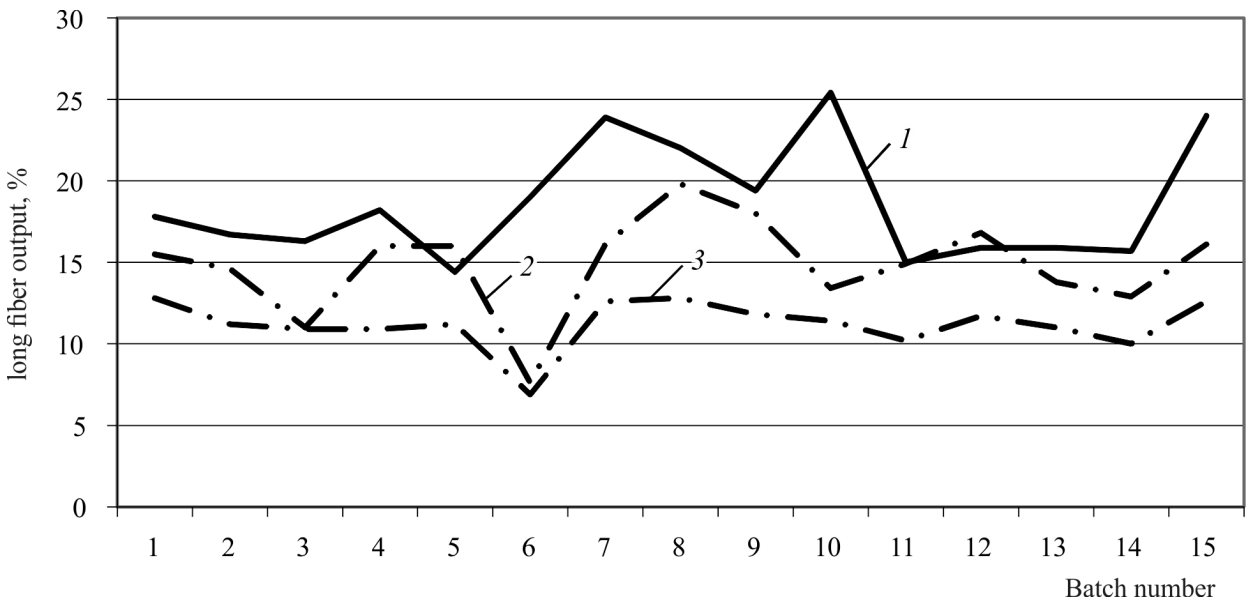

Рис. 2. Уровень значений выхода длинного волокна при определении по различным методам:
1 – выход длинного волокна на лабораторном мяльно-трепальном станке СМТ-200М;
2 – выход длинного волокна по методике технологической оценки (трепальная машина ТЛ-40);
3 – выход длинного волокна на мяльно-трепальном агрегате (МТА) льнозавода

Fig. 2. The level of long fiber output values when determined by various methods
1 – the output of a long fiber on a laboratory ribboner CMT-200M;
2 – the output of a long fiber according to the method of technological evaluation (ribboner TL-40);
3 – the output of a long fiber on a ribboner (MTA) of a flax plant

Табл. 1. Определение значимости различий между средними значениями выхода длинного волокна
Table 1. Determination of the significance of differences between the average values of the long fiber output

Test method	Average value of the long fiber yield, %	Differences between average values d, %	Error of difference of the averages S_d, %	Student's coefficient t		Conclusion on the significance of differences
				factual $t_ф$	tabular $t_т$	
CMT-200M machine	20,30	5,50	1,49	3,07	2,05	Significant
TL-40 machine	14,80					
CMT-200M machine	20,30	9,05	1,12	8,08	2,05	»
MTU	11,25					
TL-40 machine	14,80	3,55	0,87	4,08	2,05	»
MTU	11,25					

mine the significance of differences between the mean values.

The data of pairwise comparison of the values of the above attributes are shown in Tables 2-4.

Six methods currently used to estimate the quality of long fiber, four methods for fiber content, two for total yield, three for yield and short fiber number were considered. It has been found that the average level of long fiber number values determined by various methods varies considerably: absolute deviations range from 0.00 to 1.64 N, and relative deviations range from 0.00 to 13.60% (see Tables 2-4). Fiber content and total fiber yield of absolute units vary by 0.4-10.8%, relative by 1.0-32.0%, short fiber yield by 0.2-11.6%, 1.8-51.6% respectively; short fiber number by 0.40-2.75 N, 1.3-44.4% of relative units. The results of determining the technological quality of flax straw are largely due to the chosen method of evaluation and can lead to erroneous conclusions in breeding and production activities in the field of flax fiber production and processing.

Estimation by different methods of values of yield and number of long and short fiber affects the integral parameter of fiber production quality - fiber percent number (%N), on which technical and economic indicators of flax processing enterprises depend and, in particular, adequacy of determination of quality of harvested flax raw material (see Fig. 3). Two options are presented for comparison. The first one consisted in evaluating the yield of long fiber when using a ribboner CMT-200M (20,3%), the number of long fiber - according to the modification № 4 of the State Standard 10330-76 (10,73), the yield of short fiber - according to the technique of technological evaluation of quality of flax raw materials on flax scutching machine TL-40 (9,4%), the number of short fiber - according to the State Standard 9394-76 (2,38).

According to the second variant, the same features were determined on a turbine scutching machine (TSM) under production conditions (11.25%), by organoleptic evaluation (10.56 N), on the TSM (12.6%), by calculation (3.03 N), respectively. Technological quality in the first variant was 240% N, in the second - 157% N (see Fig. 3). According to the norms of fiber yield and quality[9] from grass-retting flax straw in the first variant the flax straw should be estimated by the number 2.00, in the second - 1.25. The cost of production was calculated at average prices established in recent years for long and short fiber. The following prices were adopted for 1 kg of long fiber N 10 - 131,35 rubles, short fiber - N 2 - 42,6, N 3 - 49,7 rubles, with the difference in price of 1 kg of fiber between the neighboring numbers of 7,1 p. The total cost of the manufactured goods produced from one ton of flax straw in the first version was equal to 31 994 rubles, in the second - 25 726 rubles. That is, the cost of production in the second option was 81% of the production in the first option experiment (see Figure 3).

Табл. 2. Различия среднего уровня значений номера длинного волокна при определении по существующим методам

Table. 2. Differences in the average level of long fiber number values when determined by existing methods

№ i/n	Method for determining the long fiber number	Average long fiber number, N	Differences	
			$\Delta_{абс.}$	%
1	Change № 4 GOST 10330-76 Scutched flax	10,01	page 1 – page 2	
2	Organoleptic evaluation	10,56	–0,55	5,2
Student's coefficient	$T_ф = 3,11$	$T_т = 2,05$	Significant	
3	Control combing technique GOST 10330-76 Scutched flax	11,11	page 3 – page 4	
4	Organoleptic evaluation	10,56	–0,45	4,3
Student's coefficient	$T_ф = 3,01$	$T_т = 2,05$	Significant	
5	Change № 4 GOST 10330-76 Scutched flax	10,73	page 5 – page 6	
6	Combing on the carding machine	10,99	–0,26	2,4
Student's coefficient	$T_ф = 2,90$	$T_т = 2,12$	Significant	
7	Change № 4 GOST 10330-76 Scutched flax	10,79	page 7 – page 8	
8	Spinning	10,27	+0,52	4,8
Student's coefficient	$T_ф = 4,01$	$T_т = 2,05$	Significant	
9	Control combing technique GOST 10330-76 Scutched flax	10,45	Page 9 – page 10	
10	Combing on the carding machine	12,09	–1,64	13,6
Student's coefficient	$T_ф = 7,03$	$T_т = 2,07$	Significant	
11	Control combing technique GOST 10330-76 Scutched flax	10,38	page 11 – page 12	
12	Technological evaluation of raw flax quality (manual combing)	10,38	0	0
The average values are the same				
13	Control combing technique GOST 10330-76 Scutched flax	10,48	page 13 – page 14	
14	Spinning	10,25	+0,23	2,2
Student's coefficient	$T_ф = 2,73$	$T_т = 2,07$	Significant	
15	Control combing technique GOST 10330-76 Scutched flax	10,79	page 15 – page 16	
16	Change № 4 GOST 10330-76 Scutched flax	10,91	+0,23	1,1
Student's coefficient	$T_ф = 2,40$	$T_т = 2,07$	Significant	

Табл. 3. Различия среднего уровня значений выхода и номера короткого волокна при определении по существующим методам

Table. 3. Differences in the average level of the output values and the short fiber number when determined by existing methods

№ i/n	Method for determining the output of short fiber	Average short fiber output, %	Differences	
			$\Delta_{абс.}$	%
	Short fiber output			
1	Short fiber output from dew-retted flax on an MTU, %	22,5	page 1 – page 2	
2	Standard (estimated) short fiber output, %	11,1	11,4	50,7
Student's coefficient	$T_ф$ = 18,30	$T_т$ = 2,05	Significant	
3	Short fiber output on the TL-40 machine	10,9	page 3 – page 4	
4	Short fiber output from dew-retted flax on an MTU, %	22,5	–11,6	51,6
Student's coefficient	$T_ф$ = 16,80	$T_т$ = 2,06	Significant	
5	Short fiber output on the TL-40 machine	10,9	page 5 – page 6	
6	Standard (estimated) short fiber output, %	11,1	–0,2	1,8
Student's coefficient	$T_ф$ = 1,91	$T_т$ = 2,05	Not significant	
	Short fiber number			
№ i/n	Method for determining the number of short fiber	Average short fiber number, N	Differences $\Delta_{абс.}$	%
1	Short fiber number using the organoleptic evaluation, N	5,13	page 1 – page 2	
2	Short fiber number GOST 9394–76 Flax fiber short, N	2,38	2,75	44,4
Student's coefficient	$T_ф$ = 15,70	$T_т$ = 2,05	Significant	
3	Short fiber number GOST 9394–76 Flax fiber short, N	3,12	page 3 – page 4	
4	Short fiber standard number (estimated), N	3,08	0,4	1,3
Student's coefficient	$T_ф$ = 18,40	$T_т$ = 2,05	Significant	
5	Short fiber number using the organoleptic evaluation, N	5,13	page 5 – page 6	
6	Short fiber number GOST 9394–76 Flax fiber short, N	3,12	2,1	40,9
Student's coefficient	$T_ф$ = 16,80	$T_т$ = 2,06	Significant	

Табл. 4. Различия среднего уровня значений содержания и общего выхода волокна при определении по существующим методам

Table. 4. Differences in the average level of the content and total fiber yield values when determined by existing methods

№ i/n	Method for determining the content and total fiber output	Average fiber content and total fiber output, %	Differences	
			$\Delta_{абс.}$	%
1	Fiber content (LM-3 + manual shive selection), %	30,3	page 1 – page 2	
			5,6	19,9
2	Total fiber output (MTU), %	24,7		
Student's coefficient	$T_ф$ = 25,30	$T_т$ = 2,07	Significant	
3	Fiber content (LM-3 + manual shive selection), %	35,0	page 3 – page 4	
			2,0	5,7
4	Fiber content (LM-3 + РК-2М), %	33,0		
Student's coefficient	$T_ф$ = 2,08	$T_т$ = 2,05	Significant	
5	Fiber content (LM-3 + manual shive selection), %	29,9	page 5 – page 6	
			6,9	23,1
6	Total fiber output (TL-40), %	23,0		
Student's coefficient	$T_ф$ = 19,10	$T_т$ = 2,06	Significant	
7	Fiber content (LM-3 + manual shive selection), %	35,0	page 7 – page 8	
			–0,4	1,0
8	Fiber content (ML-5), %	35,4		
Student's coefficient	$T_ф$ =1,12	$T_т$ = 2,05	Not significant	
9	Fiber content (LM-3 + manual shive selection), %	35,0	page 9 – page 10	
			0,5	1,4
10	Fiber content (CMT-200M), %	34,5		
Student's coefficient	$T_ф$ = 1,93	$T_т$ = 2,05	Not significant	
11	Fiber content (ML-5), %	35,4	page 11 – page 12	
			0,9	2,5
12	Fiber content (CMT-200M), %	34,5		
Student's coefficient	$T_ф$ = 2,06	$T_т$ = 2,05	Significant	
13	Fiber content (CMT-200M), %	33,93	page 13 – page 14	
			10,88	32,0
14	Total fiber output (TL-40), %	23,05		
Student's coefficient	$T_ф$ = 18,20	$T_т$ = 2,05	Significant	

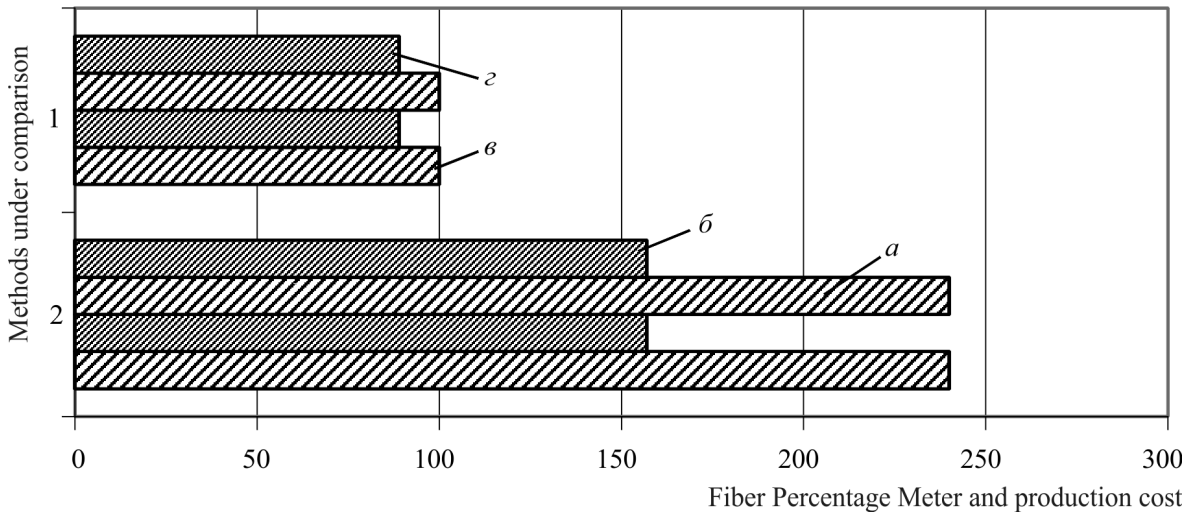

Рис. 3. Технологическое качество льнотресты и стоимость произведенной из нее продукции в зависимости от метода оценки:
а – процентономера волокна (1); *б* – процентономера волокна (2);
в – стоимость продукции в процентах (1); *г* – стоимость продукции в процентах (2)
Fig. 3. Technological quality of flax straw and the cost of its products depending on the method of evaluation:
а - fiber percentage (1); *б* - fiber percentage (2);
в - product value in percents (1); *г* - product value in percents (2)

The analysis of assessing the technological quality of flax straw fiber, formed depending on the combination of basic attributes: yield and quality of long and short fiber, fiber content and total fiber yield, revealed the obvious need to bring the level of these attributes defined by different methods to a single level, so as to increase the information value of the assessment.

CONCLUSIONS

1. A comparative analysis of assessing the level of values of the main attributes of technological quality of flax raw material, determined by different existing methods, was carried out. It has been established that deviations by the yield of long fiber of absolute units are 3,55-9,05%, relative - 24,0-44,50%; by the yield of short fiber - 0,20-11,60%, 1,80-51,6.0%; by the number of long fiber - 0,00-1,64 N, 0,00-13,60%; by quality of short fiber - 0,40-2,75 N, 1,30-44,40%; by content and total fiber yield - 0,40-10,80, 1,00-32,00% respectively.

2. In order to increase the informational value of determining technological quality of flax straw, which depends on timeliness, reliability and comparability of the results of evaluation of the main features found by different methods, it is necessary to bring them to a unified level. This will allow to make reasonable decisions when creating new fiber flax varieties in breeding work, in management of production processes in production and processing of flax fiber products.

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ИСПЫТАНИЕ НАНОЧАСТИЦ МАКРО- И МИКРОЭЛЕМЕНТОВ НА ЗЕРНОВЫХ КУЛЬТУРАХ

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Исследования проведены в северной лесостепи Тюменской области. В лабораторных и полевых условиях испытаны различные формы и дозировки наночастиц макро- и микроэлементов и сопутствующих веществ при обработке семян и растений яровой тритикале и пшеницы. Препараты имели положительное влияние на прорастание семян, более высокие нормы снижали показатели энергии и всхожести. Энергия прорастания и всхожесть семян тритикале повышались на 4–10% при применении препаратов с содержанием наночастиц меди, марганца, молибдена, биогенного железа, Титана М. Обработка суточных проростков препаратами марганца, кальция, молибдена, Титана М, биогенного железа, бора, калия способствовала увеличению длины ростка на 7-е сутки на 7,8–25%, массы ростка на 6–8%. На применение калия реагировали только уже развивающиеся ростки. Отмечено, что применение биогенного железа вызывает снижение лабораторной всхожести семян на 4–10%, но способствует развитию главного корня. Его увеличение составило 9–12% по сравнению с контролем. Включение биогенного железа и кремния в смесь к химическому протравителю снижало эффективность против корневых гнилей от 18% в начале вегетации до 30% к периоду уборки. Применение биогенного железа способствовало повышению урожайности на 0,5–0,6 т/га, или 23%, в системе комплексной защиты культуры по сравнению с контролем и на 0,16–0,23 т/га – со стандартной схемой защиты культуры. Отмечено положительное влияние биогенного железа при обработке растений в фазу колошения как отдельного элемента технологии, так и в баковой смеси с фунгицидами.

Ключевые слова: наночастицы, макроэлементы, микроэлементы, зерновые культуры, урожайность, эффективность, болезни растений

TESTING OF MACRO- AND MICRONUTRIENT NANOPARTICLES ON GRAIN CROPS

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The studies were conducted in the northern forest-steppe of the Tyumen region. Under laboratory and field conditions, different forms and dosages of macro- and micronutrient nanoparticles and associated substances were tested in the treatment of seeds and plants of spring triticale and wheat. The preparations had a positive effect on seed germination, while higher rates reduced energy and germination. The germination energy and germination of triticale seeds increased by 4-10% with the application of preparations containing nanoparticles of copper, manganese, molybdenum,

biogenic iron, Titan M. Treatment of daily seedlings with manganese, calcium, molybdenum, Titan M, biogenic iron, boron, potassium increased sprout length by 7.8-25% and sprout weight by 6-8% by day 7. Only already developing sprouts responded to the application of potassium. It was noted that the application of biogenic iron causes a 4-10% decrease in laboratory germination of seeds, but promotes the development of the main root. Its increase was 9-12% compared to the control. The inclusion of biogenic iron and silicon in the mixture to the chemical dressing reduced the effectiveness against root rot from 18% at the beginning of the growing season to 30% by the harvesting period. The application of biogenic iron increased the yield by 0,5-0,6 t/ha or 23% in the system of complex crop protection compared to the control and by 0,16-0,23 t/ha with the standard scheme of crop protection. A positive effect of biogenic iron in the treatment of plants during the earing phase as a separate element of the technology and in a tank mixture with fungicides was noted.

Keywords: nanoparticles, macroelements, microelements, grain crops, yield, efficiency, plant diseases

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INTRODUCTION

In the system of crop cultivation, seed dressing is the easiest way to improve the quality of seeds [1, 2]. Application of chemical plant protection agents has a regulatory effect both on pest objects, and on the crop itself, its growth and development. Their negative impact can be corrected by using in a complex of preparations to activate growth and reduce stress. The use of microfertilizers enhances seed germination and vegetative growth of plants in the first phases of ontogenesis[1] [3, 4]. Stimulation of growth processes can be expressed in a change in the effect on plant organs, which shows the differences in the direction of action of the preparations [5-7].

The use of foliar fertilizers with chelated iron compounds contributed to an increase in the indicators of yield structure [8, 9], the use of microfertilizers during the growing season in a mixture with nitrogen influenced the growth dynamics of spring wheat [10], fertilization with chelated zinc, copper and sulfur - on the grain quality [11]. A prolonged use of chelated forms of trace elements leads to inhibition of growth processes compared to only the seed treatment[2] [12, 13].

Reducing the volume of a substance or particle to nanoparticles to improve the conditions of penetration and delivery of necessary substances to plants should promote seed germination, accelerate plant growth, increase crop yields and protect plants from environmental influences [14, 15].

In the studies of Iranian scientists, the addition of nutrient media containing selenium particles was seen as a promising approach to

[1]Anikina L.M., Udalova O.R., Panova G.G. Influence of pre-sowing treatment of spring wheat seeds with silicon-containing chelate microfertilizers on the growth and development of its seedlings // Modern state, problems and prospects of agrarian science: proceedings of the Vth international scientific and practical conference: Simferopol: IT "Arial", 2020. Pp. 13-15.

[2]Chirko E.M., Timoshchenko V.G. Influence of growth regulators and microfertilizers on the germination of spring wheat seeds // Agriculture - problems and prospects: collection of scientific papers of Grodno: State Agrarian University, 2019. V. 45: Agronomy. Pp. 193-201.

altering plant growth, morphology, metabolism and anatomy, but there was an understanding of the phytotoxicity of such use, which definitely introduces significant epigenetic variations in DNA. Such results are also true for other nanomaterials: genetic damage to wheat, toxic effects on primary plant development, environmental instability, and cytotoxic effects on plants are evident. This necessitates a clear elaboration of safe norms for the application of nanomaterials on biological objects[3] [16, 17]. Ready-made macro- and microelement compositions are proposed for use in the main phases of plant ontogenesis in combination with pesticides, as well as a separate element of technology aimed at increasing the qualitative characteristics or productivity of agricultural plants by accumulating biomass and increasing the assimilative surface[4].

The purpose of the study was to determine the effect of preparative forms containing nanoparticles of macro- and microelements for the treatment of seeds and vegetative plants of cereal crops.

MATERIAL AND METHODS

The studies were conducted under laboratory and field conditions at the Research Institute of Agriculture of the Northern Trans-Ural Region, a branch of the Tyumen Scientific Center of the Siberian Branch of the Russian Academy of Sciences, northern forest-steppe zone. The measurements and observations were carried out according to the standard methodological guidelines adopted in the State Crop Testing Committee, crop production, and plant protection. Under laboratory conditions, a comparative assessment and selection of macro- and microelement solutions (nitrogen, phosphorus, potassium, calcium, manganese, magnesium, molybdenum, boron, zinc, copper, biogenic iron, Titan M and their mixtures) with the most positive effect on energy, germination and growth functions were performed. The content of the main active ingredient was 10-40 mg/ml, the accompanying substances in the form of silver - 1 mg/ml, stabilizers nanodispersity polyvinylpyrrolidone - 20%, collagen hydrolyzate - 15%. There are at least six variations for each element. Of these, the variants with the most positive effect were selected and studied in the second stage of research.

Seeds were treated before sowing with an hour exposure. Preparation of the working solution was calculated per 100 g of seeds, application rates from 1 to 100 ml/t or per 1 ha depending on the type of the experiment. Determination of the effects of the preparations during treatment of seeds and daily seedlings was carried out in Petri dishes and in wet rolls. Phyto-examination of seeds, assessment of seed infestation by various pathogens were performed on the 7th day. Then we sowed seeds with daily germination after treatment with preparations, 20 pieces per cup in five replications. The samples were planted according to GOST 12038-84[5]. Sprout length, root length, weight of vegetative organs, reduction of fungi on seeds were taken into account. Seeds of spring triticale were used in the experiment. Biogenic iron hydroxide (ferrihydrite) produced by the Krasnoyarsk Research Center was evaluated under field conditions in the protection system of spring wheat.

Biogenic iron was applied in appropriate phases of development to determine its effect on wheat plant development, diseases, and yield. The soil of the experimental plot is dark gray forest heavy loam. The field experiment was set up under standard agrotechnical conditions in a shallow plot area of 20 m^2 with fourfold repetition. During the growing season the lesion of root rot and leaf-rolling diseases was determined.

[3]Nanocides may become an alternative to conventional insecticides: [Electronic resource]. URL: https://glavagronom.ru/news/nanopesticidy-mogut-stat-alternativoy-obychnym-insekticidam, https://www.azonano.com.

[4]V. Popova, N.V. Goman, M.A. Kireeva Influence of foliar feeding with zinc and copper chelates on the quality of spring wheat grain when growing on meadow-chernozemic soil // Environmental readings - 2020: materials of the 11th National Scientific and Practical Conference with international participation. Omsk, 2020. Pp. 459-464.

[5]GOST 12038-84 Seeds of crops. Methods of analysis. Moscow: Publishing house of standards, 2004. 47 p.

The yield was counted by selection of sheaf material, mechanical threshing of plots. Analysis of seeds for quality parameters was carried out according to the relevant GOSTs[6]. Statistical data processing was performed using Excel program.

RESULTS AND DISCUSSION

In laboratory studies the results of different effects of the application of preparations containing nanoparticles of macro- and microelements were obtained. A comparative evaluation was carried out with more than 20 preparations with different rates of application. The positive effect of the preparations or its absence was noted. Mixtures consisting of 3-5 substances showed a neutral or negative effect when the elements and application rates were increased.

Preparations containing copper, zinc, boron, calcium and ready-mixed P + K with stabilizer PVP (polyvinylpyrrolidone) + Ag-C modifier, N + P + PVP + Ag-C at the solution rate of 5 ml/t had a positive effect on germination. Higher rates reduced energy and germination.

Triticale seeds germination energy increased with the application of preparations containing copper, manganese, molybdenum, biogenic iron, Titan M. The increase in growth energy was 4-10%. Superiority was in the preparations Titan M at 500 ml/t (+7%), molybdenum at 10-50 ml/t (+10, +7%). As a result, out of 58 variations, positive effect was found in five preparations with certain norms (see Table 1).

Seed germination in some variants was at the level of the initial germination energy or had an increase depending on the applied element. Significant increase in germination was noted for calcium, manganese preparations at the rate of 5 ml/t (+4, +5%), Titan M - 500 and molybdenum - 10-50 ml/t (+6, +10%).

The study of manganese nanoparticles (sulfate monohydrate) in most variations had a stimulating effect on the growth processes of spring triticale, but the use of collagen hydrolysate (HC) as a stabilizer of nanodispersity reduced the positive effect of the preparation in seed treatment. Manganese as normal up to 20 mg/g in the studied combinations in combination with the stabilizer (PVP) contributed to an increase of energy, germination, growth of vegetative organs, which assumes its use as a stimulating agent in seed treatment.

In variants with magnesium, variations with positive effect on germination were determined: Mg 10-20 mg + PVP with the rate of 1-5 ml/t, Mg 10 mg + HA with the rate of 1 ml/t. A greater effect on root development was observed with Mg 10 mg + Ag (silver) 1 ml + PVP at the rate of 1 ml/t. All variations of magnesium had a positive effect (at the rate of 1 ml/t) on the sprout development with an increase in its length by 1.1-2.1 cm and limitation of coleoptile growth by 0.5-1.2 cm. Treatment of daily sprouts with Mg 20 mg + PVP; Mg 10 mg + Ag 1 ml + HA contributed to an increase of sprout length by 2,7-2,9 cm and weight by 1,0-1,3 g at the rate of 5 ml.

The use of the same preparation in the treatment of seeds and already developing plants can have a different effect on their initial growth. Two criteria were compared: the total length of all sprouts (on average 9-15 cm) and the length of sprouts with normal healthy development (13,0-15,0 cm). It was noted that in some variants the sprout development was normal, without lagging, in others the effect of the preparation on growth inhibition was established. The increase in sprout length was observed for the preparations Mn (10 ml/t), Ca (10), Mo (50), Titan M (50), biogenic Fe (5 ml/t), B (5 mg/g + HA (10%), 1 ml/t), K (1000 ml/t). Of these, B 5 mg/g + HA (10%), 1 ml/t, K 1000 ml/t had a significant effect. The increase of sprout length was 1,0-3,2 cm, or 7,8-25%, of sprout crude weight 0,5-1,4 g, or 6-8%. Treatment of seeds with potassium had no effect on their germination activity, but treatment of the germinating seed had a positive effect on the growth functions of the young plant. Growth inhibition of triticale plants was observed in the following variants: Fe3O4, 5 + SiO, 2 + N, 5 + K, 10 ml/t;

[6]GOST 1386.5-93, GOST 30483-97, GOST 12042-80, GOST 10840-64, GOST 13586.1-68.

Табл. 1. Энергия и всхожесть семян при обработке препаратами, %
Tabl. 1. Energy and germination of seeds when treated with preparations, %

№ i/n	Option	Energy	Germination
1	K, 10 ml + N, 5 ml + SiO, 1 ml + Ca, 5 ml/t	86–88 (+1)	88–91 (+2)
2	Cu 2, 5 ml (> reduces energy and germination)	89–91 (+4)	89–91 (+3)
3	Mn 3, 5 ml/t (>at the control level))	89–91 (+4)	91-92 (+4)
4	Ca 5, 5 ml/t (>reduces energy and germination)	86–91 (+2)	90–94 (+5)
5	Biogenic iron, 5 ml/t	88–91 (+4)	87–92 (+3)
6	Titan M, 50 ml/t	88–92 (+4)	87–93 (+3)
7	Titan M, 500 ml/t	92–94 (+7)	91-95 (+6)
8	Mo 2, 5 ml/t	87–90 (+3)	89–91 (+3)
9	Mo 2, 10 ml/t	95–97 (+10)	96–98 (+10)
10	Mo 2, 50 ml/t	91–94 (+7)	92–94 (+6)
11	Zn 2000 ppm, 10 ml/t	82–85 (–2)	82–87 (–2)
12	Mg, 20 mg/ml + PVP particles < 10 nm, 1–5 ml/t	84–88 (–)	87–91 (+2)
13	4 B 5 mg/g + GA (10 %), 1 ml/t	83–87 (–1)	84–88 (–1)
14	P + K 10–12 mg/g + PVP 15% + Ag-C 0,5 mg/g, 500 ml/t	83–88 (-)	83–88 (-1)
15	P + K 10–12 mg/g + PVP 15% + Ag-C 0,5 mg/g, 1000 ml/t	85–87 (-)	87–89 (+1)
16	N + P 4-9 mg/g + PVP 15% + Ag-C 0,5 mg/g, 10 ml/t	79–83 (–5)	82–86 (–3)
17	5 K, 10 ml/t	78–80 (–7)	88–90 (+2)
18	5 K, 50 ml/t	85–90 (+2)	88–90 (+2)
19	5 K, 100 ml/t	86–90 (+2)	87–91 (+2)
20	7 N, 100 ml/t (от 5–50 ml/t influences positevely)	81–85 (–3)	88–92 (+3)
21	Control (water)	84–88 (– 2,95)	86–88 (–)
	LSD_{05}		2,99

Note. 1, 11–15, 18, 19 – neutral influence; 16, 17, 20 – negative; 3, 7, 9, 10 – positive.

Fe3o4, 100 ml/t; Zn 2000 ppm, 10 ml/t; N + P4-9 mg/g + PVP15% + Ag-C, 10 ml/t. The shoot length lag was 1-3.5 cm, weight - up to 4 g. Neutral effect (drug dosage was insufficient or its effect was weak) was observed in variants: Cu (2, 50 ml/t); Mn (3, 10 ml/t); Mo (2, 10 ml/t); Mg, (20 mg/ml) + PVP < 10 nm, 1 ml/t); K (500 ml/t); N (10 ml/t). The effect of some preparations when comparing the total sprout length showed a lag or was at the control level, but when comparing normally developed sprouts, their values increased, which is also confirmed by the crude weight of plants (see Table 2).

In the field study of biogenic iron we treated seeds and plants during the growing season in the main phases of protection agents application. Seed germination after treatment with tested means compared to control varied within 60-79%. The effect of biogenic iron on reduction of germination or inhibition of seed germination processes was noted. According to some authors, oxidative stress and reduction of seed germination can be caused by nanoparticles of many metals (silver, gold, iron), ferrites, as well as oxides of zinc, nickel, copper, iron, titanium, silicon [18-20]. Seed germination rate decreased by 4-10% during treatment with biogenic iron. It is probably necessary to limit the use of iron for their treatment, because it inhibits the emergence of sprouts and growth in the first phases of plant development. Bio-

Табл. 2. Рост растений яровой тритикале при обработке суточных проростков
Tabl. 2. The growth of spring triticale plants when processing day old seedlings

№ i/n	Option	Normally developed plants, %	Sprout length total / normally developed plants, cm	Sprout mass per 100 plants, g
1	Fe_3O_4, 5 + SiO, 2 + N, 5 + K, 10 ml/t	85	11,71/12,61	9,05
2	Cu 2, 50 ml/t	85	12,70	9,47
3	Fe3o4, 100 ml/t	90	11,65/12,64	9,10
4	Mn 3, 10 ml/t	90	12,27/13,31	9,73
5	Ca 5, 10 ml/t	80	13,59	10,43
6	Ca 5, 50 ml/t	80	13,00	9,81
7	Biogenic Fe, 5 ml/t	90	13,58	9,88
8	Титан М, 50 ml/t	95	12,5/13,38	9,63
9	Mo 2, 10 ml/t	95	12,81	9,15
10	Mo 2, 50 ml/t	95	13,00/13,64	9,00
11	Zn 2000 ppm, 10 ml/t	90	9,25/9,88	5,85
12	Mg, 20 mg/ml + PVP <10 nm, 1 ml/t	90	12,60	8,94
13	B 5 mg/g + GA (10%), 1 ml/t	90	13,74–14,11	9,55
14	P + K 10–12mg/g + ПВП15% + Ag-C, 10 ml/t	90	13,11	9,00
15	N + P 4–9 mg/g + ПВП15% + Ag-C, 10 ml/t	95	11,42	7,52
16	K, 500 ml/t	100	12,9	8,8
17	K, 1000 ml/t	95	14,33/15,96	9,62
18	N, 10 ml/t	90	12,69	8,61
19	Control (water)	95	12,74	9,0
	LSD_{05}	4,5	0,62	0,49

genic iron had a positive effect when treating plants during the growing season, especially during the active growth of the green parts of the plant. Treatment with biogenic iron had the same effect on the development of root system: the growth of the main root increased by 1,2-1,8 cm, or 9-12%, its weight increased by 0,6-0,9 g (see Table 3).

Application of chemical dressing reduced the length of coleoptile, and none of the preparations had a positive effect on its response. Sprout length had a significant increase of 1.7 cm only in the variant where liquid fertilizer was used, in the variant with biogenic iron there was a decrease in length by 2.2 cm and sprout weight by 0.9 g.

The efficiency of reducing infection on seeds with infection by fungi of the genus Alternaria - 10-12%, Fusarium - 2-7%, Bipolaris sorokiniana - 0-2% when treated with a chemical dresser was 100%; when adding biogenic iron and silicon to the mixture, the reduction was 90-95%.

The occurrence of root rot in the initial period of vegetation has a great impact on further growth, development and yield of the crop. In the tillering phase the disease development without treatment with a chemical dressing was 1.4%, spreading - 5.6%. During the growing season lesion increased 3-fold. Chemical dressing protected plants from root rot up to the phase of the beginning of tubing by 100%. Dur-

Табл. 3. Всхожесть и развитие зародышевых органов на 7-е сутки после обработки
Tabl. 3. Germination and development of germinal organs on the 7th day after treatment

Dressing option	Germination, %	Root length, cm	Root mass, g	Coleoptile length, cm	Sprout length, cm	Sprout mass, g
Disinfectant + insecticide + fertilizer	(72–82) 77	12,99	1,84	4,75	11,37	3,62
		+0,49	+0,13	–2,0	+1,72	–0,08
Control (without treatment)	(73–86) 78	12,5	1,71	6,75	9,65	3,70
		–	–	–	–	–
Disinfectant + Biogenic Fe, 1 ml	(66–76) 61	14,1	2,67	4,1	7,4	2,73
		+1,6	+0,96	–2,65	–2,25	–0,97
Disinfectant + SiO_2, 1 ml	(74–84) 79	14,3	2,54	4,75	9,3	3,39
		+1,8	+0,83	–2,0	–0,35	–0,31
Disinfectant + SiO2, 1 ml + Biogenic Fe,1 ml	(72–84) 78	13,7	2,34	5,0	9,7	3,56
		+1,2	+0,63	–1,75	+0,05	–0,14
LSD_{05}		1,08	0,54	1,72	1,6	0,36

ing the growing season, the decrease in protective function against disease development occurred to 78-84 and 71-79% against its spread. The inclusion of biogenic iron and silicon in the mixture to the chemical dressing reduced the effectiveness against root rot by 18-22% in the initial vegetation period, by the harvesting period of the crop - by 30-40%. When treated with a standard mixture (fungicidal disinfectant + insecticidal disinfectant + fertilizer) the effectiveness was higher by 8-17% in relation to the application of disinfectant in the mixture with iron, silicon (see Table 4).

The crop yield in conditions of average weediness before treatment with herbicides and weak manifestation of leaf-rolling diseases during the growing season was 2.4 t/ha in the control. The application of a complex of plant protection products increased by 0.4 t/ha, the double application of biogenic iron at seed dressing and at the earing phase - by 0.56 t/ha, when applying biogenic iron at tillering and earing phases in combination with silicon - by 0.63 t/ha. LSD_{05} was 0.2, which significantly exceeds the value of the standard scheme of protection (fungicide + insecticidal protector +

Табл. 4. Эффективность обработки против корневых гнилей, %
Tabl. 4. Treatment efficacy against root rot, %

Dressing option	Tillering phase			Before harvesting		
	Development	Spread	Effectiveness	Development	Spread	Effectiveness
Disinfectant + insecticide + fertilizer	0	0	100	0,72–1,01	2,90–4,05	84,42–78,2
Control (without treatment)	1,4	5,62	–	4,65	13,95	–
Disinfectant + Biogenic Fe, 1 ml	0,25	0,99	82,38	1,35	4,59	70,96
Disinfectant + SiO2, 1 ml	0,25	1,01	82,02	1,76	5,04	62,15
Disinfectant + SiO2, 1 ml + Biogenic Fe,1 ml	0,3	0,96	78,5	1,42	4,66	69,46
LSD_{05}	0,22	0,92	6	0,32	1,2	8

fertilizer). Application of silicon alone was at the level of standard protection. When assessing the use of biogenic iron, its positive effect was noted in the phases of tillering and earing and with greater efficiency in the phase of the beginning of earing in combination with fungicides or without them.

CONCLUSIONS

1. A positive effect on the germination energy (by 4-10%) and germination rate of spring triticale seeds was produced by using preparations containing copper, manganese, molybdenum, biogenic iron, Titan M. Of these, the preparations Titan M and molybdenum had a clear advantage (+7, +10%).

2. The effectiveness of micronutrient nanoparticles is enhanced by the inclusion of stabilizers that increase or decrease the effect of the elements.

3. The effect of micronutrients in the treatment of daily seedlings on the sprout length was observed in preparations of manganese, calcium, molybdenum, Titan M, biogenic iron, boron, potassium; the increase in sprout length was 7.8-25%, its weight - 6-8%.

4. Application of biogenic iron in seed pretreatment together with a chemical dressing promoted root growth by 12%; germination of seeds when treated with biogenic iron decreased by 4-10%.

5. Application of macro- and microelements in combination with chemical dressing reduced the effectiveness against root rot during the growing season by 16-30%.

6. The application of biogenic iron helped to increase the yield by 0,5-0,6 t/ha, or 23%, in the system of complex crop protection in comparison with the control and by 0,16-0,23 t/ha - with the standard scheme of crop protection. The positive effect of biogenic iron in the treatment of plants in the phase of earing as a separate element of technology, and in a tank mixture with fungicides was noted.

7. The application of macro- and micronutrient nanoparticles described in this study is possible both for seed pre-sowing treatment and during the growing season to stimulate growth.

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СОЗДАНИЕ СЕЛЕКЦИОННОЙ ГРУППЫ ГЕРЕФОРДСКИХ КОРОВ, УЛУЧШЕННЫХ БЫКАМИ КАНАДСКОЙ РЕПРОДУКЦИИ

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Представлены результаты исследований по созданию селекционной группы герефордских коров в племенном репродукторе Новосибирской области. Установлено, что по живой массе наименьший коэффициент изменчивости имеют коровы с 3-го по 7-й отел (от 1,9 до 2,7%), по молочности – от 1,9 до 5,6%. По высоте в крестце (характеризующая выраженность типа) вариация составила 1,3–1,6%. Исходя из этих показателей отобрана и оценена селекционная группа коров в количестве 82 гол. В среднем живая масса животных составила 570,5 кг с превосходством показателя стандарта породы на 50,5 кг, или 9,7%, и соответствовала классу элита-рекорд. Селекционный дифференциал по живой массе коров всего стада и селекционной группы составил 11 кг. С учетом коэффициента наследуемости и эффекта селекции на первое поколение для достижения показателей желательного типа на основе коров селекционной группы понадобится 3,5 поколения (10,5 лет), соответственно по молочности – 3,9 поколения (4,5 года). Более эффективного селекционного достижения можно добиться по высоте в крестце (1,1 поколения и 3,3 года). Десять быков-производителей, отобранных для заказного спаривания, однородны и оценены классом элита-рекорд. По живой массе превосходили стандарт породы в 3 года на 151,5 кг (8,1%), в 5 лет и старше – на 115,3 кг (14,1%). Они характеризуются хорошо выраженным желательным типом телосложения. Быки-производители, полученные от кросса канадской и сибирской селекций с комплексным индексом «Б», по качеству потомства 104–105 признаны улучшателями.

Ключевые слова: порода, селекционная группа, живая масса, молочность, изменчивость, поколение

CREATION OF A BREEDING GROUP OF HEREFORD COWS IMPROVED BY BULLS OF CANADIAN REPRODUCTION

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The results of research on the creation of a breeding group of Hereford cows at the Novosibirsk Region breeding reproducer are presented. It was found that cows from the 3rd to 7th calves have the lowest coefficient of variability for live weight (from 1.9 to 2.7%), for milk yield - from 1.9 to 5.6%. The variation in height at hips (characterizing the manifestation of the type) was from 1.3-1.6%. Based on these indicators, a breeding group of 82 cows was selected and evaluated. The average live weight of the animals was 570.5 kg, which exceeds the standard of the breed by 50.5 kg or 9.7%, and corresponded to the elite-record class. The selection differential by live weight of cows of the whole herd and breeding group was 11 kg. Taking into account the coefficient of inheritance and the effect of selection on the first generation to achieve the indicators of the desirable type based on the

cows of the breeding group will take 3.5 generations (10.5 years), respectively, for milk yield - 3.9 generations (4.5 years). More effective breeding achievement can be achieved in height at hips (1.1 generations and 3.3 years). Ten stud bulls selected for custom mating are homogeneous and rated elite-record class. They exceeded the breed standard by 151.5 kg (8.1%) in live weight at 3 years of age and by 115.3 kg (14.1%) at 5 years and older. They are characterized by a well-defined desirable type of constitution. Stud bulls obtained from the cross of the Canadian and Siberian selections with the complex index "B", according to the quality of progeny 104-105 recognized as improveers.

Keywords: breed, breeding group, live weight, milk content, variability, generation

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INTRODUCTION

The development of specialized beef cattle breeding in the Russian Federation is a priority for agriculture. 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%). This is a consequence of the reduction in the number of dairy cows and over-replacement young cattle in the share of fattening stock[1] [1, 2]. They can be replaced only by animals of beef breeds, so the creation of new genotypes of cattle with high meat productivity is the main goal of breeding and pedigree work in specialized beef herds. According to forecasts, by 2025 the number of beef cattle of specialized beef breeds should reach 10 million heads [3]. Currently, the development of beef cattle breeding is carried out both with the use of domestic cattle breeds and with the involvement of foreign cattle breeds[2,3]. The Hereford cattle breed in the breeding farms of the Russian Federation is the third and most common among the imported specialized beef cattle breeds in Siberia.

Currently, with the advent of market relations under the influence of economic factors, the beef cattle breeding industry in Russia and the CIS has the opportunity to expand the marketing niche in the market of agricultural products. As a consequence, the role of breeding farms in increasing the number of beef cattle population is growing.

Work with cattle breeds, in particular with Siberian-bred Herefords, should be aimed at improving the efficiency of forage and technological resources through the creation of new breeding groups. It is known that all breeds of animals bred in the world by artificial human selection need continuous improvement of breeding and productive qualities for the future. Otherwise, under the influence of both natural selection factors and environmental pressure, any breed will degenerate. In this regard, Herefords of domestic reproduction are improved by adding blood of Canadian selection animals to improve both breeding and meat qualities [4-

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[3]Khamiruyev T.N., Tyukavkin A.A. Canadian selection Herefords in the Trans-Baikal region // Meat cattle breeding in the arid territories of southern Middle Siberia: current status and prospects for development: proceedings of interregional scientific and practical conference with international participation. Khakassia, 2017. Pp. 76-80.

10][4]. Similar work has been started in the Siberian breeding farms.

MATERIAL AND METHODS

Animals of specialized meat Hereford breed became the object of long-term studies. The variability of the main traits of purebred Hereford cattle of "Voznesenskoye" breeding reproducer of Novosibirsk region was determined by conventional methods.

The indices of breeding differential by productivity indices were calculated and the evaluation of stud bulls by the quality of progeny with the definition of the breeding index "B" was carried out. For this purpose, 30 of their sons, 10 from each, were selected for control breeding. Bulls were tested for their own productivity from 8 to 15 months of age by four traits: live weight at 15 months of age, average daily gain at 8 to 15 months of age, lifetime assessment of meat qualities, and expression of the body type[5].

RESULTS AND DISCUSSION

According to the norms of evaluation of the breeding qualities of beef cattle, approved by the Ministry of Agriculture of the Russian Federation, the animals are divided into the following groups:

– the nucleus is the best part of the herd, comprising 50-60% of the total number of cows in the herd;

– breeding group (bull breeding group) included in the nucleus - 18-20% of the total number of cows in the herd;

– production group - cows not included in the breeding nucleus that are in the herd.

For further improvement of the herd, the most valuable is the breeding group, so its consolidation of the main traits is of great importance for its formation.

During the experiment, biometric processing was carried out on three traits: live weight, milk yield and height at hips of cows (see Table 1).

Табл. 1. Основные показатели продуктивности и экстерьера коров герефордской породы по отелам, кг/см

Table. 1. The main indicators of productivity and exterior of Hereford cows by calving, kg/cm

Calving	*n*	Indicator					
		Live weight		Milking capacity		Height at hips	
		M ± *m*	*Cv*	*M* ± *m*	*Cv*	*M* ± *m*	*Cv*
1-st	21	477,8 ± 7,2	6,9	185,6 ± 2,4	6,0	123,7 ± 0,5	2,1
2-nd	24	522,7 ± 6,5	6,1	186,9 ± 3,3	8,6	122,8 ± 0,4	1,8
3-rd	22	553,6 ± 3,1	2,6	202,1 ± 2,0	4,8	123,5 ± 0,4	1,3
4-th	18	544,4 ± 2,6	2,0	214,9 ± 2,5	4,8	124,3 ± 0,4	1,5
5-th	19	551,3 ± 3,4	2,7	216,9 ± 2,8	5,6	124,0 ± 0,4	1,3
6-th	22	553,5 ± 2,3	1,9	226,6 ± 0,9	1,9	124,9 ± 0,3	1,4
7-th	17	551,8 ± 2,8	2,1	226,5 ± 1,9	3,5	124,6 ± 0,5	1,6
8-th	19	553,6 ± 5,3	4,2	211,4 ± 4,1	8,4	122,3 ± 0,5	1,6
9-th	16	569,3 ± 7,8	5,5	217,9 ± 3,7	6,8	121,7 ± 0,7	2,3
10-th	14	570,2 ± 14,9	9,8	215,5 ± 4,2	7,3	121,9 ± 0,9	2,7

[4]Kuzmina T.N. Results of research to improve the genetic potential of the Hereford cattle breed of domestic selection // Scientific and information support of innovative development of the agro-industrial complex: materials of the XI International Scientific and Practical Internet Conference. 2019. Pp. 25-29.

[5]Amerkhanov Kh.A., Dunin I.M., Sharkaev A.A. Norms of evaluation of the breeding qualities of beef cattle // Ministry of Agriculture of the Russian Federation. M., 2010. Pp. 5-10.

Cows from the 3rd to 7th calving had the lowest coefficient of variability for live weight - from 1.9 to 2.7%, for milk yield - from 1.9 to 5.6%. The variation in the height at hips (characterizing the expression of the type) was from 1.3 to 1.6%. In this connection, 82 cows of these lactations were selected in the breeding group as the most homogeneous, which would increase the efficiency of the breeding work. It included representatives of both Siberian reproduction and those improved by Canadian producers. The average live weight of the cows was 570.5 kg with an excess of 50.5 kg, or 9.7%, over the breed standard and corresponded to the elite-record class (see Table 2).

The highest indicator was 670 kg. In terms of milk yield, height at hips, and live weight, the bulls at 12 and 15 months of age were rated elite class.

Cows are characterized by a pronounced breed type, harmonious build and correspond to the desirable exterior-constitutional type (see Fig. 1).

Admixture of new blood of Hereford bulls

Табл. 2. Показатели продуктивности и высоты в крестце селекционной группы коров племенного репродуктора «Вознесенское»

Table. 2. Indicators of productivity and height in the sacrum of the breeding group of cows of the «Voznesenskoye» pedigree breeding unit

Indicator	Value			Breed class
	M ± *m*	Б	*Cv*	
Live weight of cows, kg	570,5 ± 3,11	28,2	4,9	Elite-record
Milkiness of cows by live weight of calves at 205 days	210,3 ± 0,93	8,4	3,9	Elite
Height at hips of cows, cm	130,1 ± 0,34	3,1	2,4	»
Live weight of steers at 12 months, kg	338,2 ± 1,06	9,6	2,8	»
Live weight of steers at 15 months, kg	414,4 ± 1,2	11,2	2,7	»

Рис. 1. Лучшие представительницы селекционной группы

Fig. 1. The best representatives of the breeding group

of Canadian reproduction had a statistically significant effect (p > 0.95-0.99) - from 23.5 to 60.5%, except for the live weight of steers at 12 months of age (see Table 3). We believe that this was a consequence of stress in steers after weaning from their mothers. The breeding differential in the live weight of cows of the whole herd and breeding group was 11 kg (see Table 4).

Taking into account the heritability estimate and the genetic progress through selection effect on the first generation, it will take 3.5 generations (10.5 years) to achieve the indicators of the desirable type on the basis of cows of the breeding group, respectively, for milk yield - 3.9 generations and 4.5 years. More effective breeding achievement can be achieved in the height at hips (1.1 generations and 3.3 years).

Ten high-yield stud bulls were selected for custom mating with cows (see Table 5).

The animals are homogeneous, rated elite-record class and exceed the breed standard at 3

Табл. 3. Влияние быков-производителей канадской селекции на продуктивность и промер животных

Table. 3. The influence of Canadian breeding stud bulls on the productivity and size of animals

Indicator	Breeding		Difference	Effect size (h_x^2), %	*p*
	Siberian	Canadian			
Live weight of cows, kg	530,6 ± 8,21	564,1 ± 5,49	+33,5	38,3	> 0,99
Milkiness of cows by live weight of calves at 205 days, kg	205,2 ± 2,21	217,6 ± 0,79	+12,4	60,5	> 0,99
Height at hips of cows, cm	128,4 ± 0,21	130,3 ± 0,33	+1,9	23,5	> 0,95
Live weight of steers at 12 months, kg	338,3±1,88	341,5 ± 1,89	+3,2	2,7	< 0,90
Live weight of steers at 15 months, kg	415,5 ± 2,47	424,9 ± 1,94	+9,4	30,8	> 0,99

Табл. 4. Прогноз эффективности селекции по лучшим генотипам коров

Table. 4. Prediction of breeding efficiency by the best genotype of cows

Indicator	Economic trait		
	live weight, kg	milking capacity, kg	height at hips, cm
By herd	559	204	130
Of desirable type	570	210	131
Selection differential	11	6	1
Heritability estimate	0,28	0,66	0,89
The effect of selection on the first generation	3,1	3,9	0,9
The need for generational change	3,5	1,5	1,1
Time to achieve the indicator, years	10,5	4,5	3,3

Табл. 5. Живая масса быков-производителей, кг

Table. 5. Live weight of stud bulls, kg

Age	Indicator			± to the breed standard, kg/%
	M ± *m*	Б	*Cv*	
3 years	821,5 ± 1,19	2,4	0,29	151,5/22,6
5 years and older	935,3 ± 5,33	13,1	1,39	115,3/14,1

years by 151.5 kg (8.1%), at 5 years and older by 115.3 kg (14.1%). They are characterized by a well-defined desirable type of build (see Fig. 2).

The growth energy of young cattle in beef cattle breeding has remained at the same level for many years. The reason for the slow improvement of beef cattle lies not in the conservatism of heredity, but in the method of its improvement. For a long time, selection of beef cattle was carried out on a set of traits. This method has failed to justify itself not only in our country but also abroad, because the judgment of breeding merits of bulls only by their origin, phenotypic features is insufficient and does not give reliable results. Assessment of bulls by their own productivity and of adult stud bulls by quality of progeny is required.

In 2020, three stud bulls (Ideal 4127, Diego 4235 and Bars 53510) were evaluated for progeny quality at OJSC “Voznesenskoe” (see Table 6).

According to the test results, stud bulls Ideal 4127 and Diego 4235, obtained from the cross of Canadian and Siberian selection, were evaluated as elite class. With the complex index "B" for the quality of progeny 104-105 they are recognized as improveers.

Bulls with a complex index of own productivity "A" 112.0-113.0 are recommended for

Рис. 2. Бык-производитель Аракс 40295
(6 лет – 932-137-86, элита-рекорд)
Fig. 2. Stud bull Araks 40295
(6 years old-932-137-86, elite-record)

Табл. 6. Результаты оценки быков-производителей по качеству потомства
Table. 6. The results of the evaluation of stud bulls by the quality of the offspring

Stud bull	Live weight at the age of 15 months, kg	Average daily weight gain from 8 to 15 months, g	Lifetime meat quality score, point	Body type expression, point	Breed class	Composite index by quality of progeny (B)
Ideal 4127	429,0	1001,9	51,6	4	Elite	104
Diego 4235	427,9	986,7	54,3	4	»	105
Bars 53510	408,9	924,8	54,5	3,8	1	101

the replacement of stud bulls. Their average daily gain of live weight was 1038.1-1104.8 g.

CONCLUSION

Over the long term, breeding work with the most common animals of the Hereford breed in Siberia should be carried out by creating new breeding groups in herds. They should be homogeneous and consolidated, which is expressed in the coefficient of variability for the main traits. The lowest coefficient of variability has been established in cows from the 3rd to the 7th calving - from 1.3 to 5.6%. The breeding group of cows in the pedigree reproducer "Voznesenskoe" in the number of 82 heads was selected and evaluated on the basis of these indicators. On average the live weight of the cows was 570.5 kg with an excess of 50.5 kg or 9.7% of the breed standard and corresponded to the elite-record class. The blood of the Hereford bulls of the Canadian reproduction had a significant statistically reliable effect ($p > 0.95$-0.99) - from 23.5 to 60.5.

The breeding differential by live weight of cows of the whole herd and the breeding group was 11 kg. Taking into account the heritability estimate and the selection effect for the first generation, it would take 3.5 generations or 10.5 years to achieve the indicators of the desirable type based on the cows of the breeding group, for milk yield - 3.9 generations and 4.5 years. A more effective breeding achievement can be achieved in the height at hips (1.1 generation and 3.3 years).

Ten highly productive stud bulls, including those obtained from crossbreeding with Canadian Herefords, were selected for custom mating with them. The animals are homogeneous, estimated as elite-record class and exceed the breed standard at the age of 3 years by 151.5 kg (8.1%), at 5 years and older by 115.3 kg (14.1%), are characterized by a well-defined desirable type of build.

According to test results, stud bulls Ideal 4127 and Diego 4235, obtained from the cross of Canadian and Siberian selection, were evaluated as elite class. With the complex index "B" on the quality of progeny 104-105 they are considered to be improveers.

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ЭНДОПАРАЗИТЫ БЛАГОРОДНОГО ОЛЕНЯ (*CERVUS ELAPHUS XANTHOPYGUS)* НА ТЕРРИТОРИИ ЗАБАЙКАЛЬСКОГО КРАЯ

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Представлены результаты (2019–2021 гг.) паразитологических исследований патологического материала от 91 особи благородного оленя (*Cervus elaphus xanthopygus*). На территории Забайкальского края зарегистрирована зараженность благородного оленя восемью видами эндопаразитов: *Protostrongylu skochi* (подотряд *Strongylata* пищеварительного тракта), *Monieziabenedeni, Trichostrongylus* spp*., Dicrocoelium lanceatum, Echinococcus granulosus larva, Cysticercus tenuicollis, Eimeria* spp. Экстенсивность инвазии составляет 86,8% (*Cysticercus tenuicollis)* и 57,1% *(Echinococcus granulosus larva),* что свидетельствует о наличии природных очагов по данным гельминтозам и их широкой распространенности. Обнаружены неспецифичные для Забайкальского края гельминты *Dicrocoelium lanceatum* в желчных протоках печени у одного из исследованных благородных оленей. Данный факт свидетельствует о наличии всех условий (промежуточных хозяев) для распространения инвазии, в том числе и на сельскохозяйственных животных. Для сохранения ветеринарно-санитарного благополучия охотничьего хозяйства в Забайкальском крае, исходя из полученных данных, сформулированы основные принципы профилактики зарегистрированных гельминтозов. Для предупреждения распространения среди диких копытных животных эхинококкоза, цистицеркозов (ларвальные цестодозы) необходима усиленная борьба с волками, лисицами и с бродячими собаками, а также обязательная систематическая дегельминтизация собак (ежеквартально), допускаемых на территорию охотохозяйств. В целях профилактики ларвальных цестодозов необходимо уничтожение внутренностей, добытых в результате охоты животных, неиспользование их в корм собакам в сыром виде. Для профилактики имагинальных гельминтозов у копытных необходимо осуществлять постоянный мониторинг гельминтоносительства. По результатам исследований составлен план противогельминтозных мероприятий. Для дегельминтизации диких животных применяют оральные антигельминтные препараты, которые размещают на подкормочных площадках в смеси с сыпучими кормами (дробленое зерно).

Ключевые слова: эндопаразиты, гельминты, благородный олень, охотничье хозяйство

ENDOPARASITES OF RED DEER (CERVUS ELAPHUS XANTHOPYGUS) IN THE TRANS-BAIKAL TERRITORY

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The paper presents the results (2019-2021) of parasitological studies of pathological material from 91 individuals of red deer (*Cervus elaphus xanthopygus*). Infestation of red deer with eight species of endoparasites has been registered in the Trans-Baikal Territory was registered: *Protostrongylus kochi*, suborder *Strongylata* of the digestive tract, *Moniezia benedeni*, *Trichostrongylus spp., Dicrocoelium lanceatum, Echinococcus granulosus larva, Cysticercus tenuicollis, Eimeria* spp. The intensity of infestation is 86.8% (*Cysticercus tenuicollis*) and 57.1% (*Echinococcus granulosus larva*), indicating the presence of natural foci on these helminths and their widespread distribution. Helminths *Dicrocoelium lanceatum* unspecific for Trans-Baikal Territory were detected in the bile ducts of the liver of one of the examined red deer. This fact indicates the presence of all conditions (the presence of intermediate hosts) for the spread of invasion, including on farm animals. To maintain the veterinary and sanitary well-being of the hunting industry in the Trans-Baikal Territory,

the main principles of prevention of registered helminth infections were formulated based on the data obtained. To prevent the spread of echinococcosis, cysticercosis (larval cestodoses) among wild ungulates, increased control of wolves, foxes and stray dogs, as well as mandatory systematic deworming of dogs (quarterly) allowed in hunting farms is necessary. In order to prevent larval cestodoses it is necessary to destroy entrails of hunted animals and not use them raw as food for dogs. To prevent imaginal helminth infestations in ungulates, continuous monitoring of helminth carriage is necessary. Based on the results of these studies, a plan of helminthic measures is drawn up. For deworming wild animals, oral anthelmintic drugs are used, which are laid out on feeding grounds mixed with loose feed (crushed grain).

Keywords: endoparasites, helminths, red deer, hunting economy

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INTRODUCTION

Game ungulates are widespread in the Trans-Baikal Territory. They play an essential role in human life. The practical importance of red deer is connected with sport hunting and with obtaining organic food and important biological substances (antlers, glands) from animals for the manufacture of medicines, skins for sewing shoes. Currently, many scientific and practical works show that wild ungulates are important and most promising hunting and recreational resources of the fauna of Russia [1, 2]. The main factors restraining the increase in the number of wild ungulates in natural conditions, as well as complicating the work of aviary breeding, are helminthiases[1] [3-7].

One of the game resources of ungulates in Transbaikalia is the red deer (Manchurian elk) (*Cervus elaphus xanthopygus*). The study of endoparasites of this animal species seems relevant from several points of view. In particular, one of the important aspects is associated with the active participation of red deer in the circulation of zoonotic helminth infections [8-11].

The need for targeted parasitological research in this direction is due to a number of reasons.

1. Conducting an inventory of parasites and studying the breadth of their spread creates an opportunity to justify and implement biotechnical measures.

2. Knowledge of the species composition, seasonal and age dynamics of helminth infestations in ecosystems allows to explain the causes of diseases and predict the population dynamics of commercial animals and justify the norms of their withdrawal.

3. The study of the parasite-host link plays an important role in preventing the threat of epizootics and deaths from "undetermined causes".

4. Deciphering the life cycles of pathogens and parasites is associated with the development of measures to control them.

5. In conditions of use of the same territory by agricultural and wild animals, a clear understanding of the parasitofauna of wild animals makes it possible to predict and prevent diseases in farm animals.

[1]Tretiakov A.M., Burdukovsky S.S., Tretiakova N.Yu. Preventive and veterinary and organizational measures to prevent infectious and parasitic diseases of game animals in the hunting grounds of the Republic of Buryatia // Actual issues of development of the agricultural sector of the Baikal region. Materials of the All-Russian (National) Scientific-Practical Conference dedicated to the Day of the Russian Science. 2020. Pp. 280-286.

6. Studies are necessary for the safety of forestry and hunting workers and other people visiting forest areas, to solve problems of epidemiology, epizootology, natural nidality of diseases and prevention of emergency situations.

For a long period, there have been no studies of the parasitofauna of ungulates in the Transbaikal Territory; previously, they have not been of a targeted and large-scale nature. Currently, there is a need to organize a system of parasitological study of wild animals, aimed at solving theoretical and applied problems of scientific research at the modern level [12].

The purpose of the study is to summarize and analyze the data on the distribution and taxonomic definition of the most important endoparasites of red deer in the Trans-Baikal Territory.

The following tasks are formulated to implement the objective:

– study the species composition of endoparasites of red deer in the Trans-Baikal Territory;

– determine the intensity of affection of red deer by different species of endoparasites;

– formulate the basic principles of prevention of parasitic diseases of red deer.

MATERIAL AND METHODS

This work was carried out in the Research Institute of Veterinary Science of Eastern Siberia - branch of the SFSCA RAS. The data obtained in the field in the areas of the Trans-Baikal Territory served as materials for the study.

A study (2019-2021) of endoparasite infestation was conducted in 91 red deer aged one to eight years in different seasons. All animals were subjected to postmortem examination, and 91 samples were examined by ovo- and larvoscopic methods.

The experimental part of the work used generally accepted parasitological methods (Darling, Fulleborn, complete helminthological autopsies (CHA) by K.I. Skryabin, Baermann's helmintholarvoskopy method).

RESULTS AND DISCUSSION

Cysticercus tenuicollis is the most widespread in the red deer population in the Trans-Baikal Territory; according to the obtained data, the rate of infestation (RI) is 86% (see the table). The main source of reindeer infestation is the wolf, the population of which has significantly increased in the last 5 years. In the studied 86 wolves *Taenia hydatigena* was found in 62 individuals, and the extensiveness of infestation was 72%. A certain role in the spread of thin-necked cysticercosis is played by lynx. Thus, according to our data, out of 28 lynx carcasses that underwent complete helminthological autopsy, eight individuals were infected with *Taenia hydatigena* (EI 28%), which is also confirmed by the studies of other authors [13, 14].

More than half of the examined red deer (57%) were affected by *Echinococcus granulosus larvae*. Echinococcus larvae were found in the lungs of animals in the form of a one-

Систематический состав эндопаразитов благородного оленя на территории Забайкальского края (n = 91)
Systematic composition of red deer endoparasites in the Trans-Baikal Territory (n = 91)

Type of parasite	Location	EI, the number of infested animals (%)
Protostrongyluskochi	Lung	23 (25,3)
Suborder *Strongylata* of the digestive tract	Intestine	15 (16,5)
Monieziabenedeni	Small intestine	3 (3,3)
Trichostrongylus spp.	Rennet stomach, large intestine	2 (2,2)
Dicrocoeliumlanceatum	Liver	1 (1,1)
Echinococcusgranulosus larva	Lung	52 (57,1)
Cysticercustenuicollis	Liver, mesentery gland	79 (86,8)
Eimeria spp.	Intestine	5 (5,5)

chamber bladder with many scolexes the size of a chicken egg; on average, one animal had 10-12 Echinococcus bladders. In our opinion, wolves and foxes are the source of Echinococcus infection in herbivores. Infection with *Echinococcus granulosus* in 98 studied wolves was 83%, or 81 individuals [15]. In the process of CHA of 10 foxes, *Echinococcus granulosus* was detected in the intestines of five animals (EI 50%). Affected animals differed markedly in fatness in a negative way from the animals free of Echinococcus larvae.

In the parasitological study of 91 red deer 23 individuals were infested with *Protostrongylus kochi* (RI 25,3%) (see the table). Seasonal dynamics of infestation of red deer with *Protostrongylus kochi* is characterized by a sharp increase of infestation in autumn months with its peak in winter and early spring periods. In spring and summer infestation of animals significantly decreases. High infestation of red deer by protostrongylids is explained by the presence of different types of waterlogged biotopes (marshes, waterlogged meadows, waterlogged forests), which are favorable habitats for intermediate hosts of the pathogen, namely land mollusks of *Eulota, Pupila, Succinea*.

Representatives of suborder *Strongylata* were found in the intestinal tract of 16.5% of the examined reindeer; in this group of helminthes, representatives of genus *Nematodirus* dominated in quantitative terms (84%).

During a complete helminthological autopsy, nematodirosis pathogens were found in the lumen of the small intestine, and their larvae in the form of parasitic nodules in the small intestine wall. The sexually mature nematodiruses began to appear in late August; their presence in the intestine was not observed in the second half of spring.

In addition to nematodiruses from the representatives of the suborder *Strongylata, Hemonchuscontortus* and *Chabertiaovina* were found in the rennet stomach and large intestine of two deer, 10 and 6% of the total number of the suborder *Strongylata*.

In 3% of the examined red deer, large ribbon helminthes were found in the small intestine with well-defined interproglottid glands in the center of the penis in the form of a stroke. Considering the morphological features, these helminths were identified as Moniezia benedeni. The low percentage of monieziosis infestation is explained by a low number of intermediate hosts of the helminth - soil mites, which require soils with high humus content.

Dicrocoelium lanceatum helminths, rarely found in the Trans-Baikal Territory, were found in the liver bile ducts of one animal. Extremely rare registration of dicrocoeliasis in the region in both farm and wild animals is explained by a low number of specific additional hosts - ants of certain genera.

In addition to the above helminths, oocysts of protozoan *Eimeria* spp. were found in the intestines of 5.5% of the examined red deer. The number of oocysts in one microscope field of view averaged 17-25, which indicates Eimeria carrier, but not immeriosis as a disease.

Based on the obtained data, the main principles of prevention of registered helminth infections were formulated. To prevent the spread among wild ungulates of echinococcosis, cysticercosis (larval cestodoses) it is necessary to strengthen the fight against wolves, foxes and stray dogs, as well as mandatory systematic deworming of dogs (quarterly) allowed on the territory of hunting farms. In order to prevent larval cestodoses, it is necessary to destroy the entrails of hunted animals and to prevent the use of such entrails as food for dogs in raw condition.

To prevent imaginal helminth infestations in ungulates, constant monitoring of helminths-carrying is necessary. Based on the results of these studies a plan of antihelmintic measures is drawn up. Oral antihelmintic preparations are used to deworm wild animals, which are put out at feeding sites in a mixture with loose feed (crushed grain).

CONCLUSIONS

1. Infestation of red deer in the Trans-Baikal Territory by eight species of different endoparasites is registered: *Protostrongylu skochi*, suborder *Strongylata* of the digestive tract, *Moniezia benedeni*, *Trichostrongylus* spp., *Dicrocoelium lanceatum*, *Echinococcus granulosus* larva, *Cysticercus tenuicollis*, *Eimeria* spp.

2. The most widespread and significant in socio-epizootological terms were *Cysticercus tenuicollis* (86.8% RI) and *Echinococcus granulosus* larva (57.1% RI), indicating the presence of natural foci on these helminths and their wide distribution.

3. In one of the examined red deer, a rare helminth species *Dicrocoelium lanceatum* in the Trans-Baikal Territory was found in the liver bile ducts. This fact indicates the presence of all conditions (presence of intermediate hosts) for infestation spreading, including agricultural animals.

4. To preserve the veterinary and sanitary well-being of the hunting industry in the Trans-Baikal Territory it is necessary to carry out a set of preventive veterinary and organizational measures that must include the regulation of wolf and fox population, scheduled preventive deworming of hunting dogs, the destruction of parenchymatous organs and intestinal raw materials from harvested animals, deworming of ungulates at biotechnical (feeding) sites.

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ЭКОЛОГИЧЕСКИ БЕЗОПАСНЫЙ ПРЕПАРАТ И ТРАДИЦИОННЫЙ ДЕЗИНФЕКТАНТ ПРИ ИНКУБАЦИИ ЯИЦ

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Представлены результаты исследований по разработке зоогигиенических мероприятий, направленных на повышение выводимости яиц путем применения экологически безопасных средств и изучения токсического влияния формальдегида на качество инкубационного яйца. Исследования актуальны вследствие негативных изменений в промышленном птицеводстве, происходивших за последние годы, которые сопровождались резким ухудшением качества инкубационных яиц, снижением вывода кондиционных цыплят и их значительной смертностью в период выращивания. Применение препарата «Монклавит-1» как антисептического и дезинфицирующего лекарственного средства широкого спектра действия и исследования токсичности формальдегида при обработке яиц представляет научный интерес для повышения инкубационных качеств яиц. В работе дана сравнительная оценка использования для дезинфекции инкубационных яиц формальдегида и экологически безопасного препарата «Монклавит-1». Полученные данные и их анализ свидетельствуют о том, что предынкубационная обработка препаратом «Монклавит-1» положительно повлияла на результаты инкубации. Яиц с наличием кровяного кольца в контрольной группе отмечено больше на 0,9% ($p < 0,05$), замерших – на 1,3% ($p < 0,05$), задохликов – на 2,0% ($p < 0,05$) в сравнении с опытной группой. Кроме того, показатели выводимости яйца и вывода цыплят при обработке препаратом «Монклавит-1» зарегистрированы выше, чем в контроле, на 3,1 и 4,4% ($p < 0,05$) соответственно. Рентабельность использования препарата «Монклавит-1» превышала показатель контрольной группы на 17,3%. Производственная санитария в агропромышленном комплексе является одним из решающих факторов, позволяющим сохранить и преумножить здоровье сельскохозяйственных животных и получать от них безопасную в биологическом и экологическом отношении продукцию для обеспечения продовольственных потребностей населения государства.

Ключевые слова: «Монклавит-1», формальдегид, инкубация, цыплята, кросс «Ross-308»

ENVIRONMENTALLY SAFE PREPARATION AND TRADITIONAL DISINFECTANT IN INCUBATION OF EGGS

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The paper presents the results of research on the development of zoohygienic measures aimed at improving the hatchability of eggs through the use of environmentally safe means and the study of the toxic effects of formaldehyde on the quality of hatching eggs. The research is relevant due to the negative changes in industrial poultry farming in recent years, which have been accompanied by a sharp deterioration in the quality of hatching eggs, a decrease in the hatching of conditioned chicks and their significant mortality during the rearing period. The use of the drug "Monclavit-1" as an antiseptic and disinfectant drug of broad spectrum and the study of formaldehyde toxicity in the treatment of hatching eggs is of scientific interest to improve the incubation quality of eggs. The work gives a comparative assessment of the use of formaldehyde for disinfection of hatching eggs and environmentally safe

preparation "Monclavit-1". The data obtained and their analysis indicate that preincubation treatment with Monclavit-1 had a positive effect on the results of incubation. Eggs with blood ring in the control group were 0.9% more ($p < 0.05$), dead-in-shell eggs were 1.3% more ($p < 0.05$), and addle eggs were 2.0% more ($p < 0.05$) than in the experimental group. In addition, the rates of egg hatchability and hatchability of chicks when treated with Monclavit-1 were higher than those of the control by 3.1 and 4.4% ($p <0.05$), respectively. Cost-effectiveness of the drug "Monclavit-1" use exceeded that of the control group by 17.3%. Production sanitation in the agro-industrial complex is one of the decisive factors in preserving and increasing the health of farm animals and obtaining biologically and environmentally safe products from them to meet the food needs of the population of the state.

Keywords: «Monclavit-1», formaldehyde, incubation, chickens, cross «Ross-308»

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INTRODUCTION

Reducing incubation losses and increasing hatchery efficiency is a major challenge for the poultry farmer. Incubation losses reduce hatchery efficiency and lead to overconsumption of expensive hatching eggs [1-4].

The introduction of intensive rearing methods based on the concentration of a large number of poultry in a limited area, the use of modern feeding technologies at the present stage of development in industrial poultry farming in Russia often create a threat to the stable welfare of farms for infectious and noncontagious diseases and obtaining final products of low quality [5-8].

Negative changes that have occurred in recent years in the commercial poultry production have been accompanied by a sharp deterioration in the quality of hatching eggs, a decrease in the hatching of conditioned chicks and their significant mortality at the stage of embryonic development and during rearing.

Microbial contamination of incubated eggs is an important problem for producers of poultry products, leading to a decrease in hatchability of eggs and quality of young animals. Among the various methods of egg disinfection, such as washing, irrigation, treatment with formaldehyde vapor is considered the most effective method. Eggs can be treated with formaldehyde during incubation or immediately after transfer to hatch, but most often it is done before incubation. It should be remembered that formaldehyde, while having antimicrobial properties, is at the same time a strong toxic substance that can destroy a sleeping embryo. Thus, effective formaldehyde fumigation is a balance between its bactericidal effect on the shell microbial infestation and its toxic effect on the developing embryo [9-12]. Environmentally safe methods of treating hatching eggs reduce the risk of clutch infection without reducing hatchability [13-15].

A new less toxic and environmentally safe disinfectant "Monclavit-1" of domestic production is presented to adequately replace traditional disinfectants (formaldehyde, etc.). "Monclavit-1" exhibits sharply expressed bactericidal, fungicidal and antiviral properties, has anti-inflammatory and regenerating effect. It has high activity against gram-negative and gram-positive microorganisms, pathogenic fungi and yeasts. An important feature of the polymer that makes up "Monclavit-1" is its high adsorption capacity and tendency to complexation. It actively binds many substances, including toxins.

The purpose of the research is to study the effect of the preparation "Monclavit-1" on the incubation quality of eggs in the conditions of the Tomsk region.

The objectives are to determine the indicators of hatchability, hatchability of day-old chicks when using the drug "Monclavit-1" and to give an economic rationale for the results of the research.

MATERIAL AND METHODS

The research material was hatching eggs of Ross-308 parent flock cross, Monclavit-1 preparation and formaldehyde. The drug "Monclavit-1" in appearance is a transparent brown liquid, foaming when shaken. As an active ingredient it contains 0.12 g of crystal iodine, 0.36 g of potassium iodide, as excipients - polyvinyl-N-amidacyclosulfoiodide (3.0 g), sodium dodecyl sulfate (0.06 g) and distilled water to 100 ml.

For the study, a batch of hatching eggs in the amount of 114,000 eggs was selected and divided for treatment by 57,000 eggs in the incubation setter № 1 and № 2 (control and experimental). The difference was that the incubation eggs of hatchery setter #1 were treated with formaldehyde vapor in a disinfecting chamber, while those of setter #2 were treated with Monclavit-1 by aerosol irrigation of the shell surface. In addition, treatment of the inner surface of the incubation chamber was carried out. The drug consumption of Monclavit-1 was 200-250 ml per incubation cabinet. Repeated disinfection of the eggs of the experimental group was carried out on the 11th day of incubation by aerosol spraying through the ventilation hole of the incubation cabinet using a sprayer.

To control the quality of incubation eggs biological control was carried out before incubation: eggs were evaluated by appearance, the size and shape of eggs, the condition of the shell, the size and position of the air chamber, the presence of cracks (incision, breakage) in the shell, various kinds of inclusions in eggs, the position and mobility of the yolk, the condition of gradules were taken into account during examination with an ovoscope.

Biological control during incubation was carried out by ovoscopy of eggs on days 6, 10, and 18 of incubation:

– on the 6th day of egg incubation counting and culling unfertilized eggs, identifying eggs with dead embryos with "blood ring" defect, establishing the approximate time of death, opening eggs with dead embryos were carried out;

– on day 10 - determination of allantois closure (embryo development);

– on day 18 - fetal positioning.

All eggs with dead embryos were counted and classified as "dead". Eggs that died after the third examination in the hatching period were classified as "dead in shell". Bacteriological examination of dead egg embryos was carried out in the Regional Veterinary Laboratory. The studies were conducted under the same incubation conditions. The experimental data were statistically processed according to the method of N.A. Plokhinsky (1970) on a personal computer using Microsoft Office Excel. Scientific studies were carried out according to the scheme (see Table 1).

Табл. 1. Схема проведения исследований
Table 1. Research design

Group	Number, heads	Preparation for preincubation treatment of eggs
Control	57 000	Formaldehyde vapor (20-minute formaldehyde vapor treatment at a concentration of 600 mg formaldehyde per 1 m^3 of incubation chamber)
Experiment	57 000	The preparation "Monclavit-1" (aerosol irrigation of the shell surface and incubation chamber for 10 minutes, the drug consumption of 250 ml per incubation chamber)

RESULTS AND DISCUSSION

The incubation waste autopsy and analysis are of great importance for assessing the quality of eggs used and the incubation regime. The autopsy of incubation waste is carried out selectively on the control trays of the particular batch of eggs being evaluated. When opening eggs with dead embryos, first of all, the category of dead embryos and the approximate age of death are determined. Usually, all dead embryos are conditionally divided into three categories: "blood ring", "late dead" and "dead in shell". Embryonic mortality is known to be particularly high during periods called "critical". These are usually the 3rd-5th, 9th-11th and 19th-20th days of incubation. The first examination of eggs revealed unfertilized eggs and eggs with embryos that died in the first days of incubation with blood rings, etc.

Analysis of the results of incubation shows that the number of unfertilized eggs in both groups was almost the same, ranging from 3.1-3.3%, which is due to the high reproductive ability of birds of the parent flock.

Preincubation treatment with Monclavit-1 had a positive effect on the incubation results. It was found that the number of eggs with blood ring was 0,9% higher ($p < 0,05$), the number of late dead eggs was 1,3% higher ($p < 0,05$), and the number of dead in shell eggs was 2,0% higher ($p < 0,05$) compared to the experimental group (see Table 2).

As a result of the study it was found that the hatchability and hatchability of the treatment with the preparation "Monclavit-1" in comparison with disinfection by formaldehyde vapor were higher by 3,1 and 4,4% ($p < 0,05$), respectively (see Table 3).

Bacteriological examination in the control group identified: *Citrobacter freundii* + *Enterococcus faecalis* + *Staphylococcus faecium* +*Enterococcus agglomerans* + *Enterococcus faecium* + *Enterobacter agglomerans*+ *Escherichia coli*.

In the experimental group only one association of *Staphylococcus aureus* + *Streptococcus faecium* was identified. The number of E. coli group bacteria (E. coli) was found 5 times less and staphylococci 3.5 times less in the biomaterial of the experimental group than in the control. There is a negative effect of formaldehyde, which consists in the fact that it, being a toxic gas, can cause the death of the egg embryo already in the 1st day of incubation (see Table 4).

The use of the preparation Monclavit-1 for the treatment of hatching eggs contributed to the reduction of the cost of one day-old chick by 2 rubles in comparison with this indicator

Табл. 2. Влияние различных способов дезинфекции яйца на сохранность инкубационного яйца
Table 2. Effect of various methods of egg disinfection on the safety of hatching eggs

Group	Laid for incubation, pcs.	Unfertilized eggs		Blood ring		Dead-in-shell		Addle eggs	
		%	pcs.	%	pcs.	%	pcs.	%	pcs.
Control	450 ± 6	3,3 ± 0,2	15 ± 0,8	2,2 ± 0,2	10 ± 0,7	2,0 ± 0,2	9 ± 0,6	2,4 ± 0,2	11 ± 0,8
Experiment	450 ± 6	3,1 ± 0,1	14 ± 0,7	1,3 ± 0,2	6 ± 0,3	0,7 ± 8	3 ± 0,5	0,4 ± 0,1	2 ± 0,5

Note. Here and in Table 3.: $p \leq 0,05$

Табл. 3. Показатели выводимости яиц и вывода молодняка
Table 3. Indicators of hatchability of eggs and young animals

Group	Laid for incubation, pcs.	Breeding youngsters		Egg hatchability	
		pcs.	%	pcs.	%
Control	450	400	88,9	5	90,0
Experiment	450	414	92,0	11	94,4

Табл. 4. Микробная обсемененность эмбриона куриного яйца в 1-е сутки инкубации, %

Table 4. Microbial contamination of a chicken egg embryo on the first day of incubation, %

Sanitary-indicatory microorganisms	Incubation period, days	Group	
		control	experiment
Staphylococci	1	70	20
Coliform bacteria	1	50	10

Табл. 5. Себестоимость получения одного суточного цыпленка, р.

Table 5. Production cost of one-day-old chick, r

Cost item	Sum of expenses	
	Control group	Experiment group
Hatching egg	24	24
Payroll fund	0,000042	0,000042
Expenditures for water supply	7,96	7,96
Energy resources	1,071	1,071
Depreciation of cabinets (hatchery and incubation cabinets)	3,57	3,57
Miscellaneous expenditures	8,4	6,4
Total:	45	43

Табл. 6. Экономическая эффективность использования препарата «Монклавит-1» для обработки инкубационных яиц

Table 6. Economic efficiency of using the drug «Monclavit» for the processing of hatching eggs

Indicator	Group	
	control	experiment
Number of conditioned chickens, heads	400	414
Cost price per chicken, rubles	45,0	43
Total cost, rubles	18 000	17 139
Selling price of one chicken, rubles	90,0	90,0
Total disposal value, rubles	36 000	37 260
Profit, rubles	18 000	20 121
Product profitability level, %	100,0	117,3

with disinfection by formaldehyde vapor (see Table 5).

The profit from the use of the preparation "Monclavit-1" was higher by 2121 rubles. (see Table 6), which contributed to an increase in the profitability of the treatment of hatching eggs with the preparation "Monclavit-1" by 17.3% compared with the disinfection with formaldehyde vapor (see Table 5).

CONCLUSIONS

1. Hatching eggs with blood ring in disinfection with formaldehyde vapors were 0,9% ($p < 0,05$), late dead eggs - 1,3% ($p < 0,05$), dead in shell eggs - 2,0% ($p < 0,05$) more than those after treatment with Monclavit-1, respectively.

2. Hatchability and hatchability of the treatment with Monclavit-1 compared to formaldehyde disinfection were higher by 3.1 and 4.4%, respectively.

3. The use of the preparation "Monclavit-1" for the treatment of hatching eggs helped to reduce the cost of one day-old chick by 2 rubles compared to this indicator for the disinfection with formaldehyde vapor.

4. The number of coliform bacteria detected in the biomaterial in the experimental group was 5 times lower and staphylococci 3.5 times lower than in the control group.

5. The profit from the use of the drug "Monclavit-1" was higher by 2121 rubles, which increased the profitability level of the treatment of hatching eggs with the drug "Monclavit-1" by 17.3% compared with the disinfection with formaldehyde vapor.

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ОЦЕНКА И ВЫБОР МАШИННО-ТРАКТОРНЫХ АГРЕГАТОВ ПРИ КУЛЬТИВАЦИИ ПО ЭНЕРГЕТИЧЕСКИМ ЗАТРАТАМ

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Представлены материалы по оценке и выбору машинно-тракторных агрегатов по критериям минимизации затрат на их производство и эксплуатацию (суммарная удельная энергоемкость МТА на его производство и эксплуатацию) и максимальной производительности при выполнении технологического процесса культивации почвы. Установлено, что номенклатура технологических машин для проведения технологического процесса культивация при мощности мобильных энергетических средств до 110 л.с. определяется культиваторами типа КПС-4, КБМ-4,2 с использованием тракторов JD5620, AGCO MF3640, ЮМЗ-6, ЛТЗ 95Б, JD6020, МТЗ-80/82, МТЗ-920, Беларус-900, Беларус-921, Беларус-923, Deutz Agrofarm 430 и МТЗ-1025. Они имеют суммарные удельные энергоемкости использования с обозначенными технологическими машинами на минимальном уровне, производительность – на максимальном. В диапазоне мощностей тракторов от 110 до 145 л.с. целесообразно использовать культиваторы КШУ-5, КШУ-6, КПС-8П с мобильными энергетическими средствами New Holland T6050 Delta, CASE IH Maxxum 125, JD 6130D, JD 6135, МТЗ-1221, Беларус 1220, ЛТЗ-155 и МТЗ-1222, имеющими также максимальную производительность при минимальном уровне суммарных удельных энергоемкостей на их производство и эксплуатацию. Выявлено, что при применении культиваторов типа КШУ-12, КБМ-7,2П, КБМ-10,8П, Лидер-6Н, АПК-7,2, RTS-1831, КПО-7,2, KORUND 8/900 (мощность энергетического средства до 150–210 л.с.) по обозначенным критериям эффективности целесообразно использовать тракторы Т-150К, МТЗ-1523, ХТЗ-121, ХТА 200-10, Беларусь 1525, ХТЗ 17221, Terrion ATM 3180, Deutz Fahr Agrotron 165.7, JD 7030, ATM 4200 Terrion, МТЗ-2022. Установлено, что для использования культиваторов Лидер-7,2Н, Лидер-8 по обозначенным критериям минимизации затрат энергии и максимальной производительности требуются тракторы мощностью до 210–240 л.с. JD 7830, JD 7930, New Holland 7060, Deutz Fahr Agrotron L720 DCR, Claas Axion 850.

Ключевые слова: технологические процессы, машинно-тракторные агрегаты, формирование, удельная энергоемкость

EVALUATION AND SELECTION OF MACHINE-TRACTOR UNITS DURING CULTIVATION BY ENERGY COSTS

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The materials on evaluation and selection of machine-tractor units by the criteria of minimization of their production and operation costs (total specific energy intensity of MTU for its production and operation) and maximum productivity in carrying out the technological process of soil cultivation are presented. It has been established that the range of technological machines for carrying out the

technological process "cultivation" with the power of mobile power plants up to 110 hp is determined by cultivators such as KPS-4, KBM-4.2 type using tractors JD5620, AGCO MF3640, UMZ-6, LTZ 95B, JD6020, MTZ-80/82, MTZ-920, Belarus 900, Belarus-921, Belarus-923, Deutz Agrofarm 430 and MTZ-1025. They have the total specific energy intensity of use with the designated technological machines at the minimum level, and the productivity at the maximum. In the power range of tractors from 110 to 145 hp it is advisable to use cultivators KSHU-5, KSHU-6, KPS-8P with mobile power tools New Holland T6050 Delta, CASE IH Maxxum 125, JD 6130D, JD 6135, MTZ-1221, Belarus 1220, LTZ-155 and MTZ-1222, which also have the maximum productivity at the minimum level of the total specific energy consumption for their production and operation. It has been found that when using cultivators of the type KSHU-12, KBM-7.2P, KBM-10.8P, Leader-6N, APC-7,2, RTS-1831, KPO-7.2, KORUND 8/900 (power of the energy means up to 150-210 hp), according to the indicated efficiency criteria, it is advisable to use tractors T–150K, MTZ-1523, HTZ-121, HTA 200-10, Belarus 1525, HTZ 17221, Terrion ATM 3180, Deutz Fahr Agrotron 165.7, JD 7030, ATM 4200 Terrion, MTZ-2022. It has been established that for the use of cultivators Leader-7.2N, Leader-8, according to the indicated criteria for minimizing energy consumption and maximum productivity, tractors with a power of up to 210-240 hp like JD 7830, JD 7930, New Holland 7060, Deutz Fahr Agrotron L720 DCR, Claas Axion 850 are required.

Keywords: technological processes, machine-tractor units, formation, specific energy intensity

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INTRODUCTION

One of the main issues faced by agricultural producers in the implementation of technological processes in crop cultivation technologies is the formation of a rational composition of machine-tractor units (MTU). At the present time the market of agricultural machinery offers a wide choice of mobile power units and technological machines, equipped with the necessary devices for operation, control and management of tillage processes, sowing of seeds of agricultural crops, application of various forms of mineral fertilizers, etc. However, this causes a significant increase in the cost of purchased machinery and the corresponding financial costs in its operation. In addition, the choice of a rational composition of MTU is complicated by a large volume of calculations in the formation of technological maps for the cultivation of crops in determining the direct operating costs due to the increased nomenclature of technical support of technological processes.

In this regard, at the initial stage it is advisable to form machine-tractor units according to the criteria of minimizing the cost of their production and operation (total specific energy intensity of MTU for its production and operation) and maximum productivity in performing the corresponding technological processes [1-10].

The research of the leading scientists of Siberia in the implementation of technological

processes of tillage, application of liquid forms of mineral fertilizers, sowing of grain crops in the conditions of the Siberian region is aimed at solving the issues of reducing energy consumption in the production of agricultural products [11-15].

When considering the issues of energy saving in technological modules of crops cultivation, it is necessary to take into account the fact that technological processes of the same functional orientation must be performed in full and in the required time interval. This kind of dual goal requires a logical solution, taking into account the assessment of the significance of factors affecting the choice of machine-tractor aggregates.

The purpose of the work is to choose a rational composition of machine-tractor units on energy indicators in the implementation of the technological process of cultivation.

The research objective is to evaluate the effectiveness of the technological aggregates according to the criterion of minimization of total specific energy inputs during the technological process of cultivation.

MATERIAL AND METHODS

The method for determining the anthropogenic energy of production and operation of mobile energy vehicles and technological machines is described by known dependencies in accordance with recommendations [1-7] [16]. In this case we are talking about assessing the efficiency of using machine-tractor aggregates by two quality indicators: the minimum cost of their production and operation (total specific energy intensity of MTU for its production and operation) and the maximum productivity when performing the corresponding technological processes. It is advisable to solve the presented two-criteria task as follows:

– determination of anthropogenic energy of production and operation of mobile energy vehicles and technological machines;

– determination of energy consumption of the operating personnel;

– determination of specific (per 1 hour of work) energy intensity of tractors, technological machines and couplings in the performance of the corresponding technological process.

Anthropogenic energy of production and operation of mobile energy facilities and technological machines is determined by the formula

$$E^{j}_{A} = E^{j}_{dr} = (E^{j}_{dl} + E^{j}_{m} + E^{j}_{c} + E^{j}_{t}) / W^{j}_{ops}, \quad (1)$$

where E^{j}_{A} – energy costs in the implementation and selection of a particular (j-ro) technological process; E^{j}_{dr} - specific direct energy consumption for the implementation of j-ro PPM, MJ/ha; E^{j}_{dl} - energy inputs of live labor during implementation of the j-th CHP, MJ/h; Ej m + E^{j}_{c} + E^{j}_{t} - energy intensity of technological machines, couplings, tractors respectively per 1 hour of shift time, MJ/h; W^{j}_{ops} - output per shift of MTA in the j-th CHP, ha/h.

Energy costs of the operating personnel

$$E^{j}_{j} = \frac{n^{\cdot}_{nj} \times A^{\cdot}_{j} + n^{\cdot\cdot}_{nj} \times A^{\cdot\cdot}_{j}}{W^{j}_{ops}},$$

where $n^{\cdot}_{nj}$, $n^{\cdot\cdot}_{nj}$ – he number of main workers (tractor drivers, combine operators, drivers) and indirect labor (sowers, tractor drivers, loaders), respectively; $A^{\cdot}_{j}, A^{\cdot}_{j}$– energy equivalents of

[1]Milaev P.P. System biogeoenergetic analysis of the agricultural production processes: Methodological recommendations. Novosibirsk, 2005. 80 p.

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labor costs of the main and indirect labor, MJ/person/h.

The following energy equivalents for labor, MJ/person/h were accepted: tractor drivers, combine operators, drivers - 60.8; indirect labor - 33.3 (see footnote 4).

The specific energy intensity of tractors, technological machines and couplings is calculated by the following formulas (3) – (4):Удельную энергоемкость тракторов, технологических машин и сцепок определяем по формулам (3) – (4):

$$E_t = \frac{M_t \cdot A_t}{100}\left[\frac{a_t}{T_{nt}} + \frac{a_{кт} + a_{тт}}{T_{zt}}\right]; \quad (3)$$

$$E_m = \frac{M_m \cdot A_m}{100}\left[\frac{a_m}{T_{nm}} + \frac{a_{mt}}{T_{zm}}\right], \quad (4)$$

where E_t, E_m are the specific energy intensity of tractors and technological machines accordingly per 1 hour of work, MJ/h; A_t, A_m - norm of deductions for renovation of tractors and technological machines accordingly, %; Mrt - norm of deductions for renovation of tractors, %; att, atm - norms of deductions respectively for current repair, maintenance and storage of tractors and technological machines, %; Tnt,Tnm - normative annual load of tractors and technological machines respectively, h; T_{zt}, T_{zm} - zonal annual load of tractors and technological machines respectively, h.

The energy equivalent of 1 kg of physical weight of tractors and cars is taken at the level of 142.2 MJ, that of agricultural machinery - 116.1, the norms of the annual load, deductions for renovation, overhaul and current repairs, maintenance and storage of agricultural machinery are taken from the recommendations (see footnotes 4, 6).

RESULTS AND DISCUSSION

The assortment of technological machines for carrying out the technological process of cultivation is presented quite capacious. In each drawbar category of mobile energy equipment, the main type of use of these machines is defined with the presentation of the total specific energy intensity of both technological machines and mobile energy equipment of the corresponding class and the productivity of an aggregate as an integral part of the evaluation of its use efficiency.

When using mobile power tools up to 110 hp the following main technological machines are used: cultivators KPS-4, KBM-2,1 and KBM-4,2 (see Fig. 1).

Analysis of the material shows that with almost the same productivity (4,0-4,3 ha/h), cultivators KPS-4 and KBM-4,2 have at least a twofold advantage over the KBM-2,1 cultivator. In addition, the total specific energy intensity of the use of technological machines and mobile power equipment is in a similar ratio. In this connection two kinds of technological machines with the following mobile power equipment are offered for realization: JD5620, AGCO MF3640, UMZ-6, LTZ 95B, JD6020, MTZ-80/82, MTZ-920, Belarus-921, Belarus-923, Deutz Agrofarm 430 and MTZ-1025, having the total specific power consumption of the mentioned technological machines use at the minimum level, productivity - at the maximum.

When using mobile power equipment with the power of 110-145 hp it is advisable to use the following technological machines which form the basis in the presented class of tractors: cultivators Stepnyak-4,2, KSHU-5, KSHU-6 and KPS-8P.

It should be noted that Stepnyak-4,2 coupled with mobile energy equipment has a high (almost 2 times) total specific power capacity compared to the cultivators of this class (see Fig. 2). Besides, its productivity is 1,8-2,0 times lower than that of the indicated cultivators. In this connection for practical realization we take cultivators KSHU-5, KSHU-6 and KPS-8P in

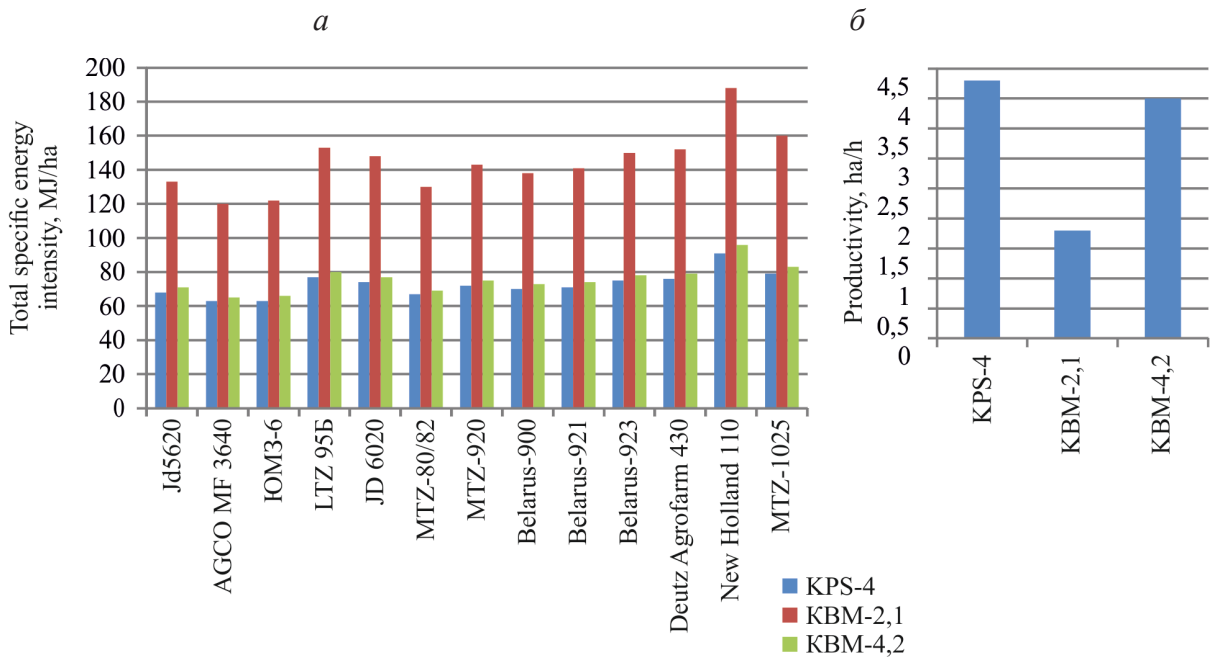

Рис. 1. Суммарная удельная энергоемкость использования технологических машин (*а*) и производительность при культивации (*б*) (мощность трактора до 110 л.с.)

Fig. 1. Total specific energy intensity of using technological machines (*a*) and productivity during cultivation (*б*) (tractor power up to 110 hp)

the aggregate with New Holland T6050 Delta, CASE IH Maxxum 125, JD 6130D, JD 6135, MTZ-1221, Belarus-1220, LTZ-155 and MTZ-1222 mobile power vehicles. It is inexpedient to use RTM-160 tractor with this class of technological machines because of high total specific power consumption.

For mobile power equipment with the power of 150-210 hp there is a wide range of technological machines (cultivators): KBM-6, KBM-7,2P, KBM-10,8P, Leader-4, Leader-6N, APK-7,2, RTS-1831, Stepnyak-5,6, KPO-7,2, KSHU-12, KORUND 8/900, KPE-3,8. This list can be continued (see Fig. 3).

Initial assessment of the appropriateness of using technological machines according to the minimum total specific energy intensity revealed that the lowest value of it has the cultivator KSHU-12 (61-69 MJ/ha). Then follow KBM-6 and KBM-7,2P cultivators according to this indicator (86-106 and 88-104 MJ/ha respectively).

There is no denying the possibility of operating other technological machines in the technological process of cultivation (it is more related to the sustainability of economic development of agricultural producers), but we recommend a scientifically sound rational approach to the choice of mobile power tools and related technological machines by the criterion of the lowest total specific energy intensity of their use.

For the final evaluation and selection of a promising variant of the unit with the designated criterion, it is advisable to further evaluate their use by the productivity of the compiled units (ha/h) (see Fig. 4).

For the practical implementation according to the mentioned criteria of minimization of energy consumption and maximum productivity of the unit created on this base it is reasonable to use KSHU-12 cultivator in combination with mobile energy vehicles T-150K, MTZ-1523, HTZ-121, HTA 200-10, Belarus 1525, HTZ 17221, Ter-

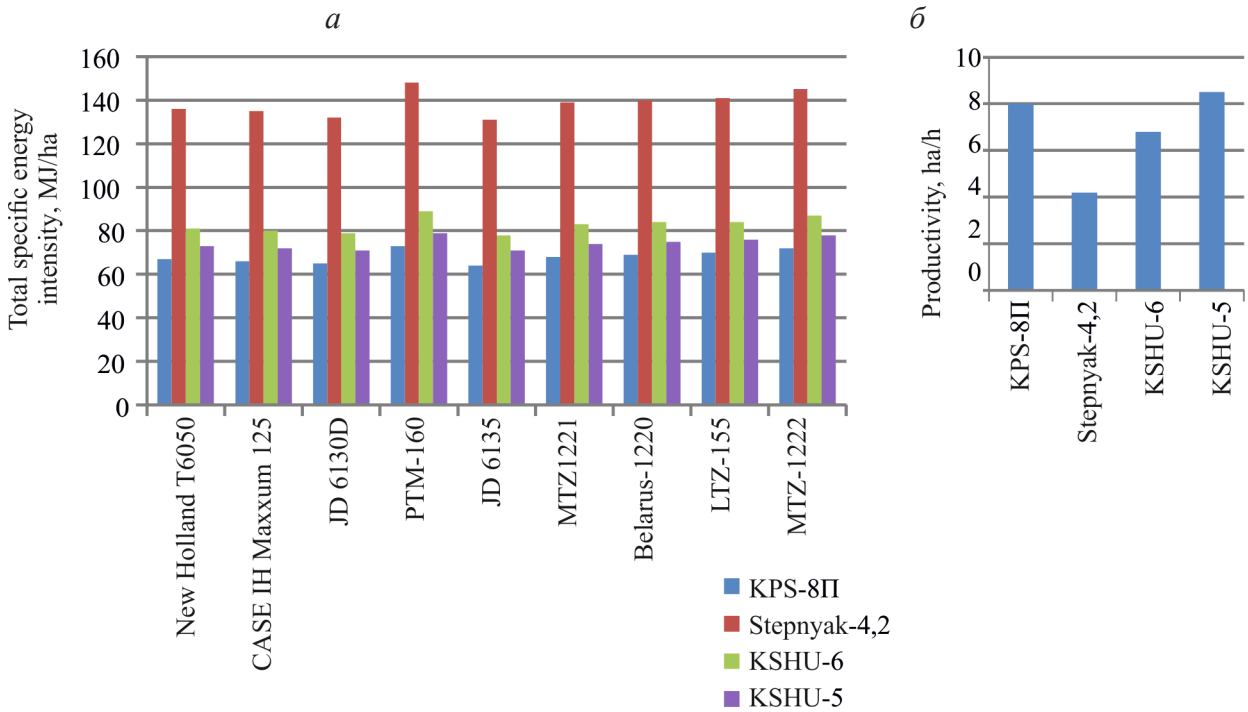

Рис. 2. Суммарная удельная энергоемкость использования технологических машин (*а*) и производительность при культивации (*б*) (мощность трактора 110–145 л.с.)

Fig. 2. Total specific energy intensity of using technological machines (*a*) and productivity during cultivation (*б*) (tractor power 110-145 hp)

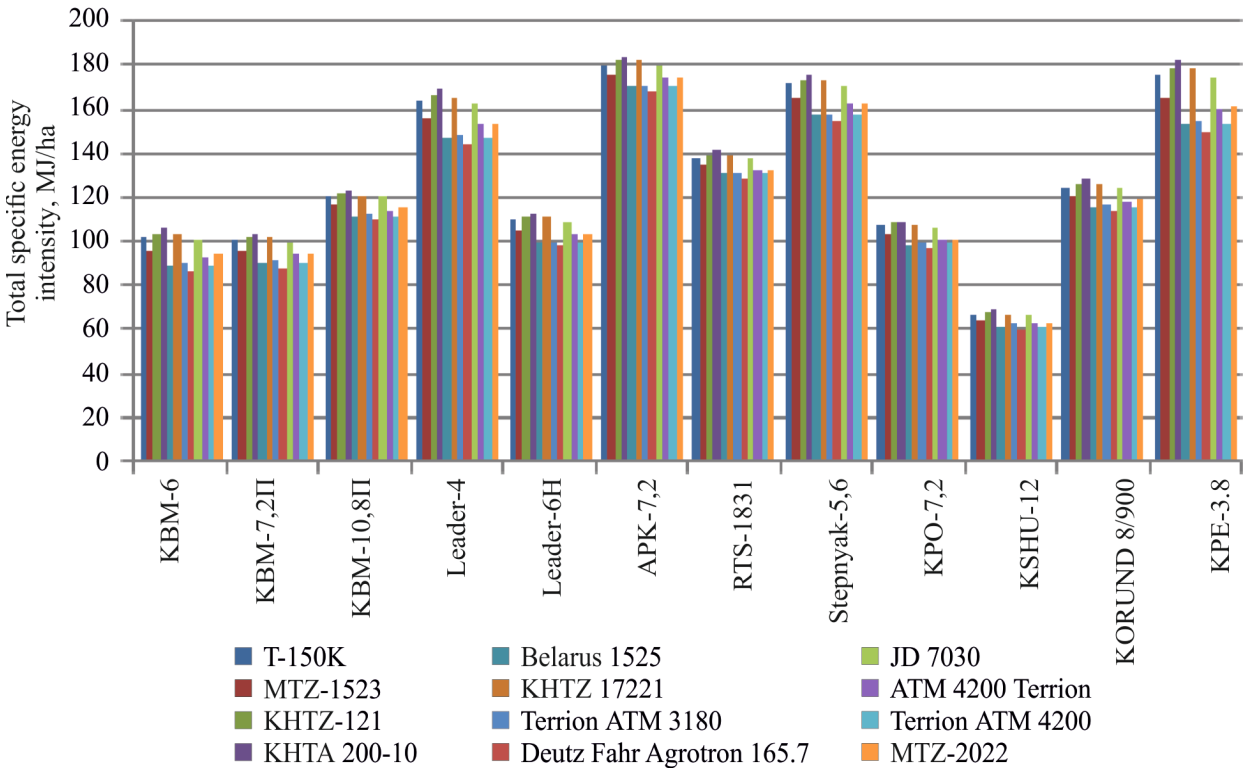

Рис. 3. Суммарная удельная энергоемкость использования технологических машин при культивации (мощность трактора 150–210 л.с.)

Fig. 3. Total specific energy intensity of using technological machines during cultivation (tractor power 150-210 hp)

rion ATM 3180, Deutz Fahr Agrotron 165.7, JD 7030, ATM 4200 Terrion, MTZ-2022.

A separate position is occupied by a number of cultivators with acceptable in this area performance: KBM-7,2P, KBM-10,8P, Leader-6N, APK-7,2, RTS-1831, KPO-7,2, KORUND 8/900 (88-104, 110-123, 98-113, 171-184, 129-141, 171-182, 114-128 MJ/ha) while operating the same mobile power equipment.

Increasing the power of mobile power tools up to 210-240 hp ensures the operation of wide-cut cultivators of Leader-7,2H, Leader-8 and Prostor-5,4 types. The unambiguous leader by the minimum of the total specific energy intensity of the use of technological machines is the cultivator Leader-7,2H (111-119 MJ/ha) (see Fig. 5).

According to this evaluation criterion, the values are quite close when using Lider-8 and Prostor-5,4 cultivators (147-156 MJ/ha), which exceed the total specific energy intensity when using Lider-7,2H cultivator.

Evaluating the effectiveness of these technological machines by the second criterion - productivity - it should be noted that the productivity of cultivators Leader-7,2H, Leader-8 is 1,7 and 1,8 times higher than that of the cultivator Prostor-5,4.

Taking into account the above material, we recommend for practical implementation in this class of mobile power tools JD 7830, JD 7930, New Holland 7060, Deutz Fahr Agrotron L720 DCR, Claas Axion 850, cultivators Leader-7,2H and Leader-8.

Further increase of the power of mobile power tools (up to 240-280 hp) enables to operate wide-cut cultivators such as KBM-14,4P, KD-720ML, Stepnyak-7,4, Stepnyak-10 and KPSH-9.

In terms of minimum energy consumption in the operation of the presented technological machines, the most representative is the cultivator KPSH-9 (96-108 MJ/ha) (see Fig. 6).

All the above-mentioned cultivators have energy intensity of their use exceeding the values of 145 MJ/ha and more. It is important to note that by productivity KPSH-9 is almost equal to KBM-14,4P and Stepnyak-10 cultivators (see Fig. 7).

Evaluating the stated material by the criteria of total specific power consumption of technological machinery and productivity in their operation, it is advisable to use KPSH-9 cultivator in the unit with mobile energy equipment MTZ-2522, K-700A Slavich, K-701 Slavich, MTZ-2822 and Terrion ATM 5280.

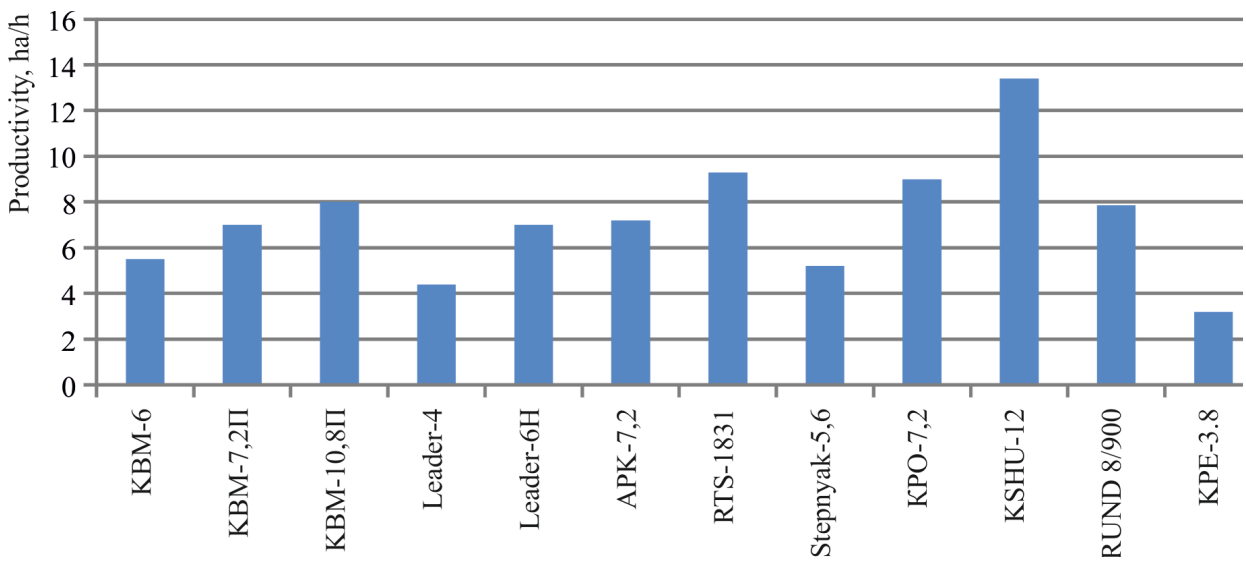

Рис. 4. Производительность технологической машины при культивации (мощность трактора – 150–210 л.с.)

Fig. 4. Process machine productivity during cultivation (tractor power - 150-210 hp)

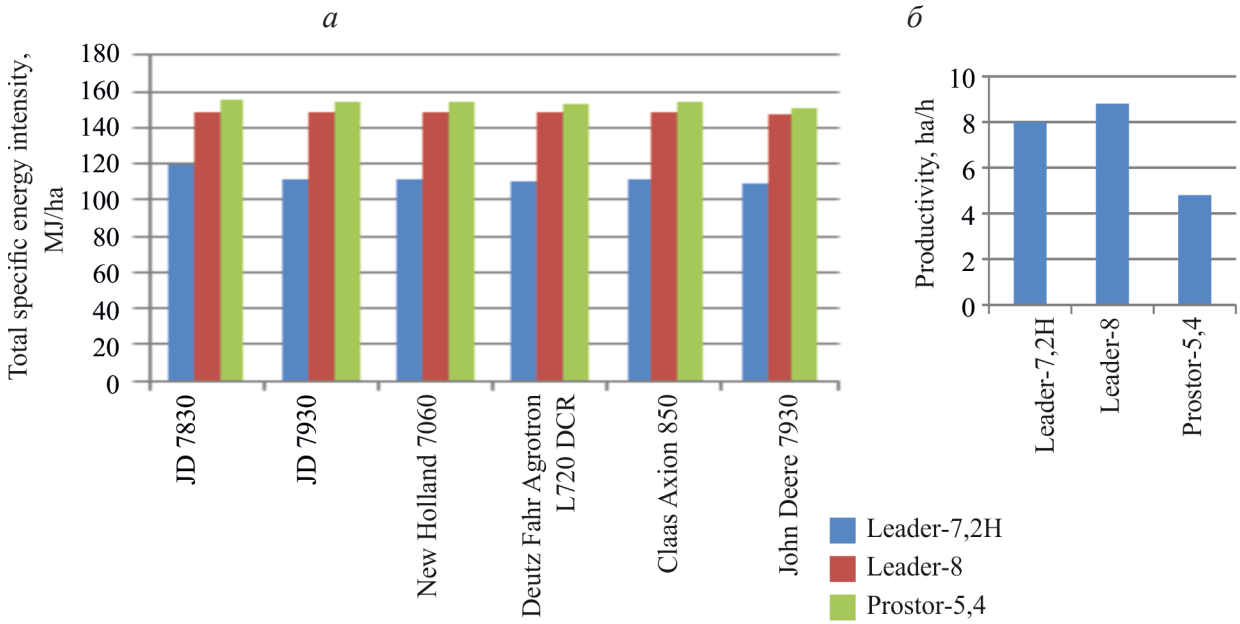

Рис. 5. Суммарная удельная энергоемкость использования энергетических средств при культивации (*а*) при производительности технологического средства (*б*) (мощность трактора 210–240 л.с.)

Fig. 5. Total specific energy intensity of using technological machines during cultivation (*a*) at their productivity (*б*) (tractor power 210-240 hp)

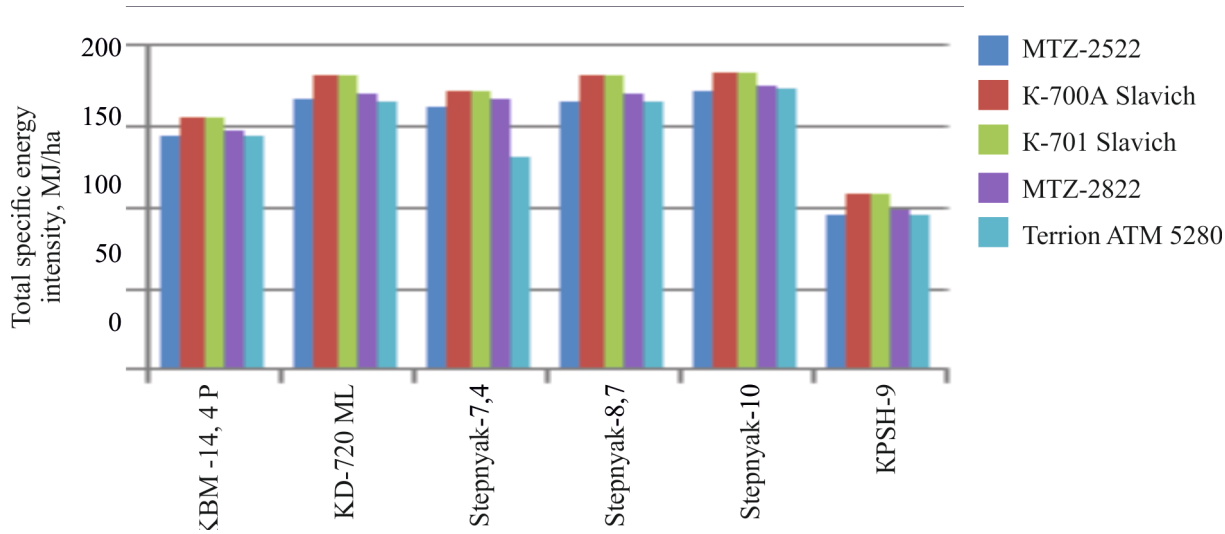

Рис. 6. Суммарная удельная энергоемкость использования технологических машин при культивации (мощность трактора 240–280 л.с.)

Fig. 6. Total specific energy intensity of using technological machines during cultivation (tractor power 240-280 hp)

CONCLUSIONS

1. At the initial stage of formation of machine-tractor units it is advisable to evaluate the effectiveness of their acquisition by the criteria of minimizing the cost of their production and operation (the total specific energy intensity of MTU for its production and operation) and the maximum productivity when performing the corresponding technological process.

2. The use of the proposed methodological approach to the evaluation and selection of the rational composition of a machine-tractor aggregate provides a 20-25% reduction in material costs for the purchase of technical support

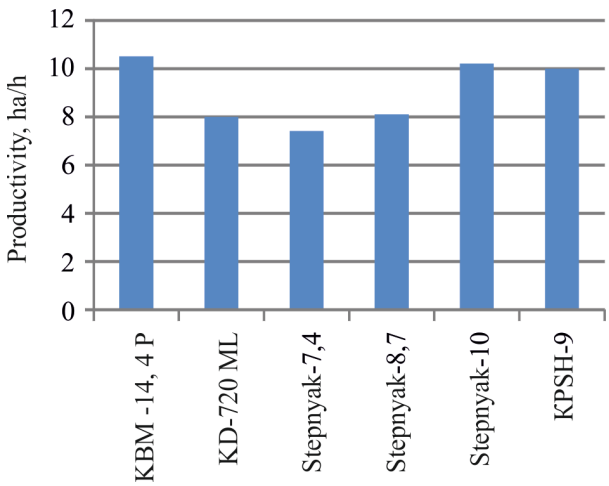

Рис. 7. Производительность технологической машины при культивации (мощность трактора 240–280 л.с.)

Fig. 7. Productivity of technological machines during cultivation (tractor power – 240–280 hp)

of technological processes in the technologies of cultivation of crops.

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К ВОПРОСУ ОПРЕДЕЛЕНИЯ МОЩНОСТИ ВИБРОВОЗБУДИТЕЛЯ

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В настоящий момент вибровозбудители, отличающиеся разным исполнением, широко применяют для осуществления всевозможных технологических операций. Использование вибрации позволяет снизить трудоемкость и уменьшить себестоимость производственных затрат. В данном исследовании представлены результаты изучения механизма возбуждения вибрационных колебаний, из которого очевидно, что на величину мощности вибровозбудителя влияют размеры корпуса, бегуна и принятый эксцентриситет. Приведены результаты по величине корпуса, эксцентриситета и величины неуравновешенной массы – бегуна, – перемещающегося по внутренней поверхности цилиндрического корпуса и возбуждающего при перемещении вибрационные колебания. Определена максимальная мощность вибровозбудителя, зависимая от того, будет ли бегун прижиматься центробежной силой к цилиндрической внешней поверхности вибровозбудителя на протяжении всей длины поверхности. Если бегун центробежной силой не сможет быть прижат к цилиндрической поверхности виборовозбудителя, то на рабочих скоростях вала отбора мощности (750 и 1000 об./мин) будут участки поверхности, по которым бегун будет прижат к поверхности и оказывать вибрационные колебания. На остальной поверхности бегун станет скользить мимо цилиндрической поверхности, вызывая стук, и не будет возбуждать вибрационные колебания. Определены участки поверхности, где бегун не будет возбуждать вибрационных колебаний. Стук относится к вибрационным колебаниям бегуна. Он возникает у бегуна, не набравшего максимальной скорости и поэтому не прижатого к корпусу цилиндрической формы. Передача энергии вибрации на корпус вибровозбудителя происходит от энергии бегуна. Бегун, касаясь корпуса, испытывает воздействие инерционных сил на корпус и возбуждает внешние силы, передающие энергию вибрации на вибровозбудитель.

Ключевые слова: глубокорыхлитель, вибровозбудитель, вибрация, амплитуда, рабочие скорости, вал отбора мощности

ON THE QUESTION OF DETERMINING THE VIBRATION EXCITER POWER

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At the moment, vibration exciters of different designs are widely used for all kinds of technological operations. The use of vibration makes it possible to reduce labor intensity and the cost price of manufacturing costs. This paper presents the results of a study of the mechanism of excitation of vibrational motion, from which it is obvious that the size of the body, the runner and the adopted eccentricity affect the value of the power of the vibration exciter. The results on the size of the body, the eccentricity and the value of the unbalanced mass - a runner - moving on the inner surface of the cylindrical body and exciting vibration oscillations during movement are presented. The maximum power of the vibration exciter, depending on whether the runner will be pressed by centrifugal force to the cylindrical outer surface of the vibration exciter over the entire length of the surface, is determined. If the runner cannot be pressed to the cylindrical surface of the vibrator by centrifugal force, then at the working speeds of the PTO (750 and 1000 rpm) there will be areas of the surface where the runner will be pressed against the surface and exert vibratory oscillations. On the remaining surface, the runner will slip past the cylindrical surface, causing a knock, and will not excite vibratory oscillations. The surface areas where the runner will not excite vibratory oscillations were determined. The knock refers to the vibratory oscillations of the runner. The knocking occurs

in a runner who has not gained maximum speed and therefore is not pressed against a cylindrical shaped body. Transmission of vibration energy to the vibrator body comes from the energy of the runner. The runner, touching the hull, experiences the impact of inertial forces on the hull. The runner excites external forces that transfer vibration energy to the vibration exciter.

Keywords: deep loader, vibration exciter, vibration, amplitude, operating speeds, power take-off shaft

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Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

At present, vibration exciters of different designs are widely used to excite mechanical vibrations, which are used to perform a variety of technological operations. At the same time, special vibrating machines are created, in which energy from the vibration exciter is transferred directly to the working body, which uses vibration (in particular, in agriculture) for destruction of various soils compacted by running systems of machines, non-moldboard deep tillage, plowing. Application of vibration enables to considerably raise labor productivity, reduce labor input and prime cost of the executed works. Vibration exciters, which excite mechanical vibrations of the working bodies of machines, are quite widespread in many areas of the economy and in everyday life.

High opportunities for the use of vibration exciters will appear when it will be possible to create designs with maximum power, readjustment of frequencies and amplitudes of mechanical vibrations. An important value for vibration machines is the change in the power of the vibration exciter, which allows to change the amplitude of mechanical vibrations and, accordingly, the amplitude of oscillations of the working bodies, affecting the layer of soil, breaking the monolithic structure of the anthropogenic compacted soil after the passes of heavy machines, which affect the subsoil horizon with the propulsion systems[1] [1-6].

Excitation of mechanical vibrations is a process of conversion of the source energy into vibrating fluctuations. According to I.N. Petryagin [7], it is possible to increase the power of the vibration exciter by shifting the rotor from the center of the body. I.N. Petryagin theoretically and experimentally justified that the increase in the rotor displacement relative to the center of the body allows you to increase the maximum power of the vibration exciter. This statement was proved in practice by determining the power of vibration exciter on the running-in-brake stand. Experimental values of vibration exciter power exactly fit the calculated characteristic, so for a long time it was believed that theoretical and calculated values [7] derived by I.N. Petryagin and experimental dependences are flawless and applicable to the development of vibration exciters of other designs[2]. We made a vibration exciter with the calculated values of I.N. Petryagin, in

[1]Trofimov I.V. Justification of design-mode parameters of vibrating cultivator for pre-sowing tillage: Ph. Orenburg, 2018. 116 p.

[2]Patent № 2578745, B06B1/16 (Russian Federation). Vibration exciter / S.G. Shchukin, V.V. Alt, M.A. Nagayka, V.A. Valkov. Application. 15.12.2014; publ. 27.03.2016. Bulletin no. 9.

which shock loads inside the body were found, which were not reported in the work[3].

There was a process of occurrence of shock loads from a cylindrical-shaped part, called a runner, when it moved along the inner cylindrical surface of the body under the influence of the rotor, whose center of rotation was shifted from the center of the body by the value of eccentricity.

Vibration exciter was driven by hydraulic motor GMSH-50, standardly installed in T-150K, driven by hydraulic motor of standard drive by hydraulic pump GMSH-50.

It is assumed that the runner does not reach the top of the inner surface of the vibrator body. The assumption was made that if we increase the rotor rotation speed, the impacts on the inside of the cylindrical body would not be heard, because the runner would run around the entire inner surface of the body. However, increasing the rotational speed from 750 to 1000 rpm did not change the process taking place, the force of the internal shock only increased.

The purpose of the work is to improve the mechanical vibration exciter to obtain its maximum power through the motion of the rotor, the center of rotation of which is displaced from the center of the body with an unbalanced mass - a runner - on the inner surface of the body.

The object of the study is the process of moving the rotor, mounted with an offset from the center of the body, unbalanced mass - runner, which excites the vibrating motion of the vibration exciter body.

The subject of the study is the determination of the vibration exciter power depending on the offset of the rotor spinning axis by the eccentricity e from the center of the body.

Research objectives:

– determination of vibration exciter design parameters, at which there is no knocking at different rotor speeds (v = 750 and 1000 rpm);

– numerical determination of the value of the rotor offset from the center of the exciter body (eccentricity e), at which the runner will touch the entire surface of the exciter body when rotating;

– determination of the magnitude of the acting centrifugal force on the runner rotated by the rotor;

– determination of the maximum eccentricity value e_{max}, at which the runner will touch the exciter body at all points (see Fig. 1).

The design and technological scheme of maximum power vibration exciter according to I.N. Petryagin [7] was made and verified in the experiment. Diameter of vibration exciter body D = 120 mm, diameter of the runner d = 72 mm, eccentricity of displacement of the rotor from the center of the body e = 15 mm. The claimed power at 1000 rpm by I.N. Petryagin [7] is N = 0.299 kW. In the presence of knocking the vibrating exciter was tested on a deep loosener GV-1,8, the following qualitative indicators of crumbling the structure of the cultivated soil were obtained (see table).

Let's consider the position of the runner 3 relative to the axis of rotation C_v, displaced on

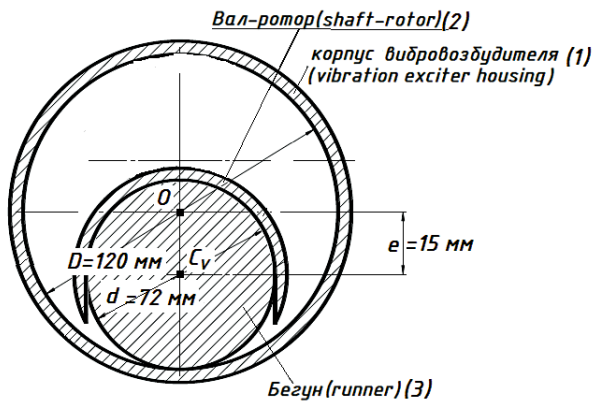

Рис. 1. Конструктивно-технологическая схема «бегункового» типа вибровозбудителя максимальной мощности (по И.Н. Петрягину [7])

Fig. 1. Structural and technological scheme of the "runner" type vibration exciter of maximum power (according to I.N. Petryagin [7])

[3]A.s. 1681979, MKY3B06 B 1/16 (USSR). Vibration exciter / I.N. Petryagin; No. 4386471/28. Application. 02.03.88; publ. 07.10.91. Bulletin № 37.

the value e of eccentricity (see Fig. 2), and describe the character of its movement, taking: S_b - center of mass of the runner 3; R - distance |OK| from the center of body O, in which the runner 3 rotates, to point K on the line |OK|, which is the contact point of the runner 3 with the surface of body 1 (see Fig. 3). The distance from the center of the runner to the axis of rotation C_v = 9 mm.

The outer diameter of the cylindrical runner d = 0.072 m (72 mm); r is the distance $|C_vS_b|$ from the center (aka center of mass) of the runner to the center of rotation Cv of the leading link.

The offset of the center of rotation C_v from the center of the inner circle of the body O is 15 mm (eccentricity e = 0.015 m (15 mm)).

When the runner is located at the lower point of the exciter (the beginning of the deflection angle φ = 0) the distance $|C_vS_b|$ = 0.009 m (9 mm);

$$\frac{D}{2} - \frac{d}{2} - e = 0{,}009.$$

The diameter of body 1 is 0.12 m (120 mm), R = 0.06 m (60 mm).

The leading link 2 begins to rotate the runner 3 (see fig. 4) in a vertical plane inside the case with the center O relative to the center of rotation C_v with a constant rotation frequency (see fig. 3) ωv = 750 rpm.

Агротехнические показатели обработки почвы при различных режимах работы ГВ-1,8 (по данным, полученным М.А. Нагайка [9])
Agrotechnical indicators of tillage at different modes of operation of GV-1.8 (based on the data obtained by M.A. Nagayka [9])

Mode of operation of GV-1,8			Agrotechnical indicator, %		
Runner mass, kg	Running speed, km/h	Oscillation amplitude (estimated), 10^{-3}m	Lumpiness	Ridgeness	Stubble field preservation
Control*	9	–	26	21	52
4,55	9	1,06	21	20,5	56
4,55	3	1,06	14	18	68,5
9,1	9	4,53	8	11,5	81
9,1	3	4,53	3	8	92

* Without the use of vibration.

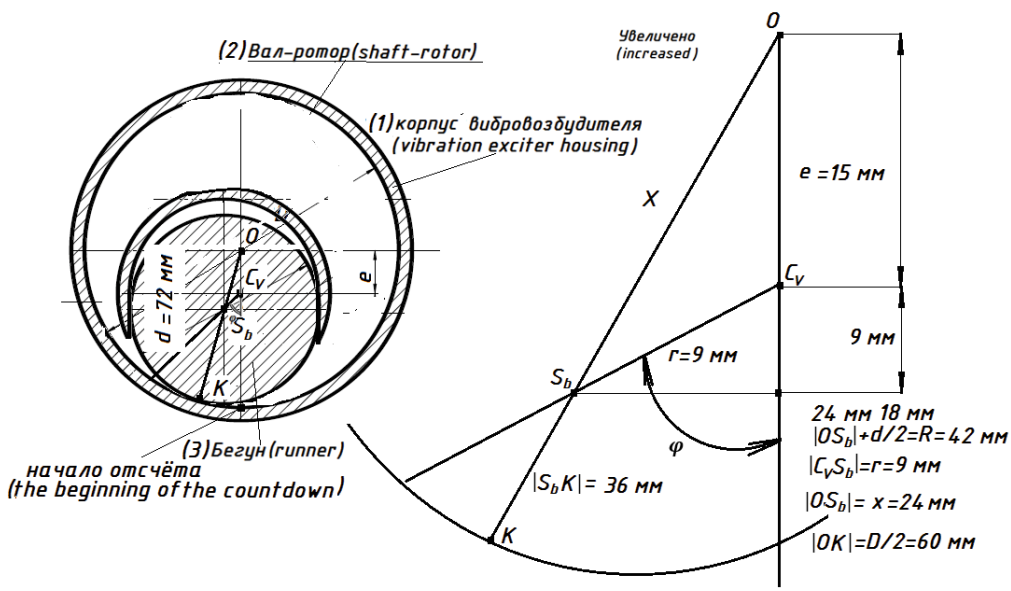

Рис. 2. Теоретическое положение радиусов из точек вращения *O* и C_v для конструкции И.Н. Петрягина [7]

Fig. 2. The theoretical position of the radii from the points of rotation O and C_v for the construction of I.N. Petryagin [7]

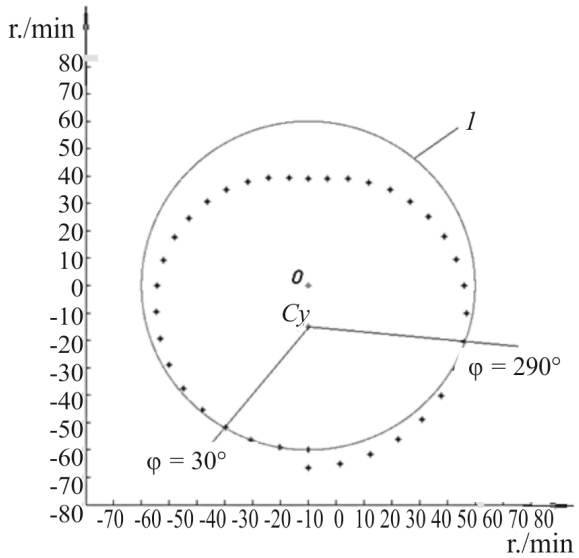

Рис. 3. Теоретическое положение точки *K* (точка касания бегуном *3* внутренней поверхности вибровозбудителя) в зависимости от поворота вокруг центра вращения C_v на величину угла φ

Fig. 3. The theoretical position of point K (the point where the runner 3 touches the inner surface of the vibration exciter) depending on the rotation around the center of rotation Cv by the value of angle φ

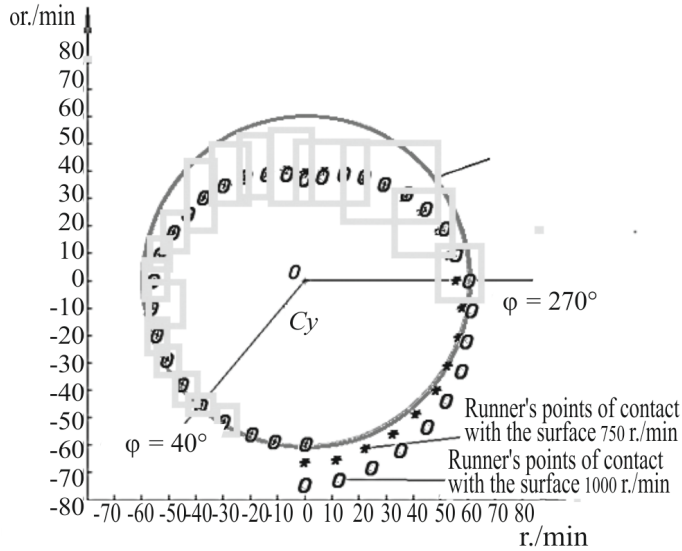

Рис. 4. Графическое решение уравнений для разной частоты вращения вала (750 и 1000 об. /мин)

Fig. 4. Graphical solution of the equations for different shaft speeds (750 and 1000 rpm)

Theoretically, the runner 3 with the center of mass at the point Sb should, when rotated by the leading link 2, touch the surface 1 of the body of the diameter D at the point K (see Fig. 2). Since there is a clearly audible impact, let us consider the position of the runner based on the physics of the process.

The point of contact K of the runner 3 and the inner surface of the vibration exciter with the center of the circle O is located on the line OK, passing through the center Sb of the runner 3. The distance from the center O to K is $|S_bO| + 1/2d$, where d = 0.072 - the larger diameter of the runner. Let's take $|OS_b|$ as X.

Then at any point of contact of the runner with the inner surface of the vibration exciter the value X is constant. At the lower point X = e + r (φ = 0), where e is the eccentricity and r is the distance from the center of the runner S_b 3 (see Fig. 4) to the center of rotation C_v, which is (see above) 0.009 m (9 mm).

Let us express X through r. In the general case

$$X^2 = (e + r \cdot \cos\varphi)^2 + r^2 \cdot \sin\varphi. \quad (1)$$

from here it follows that

$$X = \sqrt{(e^2+2r\cos\varphi + r^2)\cos\varphi^2 + r^2\sin\varphi^2} = \sqrt{e^2+2r\cos(\varphi) + r^2}. \quad (2)$$

Now let's find r at each point of the runner's position when rotating around the axis of rotation C_v based on the formulas for the acceleration and rotational motion of the body around the axis (see Fig. 2).

$$r_{i+1} = r_i + \Delta r_i = r_i + \frac{a_i \Delta t^2}{2}. \quad (3)$$

In our case, the rotating link 2 transmits to runner 3 the centrifugal acceleration, $a_i = \omega^2 \times r_i$. Taking into account the free-fall acceleration g = 9.8 m/s^2, the general formula will look like

$$r_{i\times 1} = r_i + \frac{(\omega^2 r_i + q \times \cos\varphi)\Delta t^2}{2}. \quad (4)$$

Since r depends on the angle of rotation φ, for calculations we will take the step (Δφ) equal to 10 degrees. In this case we express the time Δt through the rotational frequency

$$v = 750 \text{ rpm} = 12{,}5 \text{ cps}; \quad (5)$$

$$\Delta t = (10/360)/12,5 = 1/450 \text{ c}^{-1}; \quad (6)$$

$$\Delta t^2 = (1/450)^2 = 1/202500 \text{ c}^{-2}. \quad (7)$$

Let us also determine the angular velocity of the driving link 2, it is also the angular velocity of the runner 3. It is constant and equal to $\omega = 2\pi v$. v = 750 r./min = 12,5 r./s. Hence $\omega = 2 \times 3,1416 \times 12,5 = 78,54$ (rad/s) and $\omega^2 = 6168,5316$ (rad/s)^2. By substituting these values into the formula

$$r_{i+1} = r_i + \frac{(\omega^2 r_i + q \times \cos\varphi_i)}{2}, \quad (8)$$

we get the expression

$$r_{i+1} = r_i + \frac{(6168,53 r_i + 9,8 \times \cos\varphi_i)}{2 \times 202500}, \quad (9)$$

where $\varphi_i = \varphi_0 + \frac{2 \times \pi \times 10}{360} \times i.$ (10)

After that using numerical methods with Microsoft Excel we calculate X_i through previously obtained in the same way r_i. Adding to the value X_i half of the runner diameter, we obtain the radius-vector from O to the theoretical point of contact K of the runner 3 with the inner surface of the vibration exciter. The calculation is shown in Fig. 3.

Thus, the graphical representation presented in Fig. 3 graphical image gives a complete picture of the cause of excitation of sound vibrations (shock): it is a detachment of the runner 3 from the body 1, its acceleration without contact with the body 1 and contact at φ = 290 deg., causing a shock (knock), the sound of which is heard during operation of the vibration exciter. We investigated two practical modes of operation at speeds of 750 and 1000 rpm.

The stars and circles in Fig. 4 represent the points K and their position relative to the body with an angle of φ = 0.1745 radians (10 degrees).

Circle 1 indicates the position of the body. If the stars and circles are located inside the body 1, the trajectory of movement indicates the action of insufficient centrifugal force. On the contrary, if the stars and circles are located outside the body 1, the action of the centrifugal force in practice leads to contact of the runner with the body, which is the cause of impact of the runner on the body and excitation of oscillations. The graph of the process (see Fig. 3), shown by the asterisks, indicates that the runner 3, moving at a speed of 750 rpm, breaks away from the body at φ > 30 degrees and returns to contact with the body at φ = 290 degrees, so it affects the body at 290 < φ < 30.

The process shown by the circles in Fig. 4 indicates that the runner 3, rotating at 1000 rpm, detaches from the body at φ > 40 degrees and returns to contact with the body at φ >270 degrees and therefore interacts with the body at 270 < φ < 40. The remaining surface of the body is not in contact with the runner.

Let's define the total energy from the rotating runner as the sum of kinetic and potential energies from different types of motion inside the body of the vibration exciter. When the runner moves in a circular motion, it is the kinetic energy of the runner ΔK, and when the runner is raised and lowered, it is the potential energy ΔP. The total energy, the sum of the kinetic and potential energies, will be defined as ΔE = ΔK + ΔP. Provided the speed of rotation of the runner is practically constant (ΔK = 0 if ω is const), we define the magnitude of the change in potential energy as $\Delta\Pi = vmg\Delta h = vg\left(2(\frac{D}{2} - \frac{d}{2})\right)$.

Thus, the maximum work produced by the vibration exciter will be equal to A = ΔP = vg (D - d) m, where v is the speed of revolutions per second.

In the work of I.N. Petryagin [7] it is noted that the maximum efficiency of the vibration exciter is achieved when the ratio of the runner diameter d to the internal diameter of the body $\frac{D}{2} = 0,6$.

Let's estimate the mass of the runner based on the size and density

$$m = \pi\frac{d^2}{4}\rho l = \frac{1}{4}\rho\pi l d^2. \quad (11)$$

Let's take *S* - area of the runner, L - length of the runner, ρ - density of the material used, i.e. steel, 7800 kg/m^3, g -9.80665 m-s-2. Let us differentiate the expression and equate the derivative to zero:

$$\Delta\Pi = vg\rho\pi\frac{d^2}{4}L(D-d) = \frac{1}{4}vg\rho\pi L(d^2D - d^3) = k(d^2D - d^3); \quad (12)$$

$$k\times(2dD-3d^2)=0 \text{ или } k\times d\times(2D-3d)=0. \quad (13)$$

Let's consider $2D–3d = 0$.

From here we get

$$d = \frac{2}{3}D. \quad (14)$$

From this it follows that the maximum work can be done when the ratio D and d is equal to d = $\frac{2}{3}$D, which is very close to the ratio obtained by I.N. Petryagin [7], but calculated in a different way.

Fig. 5 shows the design of the vibration exciter, taking into account the results of work on obtaining its maximum power and operation without knocking. An invention application has been filed for the proposed variant.

There is a back side plate 10 with a hole 8 in it displaced by the eccentricity value e, the rotor shaft 3 rotates the runner 1 inside the body of the vibration exciter. The bearing stop 19 provides a free rotation of the cylindrical disc 3, from the rotation of which, through the rotor shaft 3, the rotation is transmitted to the runner 1, moved inside the cylinder of the vibrating exciter body [9, 10]. The views are given: a - from the inner side to the plate 10, on which a slot 6 is made with a cylindrical tube of the vibration exciter body 1 placed in the slot, along the inner side of which the runner 3 moves clockwise, pressed by the centrifugal force in the tube window 15 to the vibration exciter body 1; b - rear view of the plate 10, on which the drive spacer 17 is made, placed on the studs fixed in the holes 9 of the side plate 10; there is a through hole 14 for pouring lubricant into the inside of the exciter on the drive spacer 17; through the holes 9 the hydraulic motor is fixed with studs.

The claimed vibration exciter is assembled. Between the side back plate 10 and the back plate 11 there is a cylindrical tube 15 forming the vibrating exciter body, along the inner part of which the runner 1.

The proposed calculation method, used in the work, allowed to determine the value of ec-

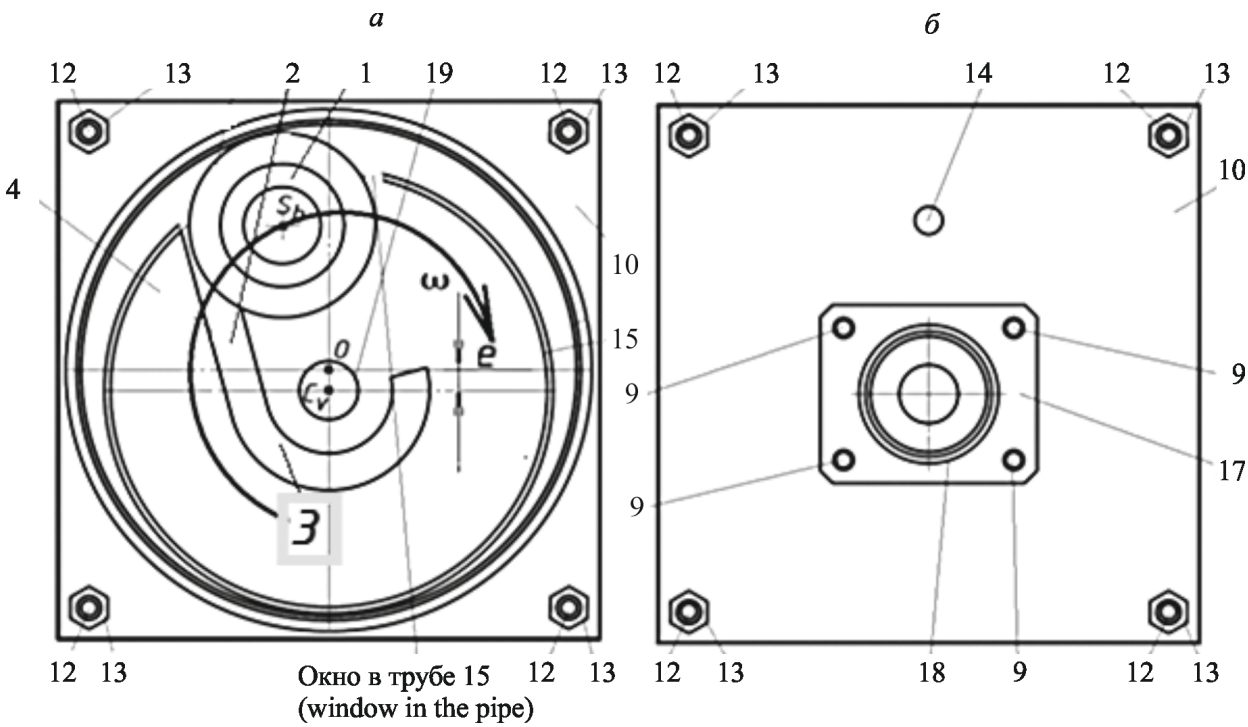

Рис. 5. Устройство боковых плит и ротора, перемещающего бегун внутри корпуса предлагаемого вибровозбудителя с мощностью [8]

Fig. 5. Fig. 5. The device of the side plates and the rotor moving the runner inside the housing of the proposed vibration exciter with power [8]

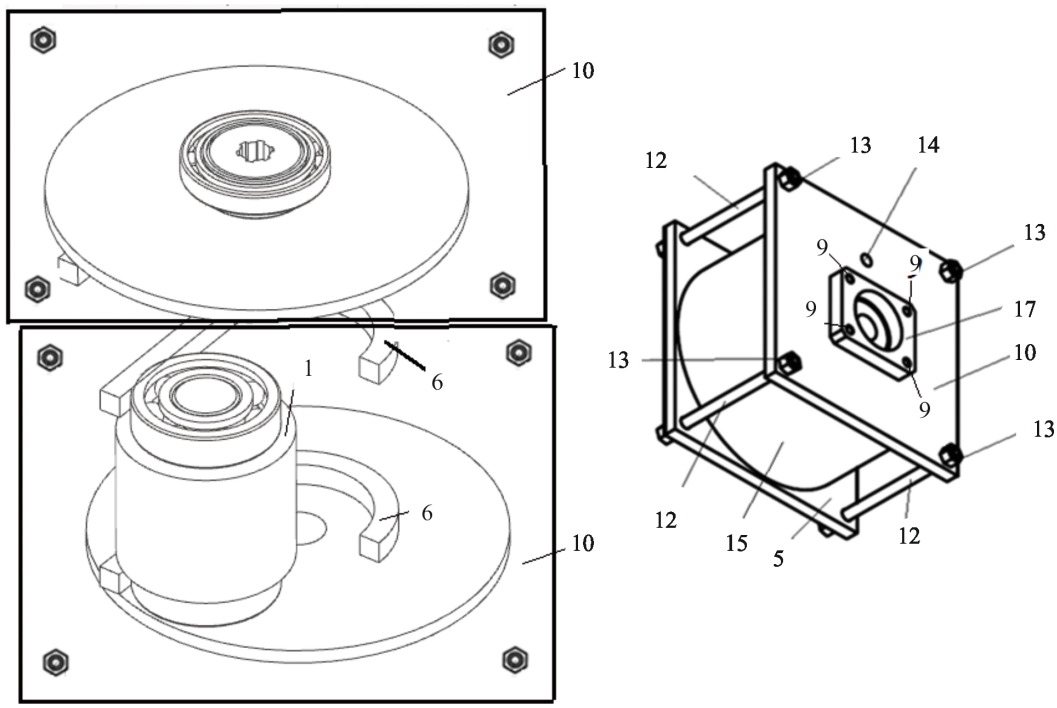

Рис. 6. Внешний вид вибровозбудителя максимальной мощности
Fig. 6. Maximum power vibration exciter appearance

centricity, at which the runner touches all points of the inner surface of the exciter. Changing parameters (rotation frequency and diameter of the runner), it was found that for the runner to touch the whole surface of the exciter body, for eccentricity e the following condition must be fulfilled:

$$16{,}11(\text{при } v - 500\ \frac{\text{об.}}{\text{мин}}) \le \frac{D-d}{e} \le$$

$$\le 17{,}06\ (\text{при } v - 1500\ \frac{\text{об.}}{\text{мин}}). \qquad (15)$$

Patent values, at which the maximum power of the claimed vibration exciter is achieved, correspond to the conditions of the diameter ratio as d = 23 D, where D - diameter of the cylindrical body, d - diameter of the runner is 72 mm, the eccentricity value is 17.06 mm.

CONCLUSIONS

1. The mechanism of excitation of vibration oscillation has been studied, which showed that the size of its body, runner and adopted eccentricity have a significant influence on the magnitude of the power of the vibration exciter.

2. On the example of calculations carried out by the numerical method, the design and technological scheme of the inertial type vibration exciter is substantiated and the results, at which its maximum power

$$W = vg(D - d)m,$$

where v is the rotation frequency of revolutions per second, are given.

A patentable solution on the necessary value of eccentricity emax, at which the runner will touch the exciter body at all points is obtained (see Fig. 1).

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ВОЗДЕЛЫВАНИЕ ПШЕНИЦЫ В ЗАВИСИМОСТИ ОТ СПОСОБА ПОСЕВА И ВНЕСЕНИЯ АЗОТНЫХ УДОБРЕНИЙ

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Представлены преимущества и недостатки наиболее распространенных типов рабочих органов сеялок. Изучен сошник, позволяющий вносить минеральные удобрения ниже уровня посева семян зерновых культур с сохранением почвенной прослойки между ними. Двухфакторный полевой опыт проведен в четырехкратной повторности с постоянной нормой высева семян яровой мягкой пшеницы Омская 36 4,5 млн всхожих семян/га в 2021 г. Норма внесения минеральных удобрений с содержанием азота 34,4% составляла 0 (контроль), 100, 150, 200 кг/га на каждом типе исследуемых рабочих органов. Приведены результаты сравнительных исследований качества работы трех типов сошников на базе серийной сеялки СКП-2,1. В ходе полевого опыта определяли глубину заделки семян, полевую всхожесть, урожайность и качество зерна по вариантам. Лучшие показатели посева по глубине заделки семян яровой пшеницы обеспечили комбинированные и дисковые сошники. Наибольшая полевая всхожесть (72,7%) получена при посеве комбинированными сошниками с внесением аммиачной селитры в норме 150 кг/га, дисковыми сошниками при той же норме – 71,0%, с серийным лаповым сошником – 55,1%. Наибольшая урожайность (3,18 т/га) получена при посеве сеялкой СКП-2,1К с комбинированными сошниками при внесении 150 кг аммиачной селитры/га. При той же норме внесения удобрений урожайность при посеве дисковыми сошниками составила 3,16 т/га. Содержание сырой клейковины на контрольном варианте зарегистрировано 31,2%, при посеве комбинированным сошником – 34,1%, при посеве дисковым сошником с внесением аммиачной селитры в физическом весе 200 кг/га – 33,4%.

Ключевые слова: сеялка, сошник, способы посева зерновых, внесение удобрений, урожай зерна, качество зерна

WHEAT CULTIVATION DEPENDING ON THE METHOD OF SEEDING AND NITROGEN FERTILIZER APPLICATION

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The advantages and disadvantages of the most common types of seed drills are presented. A coulter has been studied that makes it possible to introduce mineral fertilizers below the level of sowing cereal seeds with preservation of the soil layer between them. Two-factor field experiment was conducted in four replications with a constant seeding rate of spring soft wheat Omskaya 36 4.5 million germinated seeds/ha in 2021. The rate of mineral fertilizers with a nitrogen content of 34.4% was 0 (control), 100, 150, 200 kg / ha on each type of the studied work tools. The results of comparative studies of the quality of three types of coulters on the basis of a serial seeder SKP-2,1 are presented. During the field experiment, the depth of seed embedding, field germination, yield and grain quality were determined according to the variants. The best seeding depth of spring wheat seeds was provided by combined and disc coulters. The highest field germination (72.7%) was obtained when seeding with combined coulters with the introduction of ammonium nitrate at a rate of 150 kg / ha, disc coulters at the same rate - 71.0%, with a standard tine coulter - 55.1%. The highest yield (3.18 t/ha) was obtained when seeding with SKP-2,1K drill with combined coulters at the application of 150 kg/ha of ammonium nitrate. At the same rate of fertilizer application, the yield when seeding with disc coulters was 3.16 t/ha. The content of crude gluten in the control variant was 31.2%, when seeding with a combined coulter - 34.1%, when seeding with a disc coulter with the introduction of ammonium nitrate in the physical weight of 200 kg/ha - 33.4%.

Keywords: seeder, coulter, grain seeding methods, fertilization, grain yield, grain quality

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INTRODUCTION

The main reason for the low efficiency of crop cultivation in the Western Siberia is the inconsistency of technological and biological cycles in different climatic zones. For efficient grain production it is recommended to actively develop adaptive-landscape farming system with a set of agro-technologies of different levels of intensification based on accurate (digital) management of natural resource potential [1].

On the basis of agrolandscape zoning, rational structure of the use of sown areas, and intensification of production, grain production growth is ensured [2, 3].

Machine technologies determine the level of plant productivity, product quality and ultimately form the social and environmental aspects of agricultural production. Technical means in conjunction with their supporting systems constitute the material and technical base of technology, the adaptation of which to the natural and climatic conditions and resource capabilities of the agricultural producer determines the level of intensity. In this case, the necessary condition is the stability of the agrolandscape and the reproduction of soil fertility [4].

In crop production 76% of agricultural organizations and 78% of private farms produce according to extensive technologies, which practically do not use the achievements of science, advanced domestic and foreign experience, do not involve means of intensification (mineral fertilizers, etc.), use old-generation machines. The size of the harvest depends mainly on the prevailing weather conditions and the natural fertility of soils.

Under intensive farming the system of fertilizers provides for the application of 60-85 kg of active agent of mineral fertilizers per one hectare of crop rotation area, including nitrogen 30 kg, phosphorus 30-45 kg, potassium 10 kg. Based on soil diagnosis, phosphorus and potassium fertilizers can be applied in reserve for crop rotation or annually for individual crops. Nitrogen fertilizers should be applied locally before sowing [5, 6].

In most of the existing designs of coulter groups, seeding of seeds and fertilizer application is carried out jointly in one row (in one horizon of depth). In this case there is a change in the direction of growth (chemotropism) of the root system under the influence of chemicals (fertilizers). The disadvantage of this method is the low efficiency of using starter fertilizers, especially if the moisture content of the seed layer of soil is low. Therefore, it is preferable to have a layer of soil between the seeds and fertilizers for active development of the root system of the plant and use the full potential of the applied mineral fertilizers. Also, when applying fertilizers to a certain depth, it is possible to regulate the location of the root system of plants in the space of the arable layer [7-9].

There are several types of coulter groups: disc, tine, tyne. In turn, each of the coulter types can work in combination with various additional working tools, based on the selected seeding technology [10-12].

The operation of disc coulters is only possible on soil that has been prepared in advance by pre-cultivation. For work on chemical fallows, where there is a large amount of crop residues on the surface of the field, it is recommended to use discs with different diameters or single

disc coulters. The double disc coulter works without the additionally installed slotted disc at the front, not by cutting but by pressing the straw mass into the soil. The seeds are not fully incorporated into the soil, the crushing among the straw mass reduces their field germination. The use of disc coulters is not desirable in case of high soil moisture. The disadvantages of disc coulters include the inability to incorporate seeds over 4 cm in hard parched soils.

The most universal are tine coulters that perform several technological operations in one pass: cultivation, loosening, sowing and fertilizer application. If the seeding layer is dry, tine coulters can sow at a greater depth (4-8 cm), which allows to obtain seedlings even in the most unfavorable conditions.

The tyne coulters are able to penetrate even the densest soils and sow to almost any depth. They have less impact on the soil compared to the duckfoot tine, leaving narrow sowing strips. The soil is loosened less, more stubble and straw remain on its surface, and less moisture evaporates [13, 14].

Germination and plant development depend to a large extent on the method of sowing and fertilizing. Joint seeding is undesirable because contact of mineral fertilizers with the seeds affects the germination of the seeds. Therefore, the creation of working tools for a chisel planter with separate application of seeds and mineral fertilizers is an important task. In order to improve the efficiency of fertilizers and crop yields, we developed a combined coulter for separate application of seeds and fertilizers [15].

The purpose of the research is to carry out a comparative study of cultivation methods of spring soft wheat planters SKP-2,1K equipped with coulters for multilevel sowing and SDS-2,1 with disc coulters in comparison with the serial SKP-2,1 (control). Also, the aim of the research is to determine the effect of the seeding method, placement of fertilizers relative to the seeds and the rate of application of starting doses of nitrogen fertilizers on the yield and quality of grain.

Research objectives:

– to develop a scheme of field comparative experiment for the performance of sowing cereals by intensive technology;

– conduct laboratory and field comparative studies of chisel planter operation with combined coulters, disc coulters and serial coulters to assess the quality and yield of grain.

MATERIAL AND METHODS

Setting of field experiment was carried out 20.05.2021 by MTZ-82 tractor in the unit with a basic chisel planter SKP-2, 1. In the course of research three kinds of coulters mounted on the frame of the basic planter SKP-2,1 were compared: combined coulters for multilevel sowing (SKP-2,1K) designed by the Omsk Agricultural Research Center, disc coulters (SDS-2.1), serially produced tine coulters (SKP-2,1 - control). At different methods and variants of fertilizer application (ammonium nitrate) the rate was 100, 150 and 200 kg/ha. Spring wheat was the forecrop at sowing. The main soil treatment in autumn was not carried out. Ammonium nitrate was used as a mineral fertilizer, which was introduced simultaneously with sowing. In the course of the field experiment the depth of seed embedding, field germination, yield and quality of grain by variants were determined. Experiments were laid according to the generally accepted method of B.A. Dospekhov.

Methodology and conditions of the field agro-technical experience are based on STO AIST (Standards of the Association of Agricultural Machinery and Technology Testers) 10 5.6-2003 Sowing machines. Program and test methods, GOST 31345-2007 Tractor seeders. Test methods.

RESULTS AND DISCUSSION

All sowing passes were performed at the same seeding rate of spring wheat Omskaya 36 (4.5 million germinated seeds/ha). The entire amount of work was carried out during one work shift. The scheme shows variants of one

repetition of the experiment (see Fig. 1). The experiment was two-factor, the repetition was four times. The forecrop was spring wheat. No main tillage was done in autumn. Fertilizer was applied simultaneously with sowing, the percentage of nutrients in the fertilizer was 34.4%. Sowing was carried out with spring wheat Omskaya 36. Qualitative indicators of seeds: weight of 1000 grains - 33 g, field germination - 92%, moisture - 14%. Seeding rate for all replications - 4.5 million germinated grains/ha. Seeding depth - 6 cm.

The total number of accounting plots was 48, the size of the experimental plot was 0.25 ha. In the course of the field experiment the following indicators were determined: field germination, uniformity of the sowing depth and yield by variants. Herbicide treatment of the crops was carried out on June 20. Plots were harvested on 06.09.2021 by Wintersteiger plot harvester.

The seedlings obtained in the plots with each type of coulter group are shown in Fig. 2.

Uniform seed placement at a given depth is the most important indicator for both the evaluation of sowing and the work of the coulter group. The sowing depth can vary widely depending on the moisture of the sowing layer and the weather conditions at the time of sowing. If the spring is wet, it is recommended to sow to a depth of 4-5 cm. In hot, dry and windy weather during the sowing season, the sowing depth can be as deep as 6-8 cm. It is not recommended to sow cereal crops to a depth of less than 4 cm, as the soil dries out quickly and the seed does not have time to give seedlings.

Table 1 shows the calculated figures for the depth of seeding (by the ethylated part of the plants) of each of the studied coulter groups.

Comparative field tests showed that the coefficient of variation of the seed drill SKP-2,1 with standard tine coulters was 20%, seed drills SKP-2,1K and SDS-2,1, equipped with a combination and disc coulters, respectively, - 13%, indicating a better stability of the stroke of these coulters on the depth of seeding.

Field germination of plants for each type of coulter groups was determined after the emergence of complete shoots in the plots with an area of 1 m^2. Fig. 3 shows a graph of the dependence of field germination on the type of coulter used and the rate of nitrogen fertilizer application.

The results show that field germination on the control when sowing without fertilizer on

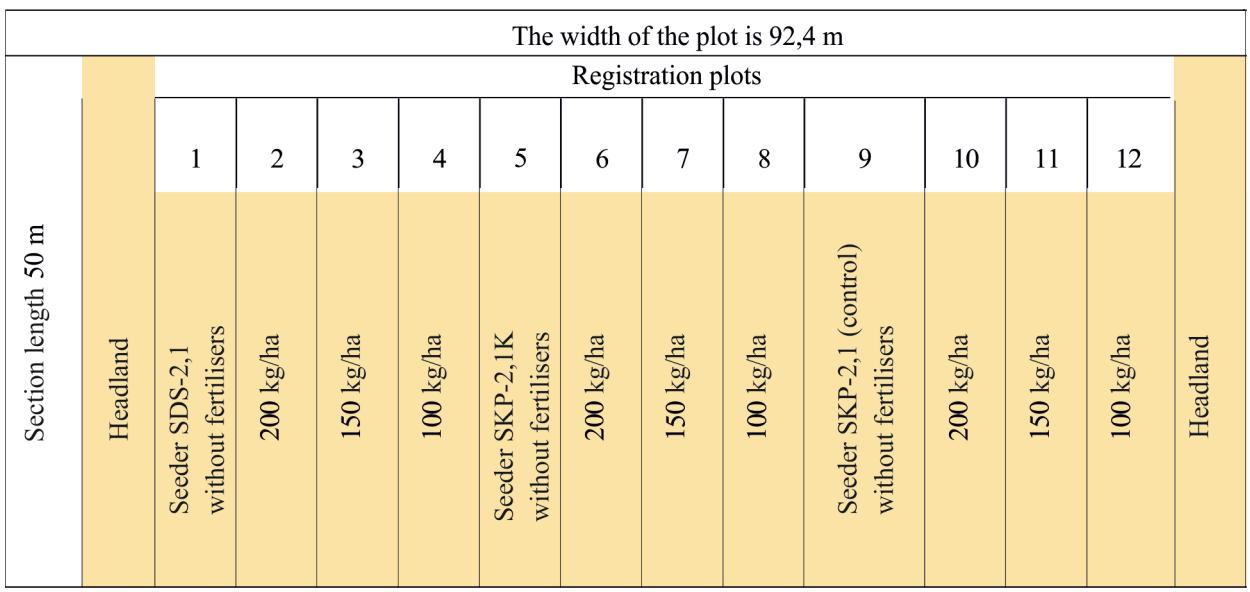

Рис. 1. Схема закладки одной повторности опыта

Fig. 1. The scheme of setting up one repetition of the experiment

а

б

в

Рис. 2. Общий вид исследуемых сошниковых групп с результатами всходов:
а – двухдисковые сошники сеялки СДС-2,1; *б* – сошники для разноуровневого посева и внесения минеральных удобрений сеялки СКП-2,1К; *в* – серийные лаповые сошники сеялки СКП-2,1 – контроль
Fig. 2. General view of the investigated coulter groups with the results of shoots:
a – double-disc coulters of the SDS-2.1 seeder; *б* – openers for multilevel seeding and application of mineral fertilizers of the SKP-2.1K seeder; *в* – serial tine coulters of the SKP-2.1 seeder – control

Табл. 1. Расчетные показатели сеялок по глубине заделки семян
Table 1. Estimated indicators of seeders by seed placement depth

Indicator	SKP-2,1	SKP-2,1K	SDS-2,1
Average embedment depth, cm	5,58	5,89	5,60
Standard deviation, cm	1,13	0,92	0,91
Coefficient of variation, %	20	13	13

serial tine coulters was 52.7%, combined coulters - 63.6%, disc coulters - 61.5%. The highest field germination (72.7%) was obtained when ammonium nitrate was added at a rate of 150 kg/ha in the variant with combined coulters. On disc coulters at the same rate - 71.0%.

Fig. 4 shows a general view of the experimental plot before harvesting and the process of harvesting of the registration plots with a Wintersteiger plot harvester.

Prior to harvesting, sheaves were harvested from each registration plot for subsequent structural analysis. Table 2 shows the values of the resulting grain yield of spring wheat during harvesting with a Wintersteiger plot combine as well as according to the results of threshing of the harvested sheaves in the laboratory on the plot threshing machine.

Fig. 5 shows a graph of the dependence of grain yield of spring wheat Omskaya 36 on the type of coulter and the rate of nitrogen fertilizer application after threshing of the registration plots by Wintersteiger plot harvester.

Analysis of the yield results shows that the increase in grain depends on the method of fertilizer application and their norm. The highest yield (3.18 t/ha) was obtained when seeding with a seeder SKP-2,1K with combined coulters at the application of 150 kg of ammonium nitrate /ha. When seeding with a disc coulter at the same rate the yield was 3.16 t/ha. Compared to the control at the same rate these values are higher by 3%.

After harvesting, the grain material from each of the variants was collected for grain quality evaluation in the grain quality laboratory of the Omsk Agricultural Research Center. Table 2 shows qualitative indices of soft spring wheat grain - gluten.

The content of crude gluten when sowing with SKP-2,1 (control) was 31,2%, when sowing with SKP-2,1K planter equipped with com-

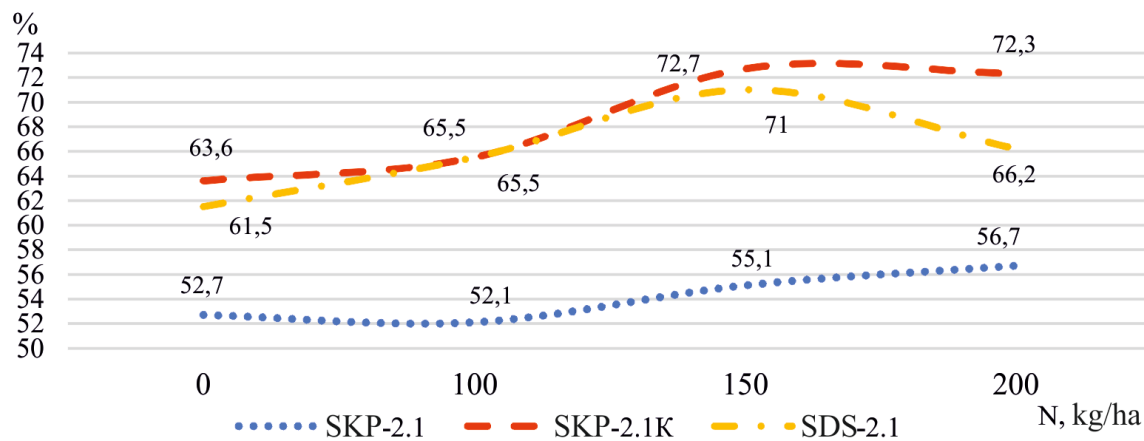

Рис. 3. Полевая всхожесть семян яровой пшеницы в зависимости от типа сошника и нормы внесения удобрений, %

Fig. 3. Field germination of spring wheat seeds depending on the coulter type and the fertilizer application rate, %

Рис. 4. Общий вид опытного участка и процесс уборки учетных делянок
Fig. 4. General view of the experimental plot and the process of harvesting of the registration plots

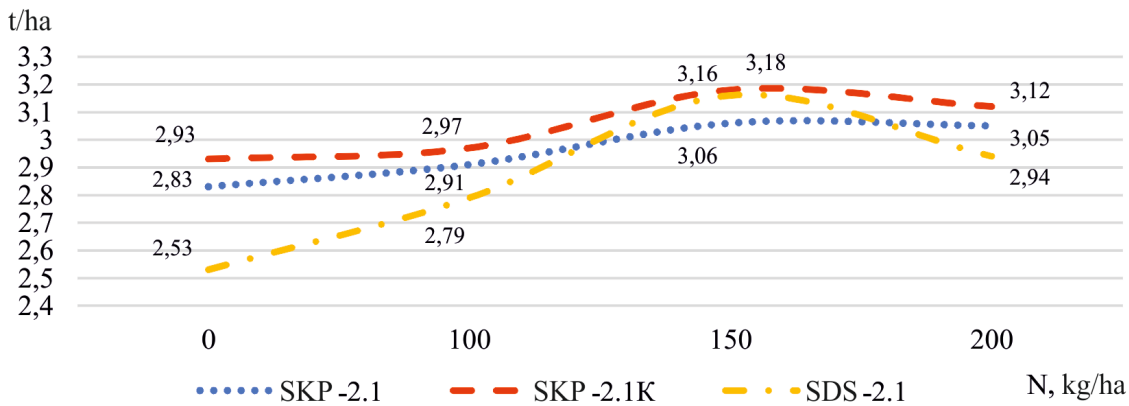

Рис. 5. Урожайность зерна при уборке комбайном в зависимости от типа сошника и нормы внесения удобрений, т/га
Fig. 5. Grain yield depending on the coulter type and the fertilizer application rate, t/ha

Табл. 2. Количество клейковины по каждому из вариантов, %
Table. 2. The amount of gluten for each of the options, %

Option	The amount of gluten
SKP-2,1 (control)	31,2
SKP -2,1 + 100 kg/ha of fertilizer	30,1
SKP -2,1 + 150 kg/ha of fertilizer	34,6
SKP -2,1 + 200 kg/ha of fertilizer	37,0
SKP -2,1K	31,2
SKP -2,1K + 100 kg/ha of fertilizer	31,0
SKP -2,1K + 150 kg/ha of fertilizer	36,1
SKP -2,1K + 200 kg/ha of fertilizer	38,0
SDS -2.1	32,0
SDS -2.1 + 100 kg/ha of fertilizer	30,0
SDS -2.1 + 150 kg/ha of fertilizer	35,1
SDS -2.1 + 200 kg/ha of fertilizer	36,5

bined coulters for multilevel sowing and application of nitrogen fertilizers - 34,1%, when sowing with double disc coulters - 33,4% (see Table 2). The maximum values of the content of crude gluten were received for all the variants of sowing with the application of ammonium nitrate in the physical weight of 200 kg/ha and were 37,0% (control), 38,0 (shallow tillage) and 36,5% (seeding with disc working tools) accordingly depending on the type of coulter and method of application.

CONCLUSION

Comparative tests of different types of coulters on the basis of a serial seeder SKP-2,1 according to the developed scheme of the experiment showed that the best performance for the depth of seeding spring wheat seeds provide combined and disc working tools.

The highest field germination (72.7%) was obtained when sowing with combined coulters at the rate of 150 kg ammonium nitrate/ha, when sowing with disc coulters at the same rate - 71.0%, standard tine coulter - 55.1%. The highest yield (3.18 t/ha) was obtained when seeding with a seeder SKP-2,1K with combined coulters at 150 kg ammonium nitrate/ha. At the same rate of fertilizer application the yield at seeding with disc coulters was 3.16 t/ha. The maximum content of raw gluten was obtained for all variants of sowing (control, combined, disc coulters) at the application of ammonium nitrate in physical weight 200 kg/ha and was 37,0; 38,0; 36,5% depending on the type of coulter and method of application.

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РАСПРОСТРАНЕНИЕ И ВОЗРАСТНАЯ ДИНАМИКА ГЕЛЬМИНТОЗОВ КУР В АЗЕРБАЙДЖАНСКОЙ РЕСПУБЛИКЕ

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Исследования выполнены в частных птицеводческих хозяйствах пяти экономических районов Азербайджанской Республики: Апшеронском, Шеки-Закатальском, Ленкоран-Астаринском, Губа-Хачмазском и Аранском. Установлено, что гельминтокомплекс домашних кур представлен паразитами, относящимися к классам *Nematoda*, включающими четыре вида – *Ascaridia galli*, *Heterakis gallinarum, Syngamus trachea, Capillaria obsignata,* и *Cestoda,* представленный одним видом *Raillietina tetragona.* Установлено их повсеместное распространение, однако при однородном таксономическом составе в экономических районах зараженность кур возбудителями отдельных гельминтозов варьирует. *Ascaridia galli* и *Heterakis gallinarum* являются доминирующими видами. Инвазированность ими кур максимальна (экстенсивность инвазии 36,8 и 35,5%) и не имеет существенных территориальных различий. Зараженность птицы нематодами *C. obsignata* и ленточными червями *Raillietina tetragona* характеризуется более низкими показателями экстенсивности инвазии и их выраженной вариабельностью в границах районов. Пораженность кур капилляриозом и райетинозом варьирует от 7,1% в Аранском районе до 28,8% в Ленкоран-Астаринском, от 5,4 до 24,8% в Апшеронском и Губа-Хачмазском районах. В среднем по республике она составляет 17,8 и 18,5% соответственно. Возрастные особенности зараженности кур гельминтами характеризуются однотипным таксономическим спектром паразитов и максимальным заражением возбудителями аскаридиоза, гетеракидоза, сингамоза, капилляриоза и райетиноза цыплят в возрасте 2,5–5,0 мес с экстенсивностью инвазии соответственно 38,9; 40,8; 21,9;19,7 и 20,9%. Пораженность взрослой птицы указанными нозоформами значительно ниже – 32,0; 30,8; 15,3; 16,2 и 16,0%.

Ключевые слова: домашние куры, гельминтоз, зараженность, экономические районы Азербайджана

DISTRIBUTION AND AGE DYNAMICS OF CHICKEN HELMINTH INFECTIONS IN THE REPUBLIC OF AZERBAIJAN

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Studies were conducted in private poultry farms in five economic regions of the Republic of Azerbaijan: Apsheronsky, Sheki-Zakatalsky, Lenkoran-Astarasky, Guba-Khachmazsky and Aransky. It was found that helminthocomplex of domestic chickens is represented by parasites belonging to class Nematoda, including 4 species - *Ascaridia galli*, *Heterakis gallinarum*, *Syngamus trachea*, *Capillaria obsignata* and Cestoda, represented by one species, *Raillietina tetragona*. Their ubiquitous distribution has been established; however, with a homogeneous taxonomic composition in economic areas, the infestation of chickens with pathogens of individual helminthic diseases varies. *Ascaridia galli* and *Heterakis gallinarum* are the dominant species. Their invasion of hens is maximum (36.8 and 35.5% prevalence) and does not have significant territorial differences. Bird

infestation with nematodes *C.obsignata* and tapeworms *Raillietina tetragona* is characterized by lower prevalence rates and their pronounced variability within areas. The infestation of chickens with capillariasis and ryetinosis varies from 7.1% in Aransky district to 28.8% in Lenkoran-Astarsky district, from 5.4% to 24.8% in Apsheronsky and Guba-Khachmazsky districts. On average, it is 17.8 and 18.5% in the republic, respectively. Age peculiarities of chickens' helminth infestation are characterized by the same taxonomic spectrum of parasites and maximum infection with the causative agents of ascariasis, heterokidosis, syngamosis, capillariasis and ryetinosis in chickens aged 2.5-5 months with prevalence of 38.9; 40.8; 21.9; 19.7 and 20.9%, respectively. The incidence of these nosoforms in adult birds is much lower and amounts to 32.0; 30,8; 15,3; 16.2 and 16.0%.

Keywords: domestic chicken, helminthosis, infestation, economic regions of Azerbaijan

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INTRODUCTION

Agrarian reforms carried out in the Republic of Azerbaijan have led to the creation of industrial and private poultry farms of various directions, which play an important role in raising productive breeds of poultry, satisfying the needs of the population for quality meat and eggs.

There are various factors that hinder the intensive development of poultry farming, production of quality poultry meat and eggs, the main of which are parasitic diseases. The causative agents of *A. galli*, *H. gallinarum*, *S. trachea*, *C. obsignata* and *R. tetragona* are parasites that intensively infect domestic chickens. Infestation occurs in both mono- and associative forms [1-3]. One of the reasons for intensive infestation of domestic chickens is the high contamination of the environment with propagative forms of helminths [4-6].

The degree of extensiveness and intensity of parasite distribution depends on the age of birds, as well as on environmental factors [7-10].

The aim of the study is to study the distribution of helminth infections in chickens and to determine the age dynamics of helminth infestation in poultry under the conditions of Azerbaijan.

MATERIAL AND METHODS

Research work on helminth infestation of chickens was conducted in 2017-2019 in five economic regions of Azerbaijan: Apsheronsky, Sheki-Zakatalsky, Lenkoran-Astarsky, Guba-Khachmazsky and Aransky.

Fecal samples were examined by helminthoscopy according to the Füllerborn method, as well as by the method of successive washes. A total of 13,976 samples were examined. 6728 birds were examined by the incomplete helminthological autopsy method (IHA) according to K.I. Skryabin. Detected cestodes were preserved in 70% alcohol, nematodes - in Barbagallo liquid.

In order to identify age-specific infestation of chickens, helminthological studies were conducted in young chickens aged 2.5-5.0 and 5-7 months and in adults.

The following indicators were calculated based on the results of the work: infestation rate (IR) - the number of infested individuals in the bird population, %, infestation intensity (II) - variability of helminth numbers in the infested birds, pcs.

The species identity of helminths was established according to their morphological features using an identifier [11].

RESULTS AND DISCUSSION

In the poultry farms of Apsheronsky, Sheki-Zakatalsky, Lenkoran-Astarsky, Guba-Khachmazsky and Aransky economic regions, helminths of two classes (nematodes and cestodes) form a helminthic complex in chickens, with a clear dominance of nematodes. This extensive group of parasitic worms is the most diverse and is represented by four suborders and four species: *Ascaridata* (*Ascaridia galli*, Schrank, 1788), *Oxiurata* (*Heterakis gallinarum*, Gmelin, 1790), *Strongylata* (*Syngamus trachea*, Montagu, 1811) and *Trichocephalata (Capillaria obsignata*, Madsen, 1945). Tapeworms (class *Cestoda*, order *Cyclophylidea*, Braun, 1900) include one species, *Raillietina tetragona*, Molin, 1858.

Ascaridiosis, heterokidosis, syngamosis, capillariasis, and ryetinosis are widespread everywhere, but within the borders of economic regions the infestation of birds with individual helminth species varies.

Two nematode species, A. galli and H. gallinarum, are dominant in Azerbaijan. Their infestation of chickens Apsheronsky, Sheki-Zakatalsky, Lenkoran-Astarsky, Guba-Khachmazsky and Aransky districts is maximal and does not have significant interdistrict differences. The number of infected birds with ascariasis and heterokidosis varies from 32.6% (AI 1-28) to 41.2% (AI 1-188) and from 27.2 (AI 1-18) to 39.1% (AI 1-30), respectively. On average for the Republic of Azerbaijan, these indicators are 36.8 and 35.5% respectively (see Table). Average infestation by other helminths species including *S. trachea*, *C. obsignata* and *R. tetragona* was recorded at 18.9% (AI 1-28); 17.8 (AI 1-33) and 18.5% (AI 1-19), respectively, two times lower than by pathogens of ascariasis and heterokidosis.

The similar helminthological situation was in Aransky and Guba-Khachmazsky districts, but the poultry here had the lowest values of C. obsignata infestation extensiveness - 7.1% (CI 1-32 ind.) and 13.8% (CI 1-14 ind.) respectively.

The minimum indicators of the infestation of domestic chickens with syngamosis, capillariasis and rayetinosis were found in the Apsheronsky district. The infestation rate of poultry by the helminth infections is 13.7% (AI 1-6), 15.0% (AI 1-7) and 5.4% (AI 1-5) respectively, which is 2-4 times lower than in other economic areas. This peculiarity is most typical for geohelminths *S. trachea*, *C. obsignata*, developing with participation of reservoir hosts, and biohelminths *R. tetragona*, having intermediate hosts in their development cycle.

Thus, helminth infestations of chickens in the Republic of Azerbaijan are widespread. The species composition of helminth complex in economic areas is homogeneous and represented by four species of nematodes and one species of cestodes with a clear dominance of *A. galli* and *H. gallinarum*, having the highest and closest values of IR. Variability of infestation of birds with some helminth species is due to heterogeneity of climatic conditions, vertical zonality and formation of characteristic ecosystems that determine the distribution of biotopes of intermediate and reservoir hosts and density of their populations.

Significant interest is the understanding of the age dynamics of chicken infestation, by which we can judge both about the nature of the epizootic process and the effects of anthropogenic pressure. The results of the research indicate the infestation of poultry of all sex and age groups (see table). Maximum incidence of all nosoforms was recorded in chickens aged 2.5-5.0 months. Their infestation with nematodes *A. galli*, *H. gallinarum*, *S. trachea* and *C. obsignata*, and also with cestodes *R. tetragona* was 38.9; 40.8; 21.9; 19.7 and 20.9%, respectively. The helminth infestation of birds gradually decreases with age. The minimum values of IR in adult birds are 32.0; 30.8; 15.3; 16.2 and 16.0%.

CONCLUSIONS

1. In poultry farms of Azerbaijan the helminth complex of house chickens is represented by parasites of two classes: Nematoda, including four suborders and four species of parasitic multicellulars - *Ascaridata* (*Ascaridia galli*), *Oxiurata* (*Heterakis.gallinarum*), *Stron-*

Зараженность кур различных возрастных групп гельминтами в некоторых экономических районах Азербайджана
Infection of chickens of different age groups with helminths in some economic areas of Azerbaijan

Poultry age, months	Fecal samples examined	Examined by PHD technique, heads	Infested									
			A. galli		*H. gallinarum*		*S. trachea*		*C. obsignata*		*R. tetragona*	
			EI, %	II, pcs.	EI, %	II, pcs.	EI, %	II, pcs.	EI, %	II, pcs.	EI, %	II, pcs.
Apsheronsky region												
2,5–4,0	540	90	34,8	1–12	36,2	1–15	16,3	1–4	17,2	2–7	6,8	2–3
5–7	670	70	38,6	1–24	23,8	1–13	13,6	1–6	14,3	1–5	5,5	1–5
Adult livestock	475	55	24,4	1–15	21,7	1–18	10,7	2–4	13,6	1–6	4,0	1–3
Total	1685	215	32,6	1–28	27,2	1–18	13,7	1–6	15,0	1–7	5,4	1–5
Sheki-Zakatalsky region												
3–5	847	440	46,5	1–27	43,3	1–27	23,7	1–4	27,0	1–14	20,4	1–10
6–8	678	536	40,0	1–22	38,6	1–23	22,3	1–9	24,9	1–17	21,5	1–11
Adult livestock	781	542	33,6	2–28	33,9	2–30	19,8	1–7	21,2	1–19	16,7	1–12
Total	2306	1518	40,0	1–28	38,6	1–30	21,9	1–9	24,4	1–19	19,5	1–12
Lenkoran-Astarasky region												
2–4	611	83	44,1	1–87	36,0	2–67	22,5	1–28	30,9	4–33	24,4	2–13
6–8	465	85	40,3	1–62	36,2	2–75	18,1	1–21	27,8	1–23	19,5	1–9
Older than 8 months	360	75	34,9	4–69	30,3	1–91	19,4	1–16	27,7	1–18	18,4	1–5
Total	1436	243	39,8	1–87	34,2	1–91	20,0	1–28	28,8	1–33	20,8	1–13
Guba-Khachmazsky region												
2,5–5,0	1090	490	48,2	1–19	45,8	1–30	26,4	1–9	15,1	1–13	30,1	1–11
5–8	1297	459	38,9	1–28	36,9	1–23	21,3	1–19	14,6	1–12	21,7	2–8
Adult livestock	1225	386	36,4	1–881	34,5	1–24	15,2	1–9	11,6	1–14	22,6	1–7
Total	3612	1335	41,2	1–881	39,1	1–30	20,9	1–19	13,8	1–14	24,8	1–11
Aransky region												
3–5	1562	1282	48,5	1–97	43,1	1–97	20,9	1–27	8,4	2–32	23,1	1–17
6–8	1888	1141	39,8	1–113	38,4	1–53	18,6	1–18	5,9	1–24	24,5	2–13
Adult livestock	1487	994	30,5	1–87	33,8	1–46	11,2	1–22	7,1	1–19	18,4	1–19
Total	4937	3417	39,0	1–113	38,4	1–97	16,9	1–27	7,1	1–32	22,0	1–19
Throughout the Republic of Azerbaijan												
2,5–5,0	4650	2385	38,9	1–97	40,8	1–97	21,9	1–28	19,7	1–33	20,9	1–17
5–8	4998	2291	39,5	1–113	34,8	1–75	18,8	1–21	17,5	1–24	18,5	1–13
Adult livestock	4328	2052	32,0	1–881	30,8	1–91	15,3	1–22	16,2	1–19	16,0	1–19
Total	13976	6728	36,8	1–881	35,5	1–97	18,9	1–28	17,8	1–33	18,5	1–19

gylata (*Syngamus trachea*) and *Trichocephalata* (*Capillaria obsignata*) - and *Cestoda* of *Cyclophylidea*, *Raillietina tetragona* species. The taxonomic composition of helminth complex of domestic chickens in economic areas is characterized by relative stability.

2. Helminth infections of chickens are widespread in Azerbaijan, but the infestation of poultry by individual helminth species varies. Infestation of poultry with ascariasis and heterokidosis in economic areas is the highest and has no significant differences, infestation of other species is several times lower. The minimum infestation of chickens with C. obsignata is in Apsheronsky, Guba-Khachmazsky and Aransky districts, the infestation of R. tetragona in four economic districts of the republic is 15.0; 13.8; 7.1 and 5.4% respectively.

3. Age dynamics of chicken infestation is characterized by maximum infestation of young birds with helminths *A. galli*, *H. gallinarum*, *S. trachea*, *C. obsignata* and *R. tetragona*. Infestation of adults by these helminth infections decreases.

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ОЦЕНКА БИОЦИДНОГО ДЕЙСТВИЯ НАНОЧАСТИЦ МЕТАЛЛОВ И БИОЭЛЕМЕНТОВ В ОДНОКЛЕТОЧНОЙ ЭУКАРИОТИЧЕСКОЙ ТЕСТ-СИСТЕМЕ

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Представлены результаты исследования биоцидных свойств наночастиц серебра, меди и диоксида кремния. Рассмотрены вопросы о безопасности использования нанокомпонентов в связи с неизученным воздействием их на экологию. Для оценки биоцидного действия наночастиц благородных металлов и биоэлементов использована одноклеточная эукариотическая тест-система, представляющая собой реснитчатый протистный микроорганизм *Paramecium caudatum*, обитающий в прудовых водоемах. Установлено, что растворы наночастиц благородных металлов и биоэлементов не являются биоинертными и биостимулирующими. Коллоидные растворы наночастиц серебра, меди и кремния диоксида имеют биоцидное воздействие, проявляют схожий дозозависимый эффект при наличии одинаковых концентраций наночастиц в исходных коллоидных растворах (300 мкг/мл). Коллоидный раствор серебра характеризуется более выраженной токсической активностью в одноклеточной протистной биологической модели, так как полная биоцидность в отношении парамеций обеспечивается разведениями коллоидного раствора наночастиц до значения 1 : 6 от исходного. По сравнению с ним у растворов наночастиц меди и оксида кремния показатель биоцидности 100% достигается только в значениях двух- и трехкратного разведения исходного раствора. Коллоидные растворы наночастиц в концентрациях, не вызывающих полной гибели инфузорий (1 : 5 от исходной для наночастиц меди и оксида кремния и 1 : 7 от исходной для наночастиц серебра), угнетают интенсивность их размножения приблизительно на одинаковую величину в 55–61% (индекс интенсивности размножения парамеций от 0,455 до 0,390 соответственно).

Ключевые слова: наночастицы серебра, наночастицы меди, наночастицы кремния диоксида, биоцидность, инфузория-туфелька, *Paramecium caudatum*

ESTIMATION OF BIOCIDAL EFFECT OF METAL AND BIOELEMENT NANOPARTICLES IN A UNICELLULAR EUKARYOTIC TEST SYSTEM

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The results of the study of biocidal properties of silver, copper and silicon dioxide nanoparticles are presented. Questions about the safety of nanocomponents in connection with their unstudied impact on the environment are considered. To evaluate the biocidal effect of noble metal nanoparticles and bioelements, a unicellular eukaryotic test-system, represented by a ciliated protist microorganism Paramecium caudatum inhabiting pond water bodies, was used. It was found that solutions of noble metal nanoparticles and bioelements are not bioinert and biostimulating. Colloidal solutions of silver, copper and silicon dioxide nanoparticles have a biocidal effect and show a similar dose-dependent effect if the concentration of nanoparticles in the initial colloidal solutions is the same (300 μg/ml). The colloidal silver solution is characterized by a more pronounced toxic activity in a unicellular protist biological model, since full biocidal activity against paramecium is provided by dilutions of the colloidal solution of nanoparticles to the value 1: 6 of the initial one. Compared to it, solutions of copper nanoparticles and silicon oxide have a biocidal index of 100% achieved only in values of two- or three-times dilution of the initial solution. Colloidal solutions of nanoparticles in concentrations that do not cause complete mortality of the infusoria (1: 5 of the original for copper and silicon oxide nanoparticles and 1: 7 of the original for silver nanoparticles) inhibit their

reproduction intensity by approximately the same value of 55-61% (paramecium reproduction intensity index of 0.455 to 0.390 respectively).

Keywords: silver nanoparticles, copper nanoparticles, silicon dioxide nanoparticles, biocidal activity, ciliates, *Paramecium caudatum*

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INTRODUCTION

Nanotechnology has greatly expanded the use of materials based on nanocomponents, which inevitably leads to their impact on the environment. To date, the impact of nanoparticles on biosphere objects remains unstudied, since many substances can become biologically active if used in the form of nanoparticles [1, 2]. Studies of water-dwelling eukaryotes have shown that nanocomponents can disturb aquatic ecosystems [3].

Earlier studies evaluated the ecotoxic effects of xenobionic substances on multicellular test objects such as insects, fish and even rodents [4]. Nevertheless, protist organisms should be recognized as the most suitable test system for the evaluation of ecotoxic effects. This is especially true for aquatic environments [5], since protozoa are natural aquatic inhabitants. Protozoa have a high potential of bioadaptation to toxicants, they do not require the creation of special conditions of maintenance.

At present, only a limited number of scientific publications are available on the evaluation of the biocidal effect of nanoparticles in a single-cell test model [6-8]. It should be acknowledged that there is actually no unified methodology for the toxic evaluation of nanoparticles on unicellular eukaryotes. Many authors often use their own adaptations and variations of this technique.

In our experiments, the free-living ciliate infusoria *Paramecium caudatum* was used to study the eco- and cytotoxic effects of colloidal solutions of metal nanoparticles and bioelements. This representative of ciliates belongs to the number of highly organized protozoa and is a widespread inhabitant of freshwater reservoirs. This free-living prostite is often used to assess the toxicity of many natural and artificial compounds [9]. On the one hand, this microorganism has all the structural features of a cell, has autonomous existence in the external environment, and reacts to external stimuli as an independent organism. On the other hand, *Paramecium caudatum* infusoria is not demanding to the conditions of cultivation, so a large amount of laboratory data can be obtained using it [10].

Three types of nanoparticles were used as test substances: silver, copper and silicon dioxide. The first of them belongs to the category of noble metals, the others to the class of bioelements. This choice was determined by their relatively wide use in veterinary and medical practice. In addition, such a set of nano-substances most widely reflects the different classes of tested nanocomponents: silver is a noble metal, copper is a biometal, silicon dioxide is a bioelement from among the non-metals. The ecotoxicity of their nanoscale forms has not been previously studied, although their biocidal properties have been investigated [6, 11].

The purpose of the study is to evaluate the biocidal properties of silver, copper and silicon

dioxide nanoparticles on the unicellular eukaryotic test object *Paramecium caudatum*.

The objectives of the study are to carry out a rapid assessment of the biological activity of colloidal solutions of nanoparticles of metals and bioelements, determine the biological impact of the tested colloidal solutions of nanoparticles on the resistance of paramecium to negative external influences, evaluate their ecotoxicity by the intensity of suppression of paramecium reproduction.

MATERIAL AND METHODS

The evaluation of the biocidal effect of colloidal solutions of silver, copper and silicon dioxide nanoparticles on the free-living *Paramecium caudatum* infusoria was performed according to the methodological recommendations[1]. Parameciums were cultured in Lozina-Lozinsky medium (pH 6.2-7.8) and at 20-26 °C (control medium). *Rhadotorula gracilis* yeast with the addition of rice grains served as the food for the test object.

In the experiments, the integrated effect of various nanomaterials on a living protist cell was evaluated; therefore, the studies included three stages. At the first stage, an express-evaluation of the biological activity of colloidal solutions of silver, copper, and silicon dioxide nanoparticles was performed. All colloids had an initial concentration of nanoparticles of about 300 μg/ml.

4.2 ml each of *Paramecium caudatum* infusoria culture in the stationary phase of growth were poured into 54 test tubes. A well-known bactericide (norfloxacin) and an adaptogen (eleutherococcus) were used as controls. Equal volumes of colloidal solutions of nanoparticles were added to the first test tube, followed by stirring and obtaining a twofold dilution of their solution (1: 2). For mathematical recording and subsequent statistical processing, a 1 × n-1 record was used, where n denotes the degree of dilution, i.e., it represents the denominator in absolute terms (e.g., 1 × 2-1 for a 1: 2 dilution). By further adding the solvent (distilled water), dilutions of 1: 3; 1: 4, 1: 5, 1: 6, and 1: 7 nanoparticles, or in our mathematical notation from 1 × 3-1 to 1 × 7-1, were obtained. The test tubes were then placed for 24 h in a thermostat at 22 °C. The contents from each tube in the amount of 0.1 ml were transferred to microaquariums for microscopic evaluation. During microscopy, the number of paramecia was not less than 100.

The state of protist microorganisms was evaluated according to the following indicators: PN - indifferent (infusoria exhibit a markedly uniform Brownian motion, indistinguishable from that of the control); BA - bioactivity (increased intensity of infusoria movement); BC50 - biocidity (death of about half (50 ± 5%) of the infusoria population); BC100 - biocidity (death of almost the entire (90 ± 10%) population of infusoria); and control samples should contain not less than 100 infusoria performing a uniform Brownian motion.

At the next stage, we determined the biological activity of the colloidal nanoparticle solutions tested by the toxic load method after exposure to superhypertensive (with tenfold excess of isotonicity) sodium chloride solution (8%). For this purpose, we used four test tubes with 1 ml of control paramecium culture where 0.3 ml of 8% sodium chloride solution was added, causing the death of all infusoria within 5 min. Paramecium death was recorded in microaquariums under a light microscope using a minute timer in seconds. Then, we performed a similar experiment with cultures of parameciums of the first stage (after daily exposure of nanoparticles). Several observations were performed to obtain reliable experiment data.

The biological activity index (BAI) was calculated according to the formula

[1]Shabunin S.V. Screening of biostimulants and biocides (adaptogens, bactericides and other drugs): guidelines. Moscow; Voronezh: All-Russian Research Veterinary Institute of Pathology, Pharmacology and Therapy, 2006. 51 p.

$$IBA = \frac{TO}{TK}, \quad (1)$$

where BAI is the index of biological activity of the studied substance; TO is the life expectancy (in seconds) of parameciums under the action of 0.3 ml of 8% sodium chloride solution after their incubation for 24 h in Lozina-Lozinsky medium with the studied concentration of the nano-substance; TK is the life expectancy (in seconds) of paramecia under the action of 0.3 ml of 8% sodium chloride solution after incubation for 24 h in control medium (Lozina-Lozinsky medium).

After calculating the BAI index, we evaluated it. When the BAI value was 1.000 ± 0.1000, we considered the nanosubstance to be bioinert. A bioactivity index value higher than 1.000 ± 0.1000 indicated a positive effect of the tested substance on the resistance of paramecium to hypertensive shock. A bioactivity index value of less than 1.000 ± 0.1000 indicated a negative effect of the tested substance on the viability of parameciums.

At the last stage of the study we evaluated the biological activity of colloidal solutions of silver, copper and silicon dioxide nanoparticles by the intensity of paramecium reproduction after the exposure to sublethal (slightly below lethal) concentrations of nanoparticles. For this purpose, we used a culture of parameciums in the active growth phase after contact with the colloidal solution of nanoparticles under study. At the beginning of the experiment, the inoculum density (the number of parameciums in 1 ml of medium) was established. For this purpose, the number of infusoria cells in 1 ml of culture was determined: 20 microliters of 5% alcohol iodine solution was added to 1 ml of paramecium. Then, the contents were stirred, placed in a Fuchs-Rosenthal chamber, and the number of parameciums in 10 squares was counted, determining the average number of cells in one square. The volume of one square was one ten thousandth of a milliliter.

After incubating the test tubes in the thermostat at 22 °C for 72 h, the density of the inoculum was determined in each test tube.

The calculations were performed according to the formula

$$RRI = \frac{DIEA \times DICB}{DICA \times DIEB}, \quad (2)$$

where RRI is the paramecium reproduction rate index; DIEA is the density of the inoculum in the experiment after 72 h of incubation; DICB is the density of the inoculum in the control before incubation; DICA is the density of the inoculum in the control after 72 h of incubation; DIEB is the density of the inoculum in the experiment before incubation.

After calculating the index of paramecium reproduction rate, the cytotoxicity of the medium was evaluated based on the following values: if the index of paramecium reproduction rate was 1.000 ± 0.100, the chemical nanosubstance was considered biologically inert. A paramecium breeding intensity index value higher than 1.000 ± 0.100 indicated a stimulating effect of the nanosubstance on paramecium. When the value of the paramecium reproduction rate index less than 1.000 ± 0.100 was obtained, the inhibition of paramecium reproduction by the chemical nanosubstance was concluded.

RESULTS AND DISCUSSION

In the course of studies to assess the toxic effect of colloidal solutions of nanoparticles of metals and bioelements, initially qualitative results were obtained (see Table 1). They were evaluated by the characteristics of the Brownian motion of parameciums, and the toxic effect of the preparation was expressed in the slowing of protist movement, and the inhibition increased with prolongation of the exposure, but the final toxicity evaluation was performed after 24 h of exposure to the tested substance.

The results show that all tested colloidal solutions of nanoparticles have different biocidal activity: all tested samples of nanoparticles showed a high level of biocidal activity at the minimum dilution (1: 2), determined by

Табл. 1. Дозозависимое действие нановеществ на парамеции при экспозиции 24 ч (по критерию «концентрация – эффект»)

Table 1. Dose-dependent effect of nano-substances on parameciums at 24 h exposure («concentration-effect» criterion)

The substance under study	Biocidity in dilutions $1 \times n^{-1}$					
	n					
	2	3	4	5	6	7
Control	–	–	–	–	–	–
Eleutherococcus	–	–	–	–	–	–
Norfloxacin	+	+	±	±	±	±
Silver nanoparticles	+	+	+	+	+	±
Copper nanoparticles	+	+	±	±	–	–
Silicon dioxide nanoparticles	+	+	±	±	±	–

Note. Dash - no biocidal activity (NB): "±" - biocidal to 50% (less than BC50); "+" - biocidal to 100% (about BC100).

Табл. 2. Влияние нановеществ на резистентность парамеций (по критерию «концентрация – сопротивляемость токсической нагрузке»)

Table 2. Effect of nano-substances on the resistance of parameciums (according to the "concentration-resistance to toxic load" criterion)

The substance under study	Biological activity index in dilutions $1 \times n^{-1}$					
	n					
	2	3	4	5	6	7
Control	1,000	1,000	1,000	1,000	1,000	1,000
Eleuthero-coccus	1,480	1,560	1,918	1,334	1,016	1,002
Norfloxacin	–	–	0,698	0,854	0,957	1,000
Silver nanoparticles	–	–	–	–	–	0,499
Copper nanoparticles	–	–	0,589	0,655	0,789	0,856
Silicon diox-ide nanopar-ticles	–	–	0,455	0,578	0,675	0,745

Note. Dash - biocidal effect.

the state of activity of infusoria. The level of biocidal activity of silver nanoparticles was significantly higher compared to bioelements (copper and silicon dioxide) nanoparticles. The dilutions of silver nanoparticles solution 1: 2-1: 6 unambiguously demonstrated high biocidal effect against infusoria, only in the last dilution (1: 7) the biocidity fell below the BC50 value.

Solutions of copper nanoparticles caused complete death of infusoria only in small dilutions (1: 2-1: 3), with increasing dilution the bioactivity decreased sharply. Silicon dioxide nanoparticles had comparable biocidal activity, as paramecium mortality was observed in similarly high concentrations of nanoparticles (dilutions 1: 2-1: 3). The known biocide norfloxacin had comparable cytotoxicity. The solutions of bioinert nanoparticles at the highest dilution (1 × 7-1, or 1: 7) had no anti-protist effect, while silver nanoparticles at the highest dilution still failed to achieve bioinertness (mortality of infusoria at less than 50% of the population was observed).

At the second stage, the biological activity index of the tested nanoparticle samples was determined by the toxic load method (after adding a hypertonic sodium chloride solution, which has a membrane-damaging effect), in which the valeonegative (reducing the survival and viability of bioorganized systems) effect was evaluated. The results of these studies are shown in Table 2.

The obtained data indicate that of all substances used in the experiments only eleutherococcus has a valeopositive effect as it increases the resistance of paramecium cells to the toxic effects of superhypertensive medium (8% sodium chloride solution): the index of biological activity of the preparation was higher than 1.000 (from 1.002 to 1.918), and the greatest biostimulating effect on paramecia was demonstrated in the dilution of 1 : 4. In the experiment, the BAI index above unity indicates an increase in the life span of paramecium cells under the influence of the preparation and is expressed in the values of more than 100% protective activity. This result is quite expected, since eleutherococcus is a well-known adaptogen. The concept of an adaptogen, first proposed by Soviet scientists in the late 1950s, states that an adaptogen is any substance that affects a biological object, correcting any of its dysfunction and causing no undesirable side effects. The adaptogen-containing plant *Eleu-*

therococcus senticosus, also called "Siberian ginseng", contains a large number of chemical substances that have a protective and/or inhibitory effect against free radicals, and the list of such substances contained in Eleutherococcus is not fully defined [12].

The other tested components, including the known biocidal agent norfloxacin together with colloidal solutions of nanoparticles, had a strong biodegrading effect (bioactivity index value below 1.000). The BAI values indicate that nanoparticles have a more pronounced negative effect on the resistance of parameciums, since the coefficient of increase of endurance of infusoria after their exposure was slightly lower than that of norfloxacin (see Table 2). Objective comparison of the toxicity of the antibiotic (norfloxacin) and nanoparticles in this experiment is not quite correct, since these drugs are of completely different classes and have different expression rates for their concentrations. We were able to assess the effect of silver nanoparticles on the endurance of paramecium only in the maximum dilution of their solution (1: 7), because its lower values had an antiprotist effect. When comparing the BAI values of nanoparticles, a higher cytotoxicity of noble metal nanoparticles (index 0.499) compared to bioelements (copper and silicon) nanoparticles (0.856 and 0.745, respectively) was confirmed.

At the last stage of the integrated biotesting of nano-substances, their evaluation was carried out according to the index of paramecium reproduction rate. For this purpose, its values at addition of sublethal concentrations of tested substances are calculated. For all of them, a dilution of 1: 5 was taken, since it exceeded the lethal concentration (1: 3) by two points in all cases (except for silver nanoparticles), except for the adaptogen eleutherococcus which actually had no such concentration. The results of determining the biological activity of the colloidal nanoparticles under study at the optimal sublethal concentration by the intensity of paramecium reproduction are given in Table 3.

Eleutherococcus solution at a concentration of 1: 5 increases the intensity of paramecium division almost 1.6-fold (infusoria reproduction rate index 1.589), which is quite understandable from the expected adaptogenic effect of this component (see Table 3). The studied biocides (norfloxacin and colloidal solutions of nanoparticles) in concentrations that did not cause complete death of the infusoria inhibited their reproduction intensity by approximately the same amount - 55-61% (paramecium reproduction intensity index from 0.455 to 0.390, respectively). All tested nanoparticles in sublethal concentrations reduced the propagation intensity of protists by at least a half. However, an objective comparison in this case is possible only for bioelements, because only they were biotested in the same dilution (1: 5), while silver nanoparticles are initially more cytotoxic and therefore were taken in the experiment in a higher dilution (1: 7).

CONCLUSIONS

1. Biotesting of nanoparticles of metals and bioelements is reliably and qualitatively carried out on a free-living infusoria *Paramecium caudatum*, as it is an inexpensive convenient model for evaluation of biocidal action.

2. None of the solutions of noble metal nanoparticles and bioelements used in the ex-

Табл. 3. Влияние изучаемых препаратов в сублетальной концентрации на размножение инфузорий

Table 3. Effect of the studied preparations at sublethal concentration on the reproduction of infusoria

The substance under study	Optimal concentration (dilution $1 \times n^{-1}$)	Infusoria rate of propagation index
Control	–	1,000
Eleutherococcus	5	1,589
Norfloxacin	5	0,450
Silver nanoparticles	7	0,390
Copper nanoparticles	5	0,462
Silicon dioxide nanoparticles	5	0,385

periment can be recognized as bioinert or biostimulating in relation to the eukaryotic test object *Paramecium caudatum*.

3. Colloidal solutions of silver, copper and silicon dioxide nanoparticles have a biocidal effect, each of which exhibits a dose-dependent effect, with the former characterized by a much more pronounced toxic activity in a single-celled protist biological model.

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