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ВЛИЯНИЕ ТЕХНОЛОГИИ NO-TILL НА СОДЕРЖАНИЕ СУПРЕССИВНОЙ И ПАТОГЕННОЙ МИКРОФЛОРЫ В ПОЧВЕ

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Представлены результаты исследований в длительном (2012–2021 гг.) стационарном опыте по формированию почвенной биоты при возделывании сельскохозяйственных культур по технологии No-till в сравнении с традиционной технологией в Ставропольском крае. В эксперименте использованы одинаковые сорта и гибриды, дозы минеральных удобрений, сроки посева, нормы высева семян, способы борьбы с сорняками и вредителями. Установлено, что постоянно находящиеся на поверхности почвы растительные остатки при технологии No-till способствуют большему размножению почвенной микрофлоры, которая сдерживает развитие патогенной микробиоты, чем при технологии с обработкой почвы. Поэтому в этой технологии после двух ротаций четырехпольного плодосменного полевого севооборота (соя – озимая пшеница – подсолнечник – кукуруза) в 1 г почвы содержалось 13 125 колониеобразующих единиц (КОЕ) патогенных микроскопических грибов родов *Fusarium, Alternaria, Cladosporium* и *Cephalosporium*. В рекомендованной технологии их разнообразие увеличилось до пяти (добавился род *Verticillium*) и количество возросло до 24 125 КОЕ/г. Сапрофитная микрофлора в рекомендованной технологии представлена двумя родами микромицетов (*Penicillium* и *Aspergillus*) численностью 48 250 КОЕ/г. В технологии No-till, кроме указанных, присутствовали грибы рода *Trichoderma* и их общая численность составила 56 750 КОЕ/г. В рекомендованной технологии количество сапрофитной микрофлоры зарегистрировано больше, чем патогенной, в 1,9 раза, в технологии No-till – в 4,3 раза. По этой причине в технологии No-till не отмечено увеличения заболеваемости возделываемых культур по сравнению с рекомендованной технологией, и урожайность в среднем за две ротации севооборота была выше в технологии No-till.

Ключевые слова: рекомендованная технология, технология No-till, растительные остатки, супрессивная микрофлора, патогенная микрофлора, корневые гнили, урожайность

THE EFFECT OF NO-TILL TECHNOLOGY ON THE CONTENT OF SUPPRESSIVE AND PATHOGENIC MICROFLORA IN THE SOIL

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The paper presents the results of research in a long-term (2012-2021) stationary experiment on the formation of soil biota in the cultivation of crops by No-till technology compared with conventional technology in the Stavropol Territory. The same varieties and hybrids, doses of mineral fertilizers, sowing dates, seed rates, weed and pest control methods were used in the experiment. It was found

that plant residues that permanently remain on the soil surface in the No-till technology contribute to greater proliferation of soil microflora, which inhibits the development of pathogenic microbiota stronger than in the technologies with tillage. Therefore, after two rotations of the four-field crop rotation soybean-winter wheat-sunflower-corn, 13 125 colony-forming units (CFU) of pathogenic microscopic fungi of *Fusarium*, *Alternaria*, *Cladosporium* and *Cephalosporium* were found in 1 g of soil in this technology. In the recommended technology, their diversity increased to five (the genus *Verticillium* was added) and their number increased to 24,125 CFU/g. The saprophytic microflora in the recommended technology was represented by two genera of micromycetes *Penicillium* and *Aspergillus* with 48 250 CFU/g, while in the technology No-till, in addition to these fungi the fungi of the genus *Trichoderma* were present, and their total number was 56 750 CFU/g. That is, in the recommended technology, the quantity of saprophytic microflora was recorded 1.9 times, and in No-till technology 4.3 times higher than the pathogenic microflora. For this reason, the No-till technology did not increase the incidence of diseases of cultivated crops compared to the recommended technology, which had no significant impact on the yield, which on average for two rotations of crop rotation was higher in the No-till technology.

Keywords: recommended technology, No-till technology, plant residues, suppressive microflora, pathogenic microflora, root rot, yield

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INTRODUCTION

Many researchers have established that prolonged cultivation of crops using the No-till technology improves the water-physical [1, 2], chemical properties of the soil and increases its fertility [3, 4], which occurs due to the presence of crop residues of cultivated crops on the surface [5, 6].

However, the plant residues create favorable conditions for the reproduction of microflora, including pathogenic, which, according to some scientists, can cause a significant increase in plant disease and lead to lower yields and economic efficiency of crops cultivated by this technology [7].

The aim of the research is to establish the effect of No-till technology on the content of suppressive and pathogenic microflora in the soil, lesion of the cultivated crops with diseases and their yields in the unstable moisture zone of the Stavropol Territory.

MATERIAL AND METHODS

Field experiments were carried out in the North Caucasian Federal Research Agrarian Center. The experimental field of the institute is located in the zone of unstable moisture of the Stavropol Territory. The sum of effective temperatures here is 3306°, the annual precipitation is 558 mm. The soil of the experimental plot is slightly humic heavy-loamy ordinary medium chernozem.

The research was conducted in four-field crop rotation soybean - winter wheat - sunflower - corn, which was established in 2012. All the crops of the crop rotation in the first variant were cultivated according to the technology recommended by scientific institutions with tillage (surface tillage for winter wheat and mouldboard tillage for other crops), in the second variant - by No-till technology.

The same doses of mineral fertilizers were applied as recommended by scientific institutions for both technologies for all the crops

studied in the experiment. Terms of sowing, seed rates, varieties and hybrids, as well as the methods of weed and pest control during vegetation of cultivated crops in both technologies were also the same. However, in the No-till technology after harvesting one crop and before sowing the next one, plots were sprayed with a total action herbicide from the glyphosate group (after harvesting soybeans and before sowing winter wheat, no such treatment was carried out) to kill the emerged weeds.

In the recommended technology, sowing of all crops was carried out with seed drills that sowed seeds into the tilled soil. In the No-till technology - Gimetal seeder is used equipped with corrugated discs (coulter, turbo disc) that cut a narrow slot in the uncultivated soil into which seeds and fertilizers are sown to the desired depth with two disc coulters. No biological or other preparations containing microflora or affecting its composition and quantity were used during all years of research.

In all years of the research, the amount of plant residues on the soil surface was counted after harvesting one crop and before sowing the next crop of the crop rotation. Yield accounting and mathematical processing of the obtained data were carried out by the methods generally accepted in experimental work.

At the end of the second rotation of the crop rotation (autumn 2020), soil samples were taken at the depth of 0-20 cm, in which the amount of suppressive and pathogenic microflora was determined. Microbiological analysis was carried out using a water-soil suspension applied on a common Czapek's selective nutrient medium. The microorganisms were cultured for 7 days at 25 °C.

Weather conditions of the studies had their own peculiarities and differed from year to year. According to the amount of precipitation, 2013, 2014, 2016 and 2017 were more humid, when with the average annual precipitation of 558 mm, it fell from 626 to 652 mm. In 2015 and 2018, their amount was close to the mean annual values (528 and 544 mm), 2019 was marked as dry (380 mm of precipitation) and the year 2020 was acutely dry (307 mm).

RESULTS AND DISCUSSION

During the harvesting of crops cultivated in the experiment, all the above-ground mass of plants was shredded and uniformly distributed across the width of the plot by the combine harvester. On average, for two rotations of crop rotation (8 years) in both technologies, plant residues annually came to the soil surface - according to the recommended technology 4.60 t/ha, under No-till technology 5.22 t/ha. However, in the recommended technology by the sowing of the next crops of the crop rotation, on average, they remained 0.12 t/ha of the crop rotation area, whereas the No-till technology by that time had 3.28 t of plant mulch/ha on the soil surface, which is 62.8% of their original amount.

In the first case, a very small amount of plant residues on the soil surface is associated with mouldboard tillage for soybeans and row crops and surface tillage after harvesting soybeans, some of whose plant residues (0.36-0.63 t/ha) mixed with soil were observed before sowing winter wheat. In the No-till technology, the decrease in the amount of plant mulch on the soil surface by 1.94 t/ha, or 37.2%, during a fairly short post-harvest autumn and early spring period before sowing spring crops is due to the high number and activity of soil microbiota that decompose plant residues, which are a nutrient substrate for them.

In the studies of D.A. Nikitin and colleagues [8] conducted in our experiment, the number of soil microflora species in conventional technology was higher than in No-till technology at the end of the first rotation of four-field crop rotation. The authors attribute this to the better oxygen supply of mouldboard-tilled soil. But there are more pathogenic species of micromycetes in cultivated soil, whereas in No-till technology cellulolytic (representatives of genera *Chaetomium, Sarocladium, Trichoderma, Zygorhynchus*) and oligotrophic/saprotrophic (species of genera *Aspergillus, Paecilomyces, Penicillium, Pseudogymnoascus*) micromycetes prevail in abundance, number and taxonomic diversity.

According to the researchers' data, the biomass of microorganisms, the total microbial and enzymatic activity are significantly higher

with a longer application of the No-till technology than in the technologies with tillage [9, 10]. The increase in the number and activity of microbiota in the No-till technology, in turn, led to a decrease in the number of pathogenic microflora [11]. The researchers explain the growth of microorganisms in the soil in No-till technology by the constant presence of plant residues on the soil surface, which are a nutrient substrate for them [12]. The presence of moisture in the soil under the layer of plant mulch, which does not allow direct sunlight to penetrate and reduces the air and soil temperature during the hot season, creates favorable conditions for the reproduction and development of suppressive microflora, which suppresses the development of pathogenic microorganisms [13]. This is facilitated by the development of the No-till technology of crop rotation, which provides biological diversity of plant communities and, as a consequence, the same diversity of soil microflora [14].

In our experiments after the second rotation of four-field crop rotation, pathogenic microflora was represented by five genera of microscopic fungi which, releasing toxic substances into the soil, affect mainly the root and root systems of plants and cause soil mycotoxicosis. The most numerous were fungi of the genus *Fusarium* and *Alternaria*, which were found in the soil under all crops of the crop rotation cultivated by both technologies. However, the recommended technology yielded 14,000 and 6,875 colony-forming units per 1 g of soil (CFU/g), respectively, and the No-till technology had yields of 6125 and 4,635 CFU/g, or significantly less (by 7,875 and 2,240 CFU/g, or 56.2% and 32.6%) (see Table 1).

It should be noted that the increased content of *Fusarium* and *Alternaria* fungi in soil carries a high risk of reducing the productivity of agrocenoses, including the emergence of fungicide-resistant strains [15, 16].

Cladosporium, Verticillium and *Cephalosporium* pathogenic fungi were also found, which were also more in number using the recommended technology. The average number of colony-forming units of pathogenic micromycetes per 1 g of soil for the recommended technology was 24 125, for No-till technology - 13 125, or 1.8 times less. At the same time, the total content of pathogenic microorganisms under all crops in the rotation in the recommended technology was significantly higher than in the No-till technology.

Supressive (beneficial) microflora represented by saprotrophic fungi of genera *Penicillium, Aspergillus* and *Trichoderma* were more

Табл. 1. Влияние технологии возделывания на содержание патогенной микробиоты в слое почвы 0–20 см после второй ротации четырехпольного севооборота, КОЕ/г

Table 1. Influence of cultivation technology on the content of pathogenic microbiota in the soil layer 0–20 cm after the second rotation of the four-field crop rotation, CFU/g

Technology	Culture	Micromycete genus					Total
		Fusarium	*Altenaria*	*Cladosporium*	*Verticillium*	*Cephalosporium*	
Recommended	Peas	9000	6500	0	0	500	16 000
	Winter wheat	16 500	6000	0	2000	5500	29 000
	Sunflower	30 000	7000	3000	0	0	40 000
	Corn	500	8000	3000	0	0	11 500
No-till	Peas	4500	5000	0	0	0	9500
	Winter wheat	4000	4500	4500	0	0	13 000
	Sunflower	13 000	5000	2000	0	0	20 000
	Corn	3000	4000	1500	0	1500	10 000
LSD_{05} of the technology		895	465	–	–	–	1517
LSD_{05} of the culture		728	324	–	–	–	1248
LSD_{05} of partial differences		1237	771	–	–	–	1835

in No-till technology - 56 750 CFU/g against 48 250 CFU/g in the recommended technology. The difference in the number of saprophytic microflora under all crops, except sunflower, was mathematically proved to be greater in the No-till technology (see Table 2).

The most numerous of all micromycetes for both technologies was a fungus of the genus *Penicillium*, which was on average 35,875 CFU/g in the recommended technology, and 50,750 CFU/g in the No-till technology, which is 14,875 CFU/g, or 41.5% more. The number of *Penicillium* and *Aspergillus* fungi under all crops was significantly higher in the No-till technology, and Trichoderma micromycetes was isolated only after peas cultivated using the same technology.

In the recommended technology the number of saprophytic microflora was higher (1.9 times) than pathogenic, and in the No-till technology - 4.3 times. Therefore, in the No-till technology it is more difficult for infectious pathogens to develop in the soil, since suppressive micromycetes in the process of life synthesize antibiotic substances that have a detrimental effect on phytopathogenic microflora. This is evidenced by the results of observations on the development of diseases of cultivated crops. In the years of experiments on both technologies root rot affected from 1.4 to 5.3% of plants of winter wheat, which had no significant effect on its yield. On average over two rotations of the crop rotation it was 4.24 t/ha using the recommended technology and 5.03 t/ha using No-till technology, which was reliably higher by 0.79 t/ha or 18.6%. This pattern was observed in all years of the experiments. Other crops of the crop rotation were also affected by diseases, especially in wet years, but epiphytoties did not exceed the threshold of economic pest damage for both technologies, and the yield of No-till technology was not inferior to that of the recommended technology and even exceeded it. The yield of soybean by the recommended technology was 1.85 t/ha, by No-till technology - 1.89, sunflower respectively 1.79 and 1.85, and corn - 3.48 and 3.83 t/ha.

Similar results were observed under the production conditions of the No-till technology. At LLC "Urozhaynoe" of Ipatovsky district of the Stavropol Territory, which has been cultivating all crops using No-till technology since 2008, the average yield of winter wheat over 9 years (2012-2020) was 4.60 t/ha. In four neighboring stable working farms of the same district, producing crops by traditional technologies with tillage, it was 3.94-4.26 t/ha. Sunflower yields in these years were 2.55 and 1.47-1.61 t/ha, respectively [17].

Табл. 2. Влияние технологии возделывания на содержание супрессивной микробиоты в слое почвы 0–20 см после второй ротации четырехпольного севооборота, КОЕ/г

Table 2. Influence of cultivation technology on the content of suppressive microbiota in the soil layer 0–20 cm after the second rotation of the four-field crop rotation, CFU/g

Technology	Culture	Micromycete genus			Total
		Penicillium	*Aspergillus*	*Trichoderma*	
Recommended	Peas	29 500	6000	0	35 500
	Winter wheat	27 500	4000	0	31 500
	Sunflower	24 500	500	0	25 000
	Corn	62 000	39 000	0	101 000
No-till	Peas	17 000	2500	500	20 000
	Winter wheat	52 500	1500	0	54 000
	Sunflower	22 500	3500	0	26 000
	Corn	111 000	16 000	0	127 000
LSD_{05} of the technology		3869	1090	–	4320
LSD_{05} of the culture		3128	995	–	3880
LSD_{05} of partial differences		4950	1495	–	5250

CONCLUSION

When crops are cultivated using No-till technology, plant residues constantly on the soil surface contribute to greater reproduction of soil microbiota, which restrains the development of pathogenic microflora, than under the recommended technologies with soil tillage. Therefore, the number of pathogenic microscopic fungi in No-till technology is significantly lower and the number of suppressive microflora is higher than in the cultivated soil, which restrains plant disease affection and contributes to higher yields of crops cultivated by this technology.

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ПРИЕМЫ ПОВЫШЕНИЯ ПРОДУКТИВНОСТИ ГОРЧИЦЫ БЕЛОЙ В УСЛОВИЯХ СРЕДНЕГО ПОВОЛЖЬЯ

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Представлены результаты изучения использования микроудобрений и регуляторов роста для повышения продуктивности и качественных показателей горчицы белой. Исследования проводили в условиях лесостепи Среднего Поволжья в 2019–2021 гг. Применение биологических препаратов оказывало влияние на интенсивность начального роста горчицы. Наибольшие показатели силы роста семян горчицы отмечены на вариантах с Изагри Вита и Мегамиксом, длина проростков существенно превышала контрольный вариант на 0,63–0,97 см. Данные препараты стимулировали увеличение всхожести семян на 2,66–2,98% относительно к контролю (94,68%). Урожайность горчицы в среднем за 3 года составила 1,39–1,59 т/га. Изучаемые препараты способствовали увеличению продуктивности на 0,02–0,20 т/га относительно контрольного варианта. Наиболее эффективными являются Изагри Вита и Агроверм, применение которых позволило получить прибавку урожая горчицы на 0,17–0,20 т/га. Наибольшая масличность семян отмечена на вариантах с регуляторами роста Альбит (26,70%) и Циркон (26,99%), что было выше контрольного варианта на 1,44 и 1,73%. Морфометрические показатели растений горчицы также изменялись в зависимости от применения стимуляторов роста. Применение Циркона способствовало увеличению высоты растений (до 102,6 см) и образованию наибольшего числа стручков на одном растении (194,1 шт.). Использование Агроверма позволило образованию максимального количества ветвей (10,3 шт.). На вариантах с обработкой Мегамиксом и Гуматом+7 сформировались наиболее крупные семена, масса 1000 семян составила 6,82 и 6,79 г. Все изучаемые препараты способствовали снижению процентной концентрации линоленовой кислоты до 9,56–10,28%. Обработка препаратом Агрика максимально увеличивает содержание эруковой кислоты до 36,20%, препаратом Циркон – олеиновой кислоты до 31,20% и снижает концентрацию линолевой и линоленовых кислот на 8,0 и 1,52%. Применение микроудобрений и регуляторов роста может выступать в качестве приемов повышения продуктивности горчицы белой.

Ключевые слова: горчица белая, микроудобрения, регуляторы роста, продуктивность, масличность, жирнокислотный состав, посевные качества

METHODS OF INCREASING THE PRODUCTIVITY OF WHITE MUSTARD IN THE CONDITIONS OF THE MIDDLE VOLGA REGION

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The results of the study of the use of microfertilizers and growth regulators to improve productivity and quality indicators of white mustard are presented. The research was conducted in the forest-steppe

conditions of the Middle Volga region in 2019-2021. The use of biological preparations influenced the intensity of initial growth of mustard. The highest rates of mustard seeds growth force were noted in the variants with Izagri Vita and Megamix, the length of the seedlings significantly exceeded the control variant by 0.63-0.97 cm. These preparations stimulated an increase in seed germination by 2.66-2.98% relative to the control (94.68%). Mustard yields averaged 1.39-1.59 t/ha over three years. The studied preparations contributed to an increase in productivity by 0.02-0.20 t/ha with respect to the control variant. The most effective are Izagri Vita and Agroverm, the use of which allowed to get an increase in the mustard yield by 0.17-0.20 t/ha. The highest oil content of seeds was observed in the variants with the growth regulators Albit (26.70%) and Zircon (26.99%), which was higher than the control variant by 1.44 and 1.73%. Morphometric indices of mustard plants also changed depending on the application of the growth stimulants. The application of Zircon contributed to an increase in the plant height (up to 102.6 cm) and the formation of the highest number of pods per plant (194.1 pcs). The use of Agroverm allowed the formation of the maximum number of branches (10.3 pcs). The variants treated with Megamix and Humate +7 formed the largest seeds, the weight of 1,000 seeds was 6.82 and 6.79 g. All of the studied preparations contributed to a decrease in the percentage concentration of the linolenic acid to 9.56-10.28%. Treatment with Agrika maximizes the content of erucic acid to 36.20%, with Zircon - oleic acid to 31.20% and reduces the concentration of linoleic and linolenic acids by 8.0 and 1.52%. The use of microfertilizers and growth regulators can act as methods of increasing the productivity of white mustard.

Keywords: white mustard, microfertilizers, growth regulators, productivity, oil content, fatty acid composition, sowing qualities

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INTRODUCTION

Increased productivity of crops is provided by expanding the sown areas, development of optimal cultivation technology, creation of new varieties characterized by resistance to adverse environmental factors [1]. Currently, the trend of modern agriculture development in the direction of biologization involves the transition to more environmentally friendly agricultural technologies, which include the use of safe biological preparations as a factor contributing to the stress tolerance of plants, their productivity and efficiency of agricultural production in general [2]. Every year, the range of biological preparations of different chemical nature (microfertilizers, growth regulators) with a wide spectrum of action is expanding, and they are increasingly used in crop production practice. Their use, in small doses too, helps to stimulate the growth processes of plants and their protection from abiotic stresses, increasing soil fertility and obtaining high yields at lower costs [2, 3].

There is experience in applying microfertilizers to individual crops, including cereals and legumes [4, 5], oilseed flax [6], rapeseed [7], etc. [8, 9]. Studies show that the application of microfertilizers and growth regulators had a positive effect on the adaptive abilities

of plants, on changes in growth processes, and contributed to an increase in photosynthetic activity, seed coarseness, and seed yield [4, 10]. The use of biological complexes did not affect the biometric indicators of plants, but had an impact on product quality and plant resistance to disease and pest damage [3, 11].

White mustard (*Sinapis alba*) is currently one of the most used crops by humans, the most important source of oil seeds, green fodder and green fertilizer [12]. Potential productivity of mustard reaches 2.0 t/ha with up to 25-35% oil content in its seeds, which is used in many industries [13]. Mustard oil has high taste qualities and is used directly for food purposes, as well as in cannery, confectionery and baking industries [14]. The oil of most white mustard varieties contains up to 24-57% erucic acid and 15-36% oleic acid and is used in technical industry and for biodiesel production [15]. In addition, in agronomy mustard is used as a green fertilizer. Its biomass, having phytomeliorative and phytosanitary properties, has a positive effect on soil fertility [13, 16].

White mustard belongs to the early spring crops and is characterized as a crop capable of adapting to different growing conditions [14, 17]. However, its productivity largely depends on the elements of cultivation technology.

The use of micronutrient preparations for cruciferous crops, including mustard [18], is insufficiently studied at present, with few studies conducted in other agroclimatic conditions.

The aim of the research is to study the effect of microfertilizers and growth regulators on productivity and quality indicators of white mustard in the forest-steppe conditions of the Middle Volga region.

MATERIAL AND METHODS

Studies were conducted in 2019-2021 in the fields of the Federal Scientific Center for Bast Crops (Penza Research Institute of Agriculture). The object of the research was white mustard variety Lucia. The experiment consisted in pre-sowing treatment of mustard seeds with microfertilizers and growth regulators at the rate of 1.0 l / t, Albit - 0.5 l / t. The field experiment scheme included the following variants: 1. Control (no treatment); 2. Gumat+7; 3. Agroverm; 4. Izagri Vita; 5. Megamix; 6. Zircon; 7. Agrika; 8.

The growing season of mustard in 2019 proceeded in dry conditions, the HTC was 0.65. The growing season of the crop in 2020 was characterized by a slight deficit of precipitation, HTC = 0.72. Conditions of 2021 were more favorable for crop development and were characterized as moderately arid (HTC = 0.80).

Mustard was sown according to optimal technological parameters: sowing date - early (I ten-day period of May), method of sowing - in-line, seeding rate - 2.0 million germinated seeds/ha. Total area of the plot is 10 m^2, repetition of the experiment is 4 times. Plot placement is systematic. The forecrop was pure fallow.

Setting up the experiment, all yield records, phenological observations and analyses were carried out according to the methodological recommendations[1].

RESULTS AND DISCUSSION

Initial changes occurring in seeds after their treatment with biologically active preparations have a great impact on the further stage of development of the adult organism and on the productivity of the plant as a whole.

The results of laboratory studies showed that treatment of mustard seeds with microfertilizers and growth regulators had a positive effect on the sowing qualities of seeds, provided higher rates and increased intensity of initial growth.

The most effective in treatment of mustard seeds were Izagri Vita and Megamix, application of which stimulated laboratory germination of seeds by 2,66-2,98% relative to the control (94,68%) with the least significant difference of 1,45%. It should be noted that the germination energy of treated seeds significantly increased by 2,06-5,66% relative to the control. It was the highest when using the microfertilizer Izagri Vita (73,56%) and Agroverm (74,56%) (see Table 1).

[1]Methodology of field and agrotechnical experiments with oil crops. Krasnodar: VNIIMK, 2010. 323 p.

All seeds treated with growth stimulants had strong seedlings with a length of 2.67-3.64 cm according to growth force evaluation criteria. However, the greatest length of seedlings (3.30; 3.60 and 3.64 cm) were variants with Megamix, Izagri Vita and Agroverm. Initial growth rates here significantly exceeded the control variant by 0.63-0.97 cm with the smallest significant difference of 0.47 cm.

The revealed pattern was also observed in the weight of 100 sprouts. Under the influence of the above microfertilizers maximum values on the weight of 100 sprouts (4,86 and 5,62 g) were noted, which exceeded the control by 19,1-37,7%. Application of Gumat+7 and Agrika contributed to an insignificant increase in the weight of 100 sprouts by 0.54-0.64 g at the value of LSD_{05} = 0.69 g.

Mustard yields averaged 1.39-1.59 t/ha in 3 years, the preparations used increased productivity by 0.02-0.20 t/ha relative to the control variant (see Table 2).

The variants with Gumat+7 and Megamix had insignificant increase in the yield, only by 0.10 and 0.11 t/ha. The variants with treatment with microfertilizer Agrika and growth regulators Zircon and Albit showed statistically insignificant increase in seed yield by 0.02 - 0.06 t/ha ($LSD_{0.5}$ = 0.09 t/ha).

The most effective were the variants with the use of microfertilizers Izagri Vita and Agroverm, where the highest seed yield was formed (1.56 and 1.59 t/ha) and the highest overall responsiveness of the crop to the application of these biological preparations was noted, the responsiveness index was 0.08 and 0.11 respectively. It shows that on these variants the plants not only more effectively absorb the elements of mineral nutrition from soil and microfertilizers, but also synthesize more organic matter per unit of the absorbed element than on other variants.

Oil content in mustard seeds varied from 25.26 to 26.99%. All the studied preparations contributed to a greater or lesser extent to the oil content of seeds. Seed treatment with biopreparations Gumat+7, Agroverm and Agrika did not significantly increase oil content; the percentage increase relative to the control variant was 0,18-0,44 while LSD05 = 0,94. The most significant increase in oil content in seeds was noted in the variants with treatment with Megamix, Albit and Zircon, where the increase was 1,16; 1,44 and 1,73% respectively. Application of the microfertilizer Izagri Vita insignificantly increased the oil content of seeds (by 1.0%), which was within the smallest significant difference.

Morphometric traits of mustard plants also varied depending on the application of growth stimulants. For example, plant height ranged from 87.3 cm to 102.6 cm, the coefficient of variation was 12.56%. The use of the biological drug Zirkon stimulated the greatest growth of mustard plants, the height was 102.6 cm with a height of 91.3 cm in the control variant. When using Izagri Vita, Agrika and Albit, the height of mustard plants even decreased to 87.3-89.8 cm compared to the variant without treatment (see Table 3).

Табл. 1. Посевные качества горчицы белой в зависимости от обработки микроудобрениями (2019–2021 гг.)

Table 1. Sowing qualities of white mustard depending on the treatment with microfertilizers (2019–2021)

Option	Spread		Germination energy, %	Laboratory germination, %
	Seedling length, cm	Weight of 100 seedlings, g		
Control	2,67	4,08	68,90	94,68
Humate+7	2,88	4,62	71,89	96,91
Zircon	2,78	4,20	72,63	95,34
Agroverm	3,64	5,62	74,56	95,34
Izagri Vita	3,60	4,86	73,56	97,34
Megamix	3,30	4,86	71,25	97,66
Agrika	2,67	4,72	70,96	96,91
Albit	2,70	4,18	72,51	95,71
LSD_{05}	0,47	0,69	2,03	1,45

Табл. 2. Продуктивность горчицы в зависимости от применения микроудобрений (2019–2021 гг.)
Table 2. Productivity of mustard depending on the use of microfertilizers (2019–2021)

Option	Yield, t/ha	Yield increase, t/ha	General response	Oil content, %
Control	1,39	–	–0,09	25,26
Humate +7	1,49	0,10	0,01	25,70
Agroverm	1,59	0,20	0,11	25,67
Izagri Vita	1,56	0,17	0,08	26,26
Megamix	1,50	0,11	0,02	26,42
Zircon	1,45	0,06	–0,03	26,99
Agrika	1,42	0,03	–0,06	25,44
Albit	1,41	0,02	–0,07	26,70
LSD_{05}	0,09	–	–	0,94

The greatest number of branches was observed in the variants with treatment with Megamix (9.4 pcs), Izagri Vita (9.4 pcs) and Agroverm (10.3 pcs). The maximum number of pods per plant (194.1 pcs) was in the variant with Zircon. At the same time, the number of seeds in a pod practically did not depend on microfertilizers and averaged 5.2- 5.8 units. Productivity per plant increased depending on the studied preparations, the weight of seeds per plant was 4.13-4.74 g, which exceeded the control by 0.14-0.75 g.

Mustard seed fineness changed little depending on the applied preparations, the coefficient of variability of this trait was low (3.22%). The weight of 1000 seeds varied from 6.32 to 6.82 g in the treated variants with 6.26 g in the control. The largest seeds were formed on the variant with treatment with Megamix (6.82 g) and Gumat+7 (6.79 g). In addition, the studied preparations affect the quality of oil. Treatment with Zircon increased the oleic acid content up to 31,20% while it decreased the concentration of linoleic and linolenic acids by 8,0 and 1,52% compared to the control (see table 4).

The use of Agrika maximizes the percentage of erucic acid (up to 36.20%) and minimizes the content of saturated acids (up to 3.52%). The highest content of linolenic acid was observed in the variant without treatment. All the preparations studied contributed to a decrease in the percentage concentration of this acid to 9.56-9.92%, except for Megamix and Agrika, where its content was 10.20 and 10.28%, respectively.

CONCLUSION

Application of microfertilizers and growth regulators to varying degrees affects the productivity, quality and sowing properties of white mustard and can act as methods of increasing

Табл. 3. Элементы структуры урожая горчицы в зависимости от применения микроудобрений (2019–2021 гг.)
Table 3. Elements of mustard yield structure depending on the application of microfertilizers (2019–2021)

Option	Plant height, cm	Number per plant, pcs.			Weight, g	
		branches	seedpods	seeds in a pod	seeds per one plant	1000 seeds
Control	91,3	8,8	135,1	5,3	3,99	6,26
Humate +7	92,6	7,9	139,8	5,4	4,16	6,79
Zircon	102,6	8,5	194,1	5,8	4,53	6,56
Agroverm	97,8	10,3	169,2	5,4	4,74	6,47
Izagri Vita	89,6	9,4	146,9	5,2	4,71	6,57
Megamix	96,4	9,4	176,0	5,6	4,18	6,82
Agrika	89,8	7,9	151,5	5,2	4,67	6,41
Albit	87,3	7,1	168,4	5,3	4,13	6,32
V, %	12,56	27,15	23,73	4,44	22,11	3,22

Табл. 4. Содержание основных жирных кислот в маслосеменах горчицы в зависимости от микроудобрений, %

Table 4. The content of essential fatty acids in mustard oilseeds depending on microfertilizers, %

Option	Acid				
	saturated	olein	linoleic	linolenic	erucic
Control	3,61	21,75	19,66	11,04	28,13
Humate +7	3,72	30,99	10,26	9,56	30,45
Agroverm	3,52	29,20	9,86	9,90	32,42
Izagri Vita	3,74	30,68	10,80	9,58	30,44
Megamix	3,52	29,16	9,57	10,20	32,65
Zircon	3,80	31,20	11,26	9,52	29,06
Agrika	3,52	25,13	10,07	10,28	36,20
Albit	3,71	30,18	10,63	9,92	30,96

its productivity. The most effective are Isagri Vita and Agroverm, the use of which has provided an increase in mustard yield by 0.17-0.20 t / ha compared with the control variant. The use of Megamix, Albit and Zircon increased the oil content of seeds by 1.16-1.73%. The largest seeds were formed on the variants with treatment with Megamix and Gumat+7, the weight of 1000 seeds was 6,82 and 6,79 g. The highest intensity of mustard seed germination was noted on the variants with Izagri Vita and Megamix where the rates of initial growth and germination significantly exceeded the control variant by 0,63-0,97 cm and 2,66-2,98%.

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СЕЛЕКЦИОННО-ИММУНОЛОГИЧЕСКИЕ СХЕМЫ В АГРОЦЕНОЗАХ МОРКОВИ СТОЛОВОЙ

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Представлены результаты исследований, направленных на повышение устойчивости моркови столовой к основным болезням культуры, вызванным грибами родов *Alternaria* и *Fusarium*. Отмечено, что фузариозные и альтернариозные инфекции поражают растения моркови первого и второго года жизни, снижают лежкость корнеплодов в период хранения, вызывают выпады семенников, ухудшают посевные качества семян, что наносит значительный ущерб товарному производству и семеноводству. Многолетние исследования (2011–2020) проведены в Московской области. Эксперимент поставлен на инфекционно-провокационных фонах, *in vitro* и в естественных неконтролируемых условиях. Объект исследования – растения моркови столовой первого и второго года жизни. Использован исходный, сортовой, линейный, селекционный и гибридный материал моркови столовой отечественной селекции, образцы иностранной селекции, фитопатогенные грибы из родов *Alternaria*, *Fusarium*. В лабораторных и полевых условиях разработаны основные принципы последовательности включения различных методов иммунологической оценки и чередования двулетнего и однолетнего циклов развития растений моркови столовой в схемы соответствующих этапов селекционного процесса с целью повышения напряженности и эффективности отбора, экономии времени и селекционного материала. В ходе исследований выявлена тесная корреляционная зависимость между лабораторными и полевыми опытами. В результате применения селекционно-иммунологических схем в селекционном процессе, выделены сорта – источники групповой устойчивости к поражению *Alternaria* и *Fusarium* на разных стадиях онтогенеза: Бирючекутская, Суражевская 1, Витаминная 6, НИИОХ 336, Лосиноостровская 13, Бессердцевинная, Королева осени, Леандр, Московская зимняя А-515, Шантенэ роял, Нюанс.

Ключевые слова: схемы, селекционный процесс, морковь столовая, устойчивость, *Alternaria*, *Fusarium*

SELECTION AND IMMUNOLOGICAL SCHEMES IN AGROCENOSES OF TABLE CARROTS

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The results of research aimed at increasing the resistance of carrots to major crop diseases caused by fungi of genera *Alternaria* and *Fusarium* are presented. It has been noted that fusarium and alternaria infections affect carrot plants in the first and second years of life, reduce the storability of root crops during storage, cause seed-breeding plot drop-out, deteriorate seed quality, which causes significant damage to commercial production and seed production. Multi-year studies (2011-2020) were conducted in the Moscow region. The experiment was performed on infection-provoking backgrounds, *in vitro* and under natural uncontrolled conditions. The object of the study were table carrot plants of the first and second year of life. The original, varietal, linear, breeding and hybrid material of table carrots of domestic selection, samples of foreign selection, phytopathogenic fungi of genera *Alternaria*, *Fusarium* were used. In the laboratory and field conditions the basic principles of the sequence of inclusion of different methods of immunological evaluation and alternation of two-year and one-year cycles of development of carrot table plants in the schemes of the corresponding stages of the breeding process to increase the intensity and efficiency of selection, saving time and breeding material were developed. The research revealed a strong correlation

between laboratory and field experiments. As a result of the application of selection and immunological schemes in the breeding process, the following varieties - sources of group resistance to *Alternaria* and *Fusarium* infestation at different stages of ontogenesis were identified: Biryuchekutskaya, Surazhevskaya 1, Vitaminnaya 6, NIIOH-336; Losinoostrovskaya 13; Bessertsevinnaya, Queen of Autumn, Leandr, Moscow winter A-515, Chantene royal, Nuance.

Keywords: schemes, breeding process, table carrot, stability, *Alternaria*, *Fusarium*

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The authors declare no conflict of interest.

INTRODUCTION

Cultured carrot (international scientific name - *Daucus carota*) is the main vegetable crop of the celery family (Apiaceae). It is widely cultivated in different countries of the world. In the Russian Federation carrot occupy about 70 000 ha, of which 30 000 ha are in commercial farms [1]. Exposure of carrot roots to fungal diseases in the world is more than 40%, which is the main difficulty in obtaining consistently high yields, maintaining marketability, growing full-grown healthy seeds[1] [2, 3]. The situation is exacerbated by the emergence of resistant isolates of various pathogens [4]. The most common and harmful diseases on table carrots are alternariosis and fusariosis. Alternariosis mortality during storage is 30-60% (rotting of the growth point), and seed drop-out can reach 40% [5]. The disease leads to leaf desiccation and die-off in first-year seedlings, resulting in a 70- 80% decrease in root crop [6]. Table carrot diseases caused by fungi of the genus *Fusarium* are widespread, the frequency of their occurrence is 67% [7]. Infestation of carrot seeds with Fusarium can reach 35%, resulting in a 40% decrease in yield [8-10].

Chemical measures to control diseases in table carrots are often ineffective and not environmentally friendly. In this regard, there is a need to create tolerant varieties and hybrids of table carrots to the complex of pathogens [11].

Evaluation of varieties and hybrids for disease tolerance is one of the stages of breeding and state testing for economic value. Evaluation of variety samples at all stages of the breeding process should be carried out on infection-provoking backgrounds, *in vitro* and under natural uncontrolled conditions[2] [12–14].

The aim of the research is to study ways of increasing the efficiency of targeted breeding of carrots for tolerance to *Alternaria* and *Fusarium*, including a comprehensive assessment at all stages of ontogenesis of the crop with subsequent isolation of gene sources to create new varieties and hybrids.

MATERIAL AND METHODS

Studies were conducted in the Department of Breeding and Seed Production of the All-Russian Research Institute of Vegetable Growing - branch of the Federal Scientific Vegetable Centre in 2011-2020 on infection-provoking backgrounds, *in vitro* and under natural uncontrolled conditions. The object of the study was table carrot plants of the first and second year of life. The initial, varietal, linear, breeding and

[1]Sokolova L.M. Creation of the source material of table carrots for breeding for resistance to *Alternaria radicinia* M.DR.ET E, *Fusarium avenaceum*: Ph.D. in Agricultural Sciences: Vereya, 2010. 171 p.

[2]Sokolova L.M. Creation of the source material of table carrots for breeding for resistance to *Alternaria radicinia* M.DR.ET E, *Fusarium avenaceum*: Ph.D. in Agricultural Sciences: Vereya, 2010. p. 32.

hybrid material of table carrots of domestic selection, as well as samples of foreign selection, phytopathogenic fungi of genera *Alternaria*, *Fusarium* were used. In the course of the study, the methods of the breeding process were studied.

The recordings and observations were performed according to standard (according to GOST 12044-93 of 2000) and new improved methodological recommendations (see footnote 2)[3,4]. In the course of investigations, the following methods were tested and widely used for tolerance to the most common pathogens of p. Fusarium and Alternaria: isolation of fungal phytopathogenic microorganisms from soil and plant material, identification of seed material spoilage, obtaining pure cultures of pathogens, evaluation of pathogen aggressiveness, multiplication of infectious substrate (grain mixture + pathogen) with subsequent introduction to provocation-infectious background, artificial infection of detached leaf plates (spraying) infection of root discs (mycelial blocks), infection on provocation-infection backgrounds of vegetating carrot plants of the first year of life (spraying with a suspension of pathogen spores), infection of seedlings under laboratory conditions (introduction of pathogenic substrate into sterile sand), evaluation of carrot table plants on culture liquid filtrate (mycotoxin) (see footnotes 3, 4). Mathematical processing of the data was performed by methods of analysis of variance and correlation analysis[5], as well as with the help of Microsoft Office Excel application software package.

RESULTS AND DISCUSSION

Variety response to local pathogen *A. radicina*, *A. dauci* and *F. oxysporum* lesions was performed in uncontrolled conditions of open ground on natural background, the intensity of which depends on agroclimatic parameters of the year, and on artificial provocative-infectious backgrounds with controlled infection load. This allowed annual objective control of samples by resistance groups. The following tolerant varieties were identified as a result of the annual lamina evaluation to alternaria and fusariosis: Surazhevskaya 1, Vitaminnaya 6, Losinoostrovskaya 13, Leandr, Moskovskaya zimnyaya A-515, Koroleva oseni, Chantene royal, Nuance (see Fig. 1).

During 7 months of storage the death of root crops from the complex of pathogens can reach 60%. In this regard, an informative method by which we can determine the safety of root carrots is the infection of carrot table root discs with agar blocks of the most harmful pathogens *Alternaria radicina* and *Fusarium oxysporum*. The varieties Vitaminnaya 6, Losinoostrovskaya 13, and Surazhevskaya 1 stood out as a result of the comprehensive evaluation (see Fig. 2).

The method of seedling infestation under laboratory conditions is simple and accessible. This method provides, regardless of the growing season, the results comparable with the field assessment on provocation backgrounds *A. radicina* and *F. oxysporum*. As a result of the complex evaluation, four tolerant varieties were identified.

Preliminary evaluation by this method allows to significantly reduce the amount of analyzed material in provocative backgrounds in the open ground, as susceptible samples are excluded from the work, and tolerant genotypes of variety samples are planted in vessels for further breeding work.

A method for evaluating the resistance of carrot table seedlings by using mycotoxins produced by *A. radicina* and *F. oxysporum* has been improved and tested. The method was based on germination of seeds on filter paper moistened with culture liquid filtrate. Stability of samples was determined by germination and linear parameters of the seedlings. The higher

[3]Leunov V.I., Khovrin A.N., Tereshonkova T.A., Sokolova L.M., Gorshkova N.S., Alexeeva K.L. Methods for accelerated breeding of carrot for complex resistance to fungal diseases (*Alternaria* and *Fusarium*). Guidelines. M., 2011. 61 p.

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[5]Dospekhov B.A. Methodology of Field Experiment. Moscow: Kolos. 1985. 415 p.

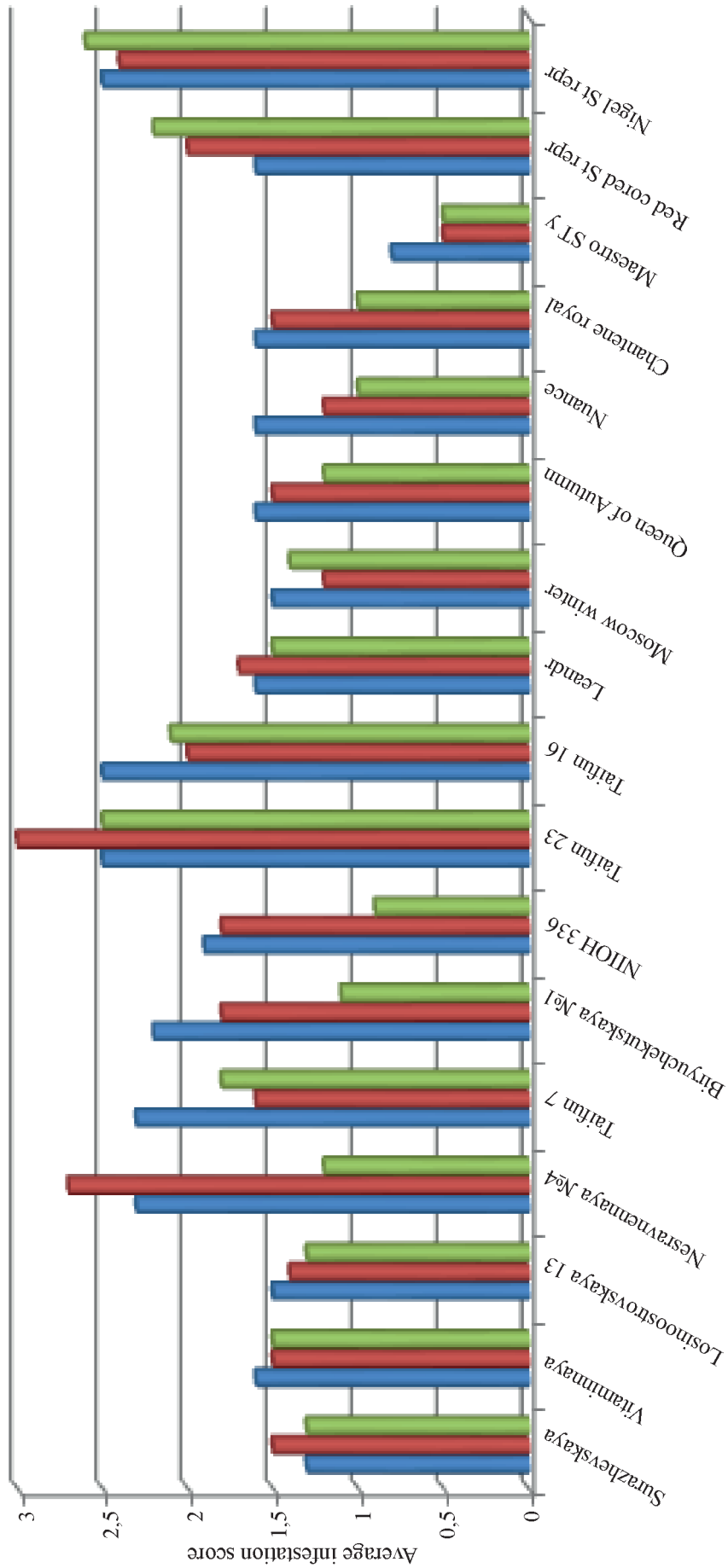

Рис. 1. Оценка устойчивости сортового материала моркови столовой к *Fusarium oxysporum* и *Alternaria dauci* на инфекционных фонах и в естественных условиях (2011–2019 гг.)

Fig. 1. Evaluation of varietal resistance of table carrots to *Fusarium oxysporum* and *Alternaria dauci* in infectious backgrounds and in natural conditions (2011-2019)

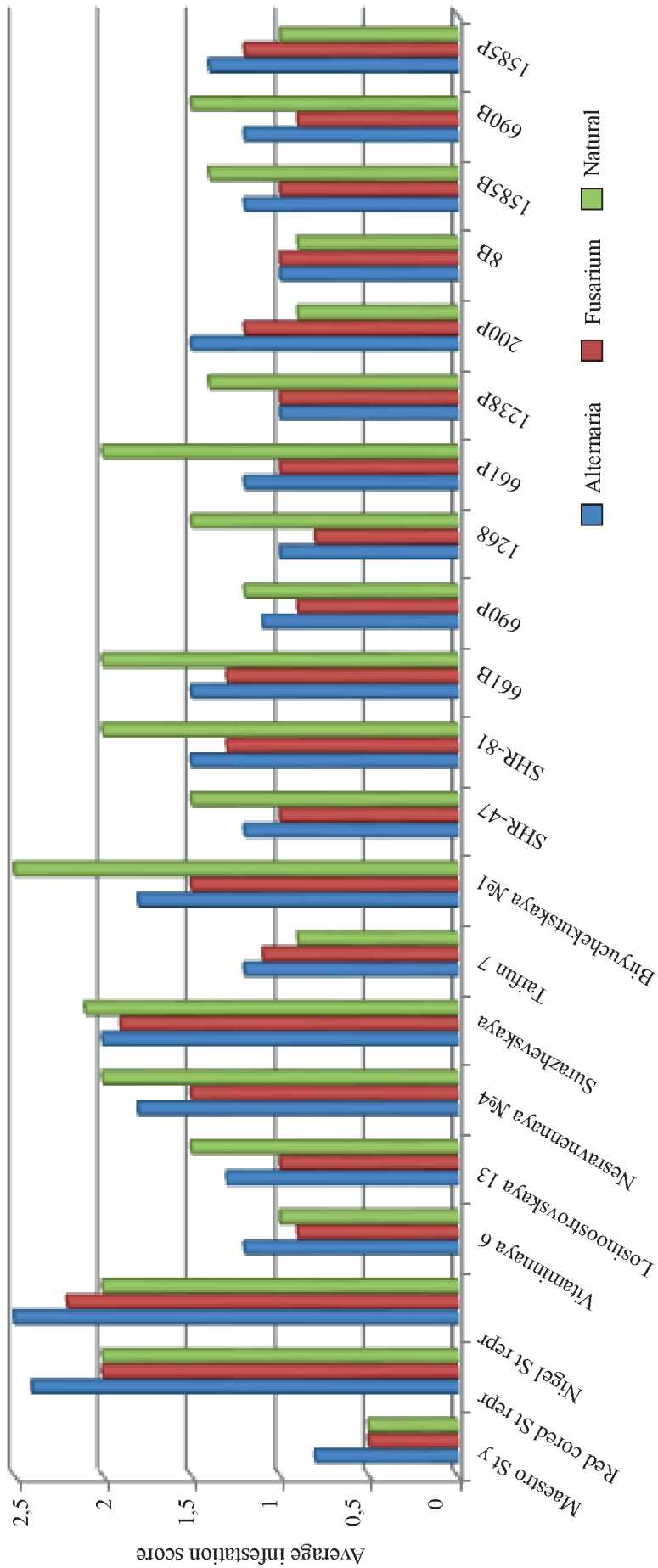

Рис. 2. Оценка устойчивости к патогенам *Alternaria radicina, Fusarium oxysporum* корнеплодов моркови столовой методом дисков (аграровые блоки) (2011–2019 гг.)

Fig. 2. Assessment of resistance to pathogens *Alternaria radicina, Fusarium oxysporum* of table carrots root crops by disk method (agar blocks) (2011-2019)

this indicator, the higher is the resistance of the studied sample to pathogens. The seeds of alternariosis and fusarium-resistant forms of the crop do not germinate [15, 16]. Seven tolerant cultivars of carrot to *A. radicina* and *F. oxysporum* were isolated in the course of studies.

The proposed method by infection with pure cultures of pathogens, as well as the method of seedling evaluation, allows to accelerate the breeding process by selecting resistant genotypes at the seedling stage and obtain their seed progeny in the one-year cycle of development. For this purpose, selected seedlings are planted in vessels and grown under open-ground conditions up to the steckling stage. After the vernalization and spring analysis of the main features, the selected uterine rootstocks are again planted in vessels and placed in a heated greenhouse for the cultivation of seed plants.

The basic principles of the sequence of inclusion of different methods of immunological evaluation and alternation of 2- and 1-year development cycles of table carrot plants in the schemes of the corresponding stages of the breeding process were developed to improve the efficiency of genotype selection and resistance breeding, as well as to save time and breeding material (see Fig. 3-5).

During the years of research, 54 tolerant, 247 weakly susceptible, 213 moderately susceptible, and 124 susceptible varieties of table carrots were identified. As a result of breeding and immunological system of methods, valuable material of table carrots, which has complex tolerance to the most harmful pathogens from p. *Alternaria* and p. *Fusarium*, was obtained from the lines of varietal and hybrid populations.

At the nursery stage of source material, the assessment of plant resistance in soil infectious backgrounds was used in combination with spraying vegetating plants with spore suspension and a set of laboratory methods (see Fig. 4).

The result is an initial assessment of the stability of the collection, an assessment of the alignment of the samples and sequential individual sampling of root crops before and after storage.

At the breeding nursery stage, the same scheme is recommended for plants of the first year of life as for the nursery of the original material (see Fig. 5). For plants of the second year of life, it is necessary to use the method of infection of rootstock discs, which should result in the assessment of alignment of linear and varietal samples by resistance and individual selection of resistant plants (by preserving the head of the rootstock). Preliminary assessment of resistance to leaf diseases is recommended by spraying with a suspension (the result after 14 days) under laboratory conditions. In this way, a comprehensive control of seedling resistance and seed collection from resistant plants is carried out.

Information on the application of breeding and immunological schemes and the complex conduct of laboratory and field experiments is obtained by examining the correlation between all the studies. As a result of the correlation analysis conducted from 2011 to 2019, a fairly close correlation relationship between field and laboratory experiments was noted (see table).

There was a close correlation between spraying of leaf plate spore with suspension (*A. dauci*) and infection background (*A. dauci*) (r = 0.73), infection of seedlings (*A. radicina*) and infection background (*Fusarium*) (r = 0.70), infection of seedlings (*Fusarium*) and infection background (*A. radicina*) (r = 0.70), seedling infection (*Fusarium*) and infectious background (*Fusarium*) (r = 0.75), disc infection with mycelial blocks (*A. radicina*) and infectious background (*A. radicina*) (r = 0.74), disc infection with mycelial blocks (*A. radicina*) and infectious background (*Fusarium*) (r = 0.71), infection of discs with mycelial blocks (*Fusarium*) and infectious background (*A. radicina*) (r = 0.71), infection of discs with mycelial blocks (*Fusarium*) and infectious background (*Fusarium*) (r = 0.73), culture fluid filtrate (*A. radicina*) and infectious background (*A. radicina*) (r = 0.78), culture fluid filtrate (*A. dauci*) and infectious background (*A. dauci*) (r = 0.74), culture fluid filtrate (*Fusarium*) and infectious background (*Fusarium*) (r = 0.71).

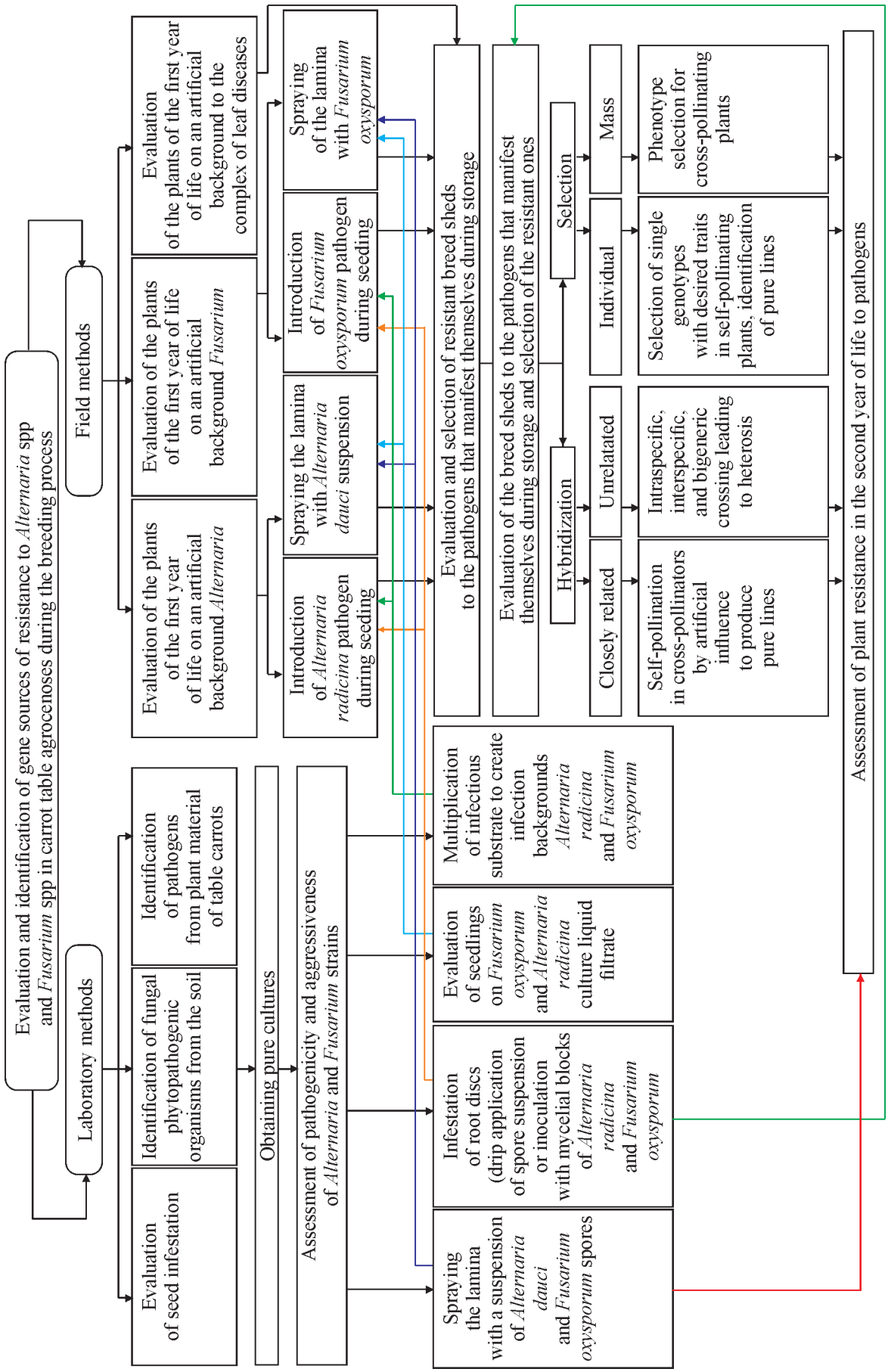

Рис. 3. Схема селекционного процесса, включающая мониторинг и выявление генисточников устойчивости в агроценозах моркови столовой (линии показывают, какие результаты из какого опыта вытекают и какие опыты можно проводить взаимосвязано)

Fig. 3. Scheme of the breeding process, including monitoring and identification of resistance genes in carrot table agrocenoses (The lines show which results follow from which experiments and which experiments can be performed in correlation)

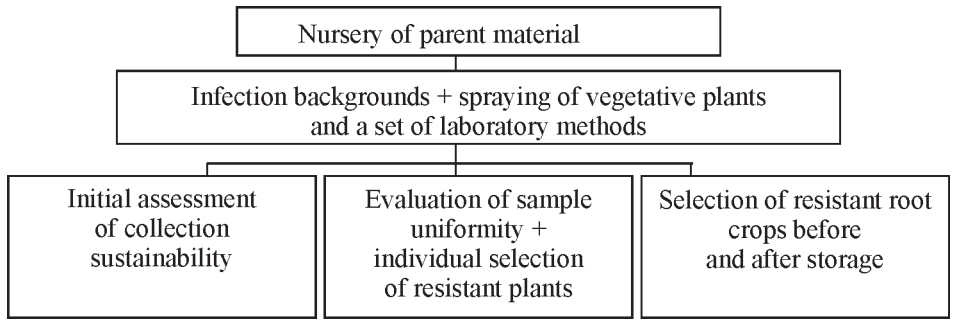

Рис. 4. Схема оценки устойчивости в питомнике исходного материала

Fig. 4. Sustainability assessment scheme in a parent material nursery

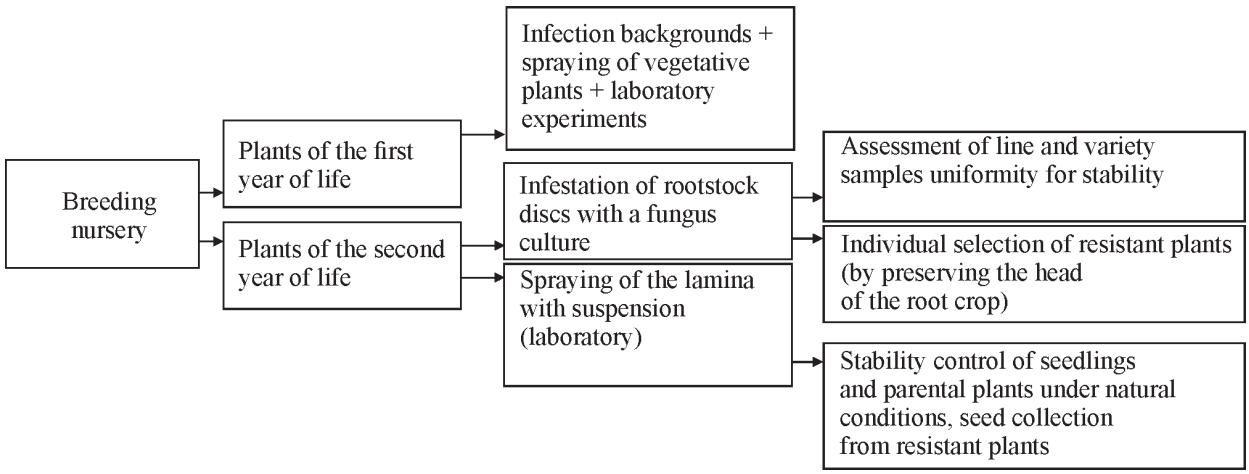

Рис. 5. Схема оценки устойчивости в селекционном питомнике

Fig. 5. Sustainability assessment scheme in a breeding nursery

Корреляционная зависимость между полевыми и лабораторными методами оценки устойчивости моркови столовой (2011–2019 гг.) ($r \pm Sr$)

Correlation relationship between field and laboratory methods for assessing stability of table carrots (2011-2019) ($r \pm Sr$)

Parameter	Infection background (*A. dauci*)	Infection background (*A. radicina*)	Infection background (*Fusarium*)	Natural background (control)
Field experiments				
Infection background (*A. dauci*)		0,69	0,65	0,55
Infection background (*A. radicina*)			0,63	0,58
Infection background (*Fusarium*)				0,57
Laboratory experiments				
Spraying with a suspension of leaf plate spores (*A. dauci*)	0,73		0,56	0,43
Culture fluid filtrate (*A. dauci*)	0,74		0,68	0,59
Infestation of seedlings (*A. radicina*)		0,61	0,71	0,44
Infestation of discs with mycelial blocks (*A. radicina*)		0,74	0,71	0,41
Culture fluid filtrate (*A.radicina*)		0,78	0,63	0,45
Infestation of seedlings (*Fusarium*)		0,7	0,75	0,53
Infestation of discs with mycelial blocks (*Fusarium*)		0,71	0,73	0,64
Culture fluid filtrate (*Fusarium*)		0,68	0,71	0,54

CONCLUSION

Immunological selection is very important in crop breeding for disease resistance. The basis is the hereditary heterogeneity of the variety or lines with respect to one or another disease. Field or relative resistance is the most complex type of resistance. Field resistance can be determined by such features as absence or presence of leaf pubescence, coloration, leaf structure, etc. At the same time, the effectiveness of the breeding process on the trait of disease resistance depends mainly on the methods of evaluation and selection of starting material. Variety samples response to pathogen damage should be carried out in uncontrolled conditions of the open ground on a natural background, the intensity of which depends on agroclimatic parameters of the year, on artificial provocative infectious backgrounds with controlled infection load. This allows annual objective evaluation of samples by resistance groups.

The proposed integrated assessment accelerates the breeding process by carrying out preliminary diagnosis of resistance of a large number of carrot varieties and the selection of resistant genotypes. Preliminary evaluation by laboratory methods in the off-season period allows to significantly reduce the volume of analyzed material in provocative backgrounds in the open ground, since susceptible samples are excluded from the work. The studies revealed a close correlation between laboratory and field experiments.

As a result of the application of breeding and immunological schemes in the breeding process in the conditions of the Moscow Region, the following varieties - sources of group resistance to *Alternaria* and *Fusarium* defeat at different stages of ontogenesis - were identified: Biryuchevskaya, Surazhevskaya 1, Vitaminnaya 6, NIIOH 336, Losinoostrovskaya 13, Bessertsevinnaya, Koroleva oseni, Leandr, Moskovskaya zimnyaya A-515, Chantene royal, Nuance.

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ТЕХНИЧЕСКАЯ ЭНТОМОЛОГИЯ: ИСТОРИЯ, СОВРЕМЕННОЕ СОСТОЯНИЕ И ПЕРСПЕКТИВЫ РАЗВИТИЯ

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Представлены направления технической энтомологии, включающие производство живых насекомых и продуктов их жизнедеятельности, переработку насекомыми органических отходов с получением биоудобрений. Освещены исторические аспекты становления, развития и современное состояние этой практической отрасли биотехнологии в России и в других странах. Разведение насекомых и клещей предусматривает их использование в качестве опылителей растений; энтомофагов и гербифагов – для защиты культурных растений от вредителей и сорняков; фитофагов, служащих в качестве тест-объектов, – для оценки средств контроля их численности; кормовых видов насекомых – для кормления домашних и сельскохозяйственных животных. Затронута проблема редких и исчезающих видов полезных насекомых. Показана необходимость их искусственного разведения с целью дальнейшего обогащения ими агро- и биоценозов. Проанализирован опыт использования разных видов насекомых для переработки отходов органического происхождения с получением зоогумуса. Отмечено важное практическое значение биологически активных веществ, получаемых от представителей класса Insecta. Помимо традиционных продуктов жизнедеятельности насекомых (продукты пчеловодства, шелководства), на мировом рынке пользуются спросом белковый концентрат, хитин и его производные, комплекс жирных кислот, органические формы минеральных веществ, меланины, антимикробные пептиды, гормоны насекомых, нашедшие применение в медицине и ветеринарии, косметологии, животноводстве, растениеводстве и защите растений, пищевой промышленности и в других отраслях человеческой деятельности. Рассматривается вопрос о возможности и целесообразности использования белковой муки, полученной из ряда видов насекомых, для питания человека. В обзоре основной акцент сделан на достижениях и опытных разработках в области технической энтомологии, полученных учеными и практиками в условиях Западной Сибири.

Ключевые слова: технобиоценоз, фитофаги, энтомофаги, кормовые насекомые, продукты жизнедеятельности насекомых

TECHNICAL ENTOMOLOGY: HISTORY, CURRENT STATE AND PROSPECTS OF DEVELOPMENT

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Areas of technical entomology, including the production of living insects and their products, processing of organic waste by insects to produce bio-fertilizers are presented. Historical aspects of the formation, development and current state of this practical branch of biotechnology in Russia

and other countries are covered. Breeding insects and mites includes their use as plant pollinators; entomophages and herbophages - to protect cultivated plants from pests and weeds; phytophagans serving as test objects - to evaluate means of controlling their numbers; feeder insect species - to feed domestic and farm animals. The problem of rare and endangered species of useful insects is touched upon. The necessity of their artificial breeding for further enrichment of agro- and biocenoses is shown. The experience of using different types of insects to process waste of organic origin to produce zoogumus is analyzed. The important practical value of biologically active substances derived from members of the class Insecta are noted. In addition to traditional insect products (bee products, sericulture products), protein concentrate, chitin and its derivatives, complex fatty acids, organic forms of minerals, melanins, antimicrobial peptides, insect hormones, which find use in medicine and veterinary medicine, cosmetology, animal husbandry, crop production and plant protection, food industry and other areas of human activity are in demand in the global market. The question of the possibility and expediency of using protein meal obtained from a number of insect species for human nutrition is being considered. The review focuses on the achievements and experiential developments in technical entomology obtained by scientists and practitioners in the conditions of Western Siberia.

Keywords: technobiocenosis, phytophagans, entomophages, feeder insects, insect waste products

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Конфликт интересов
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Technical entomology as a separate branch of biotechnology in Russia was formed in the 70-80s of the 20th century and is now directly related to many areas of human activity. The main goal of technical entomology is the study of theoretical and practical aspects of the reproduction of insect cultures as artificial populations with specified properties under conditions of technobiocenosis. The technobiocenosis is understood as a life system of an artificial population, simplified in terms of food connections, stable in terms of conditions of existence and directed by the experimenter. It is a closed biotechnological ecosystem created by man [1, 2].

The beginning of the formation of a new direction in biotechnology was the 1984 All-Union meeting "Modern Issues of Biotechnology", where insects were first considered as objects of this science. In 1986, the first All-Union Conference on industrial breeding of insects was held, which defined the main objectives of technical entomology[1] and highlighted its three key areas:

– production of live insects used for various purposes;

– processing of organic waste by insects to produce bio-fertilizers;

– production of insect metabolic byproducts.

The directions of technical entomology formulated in the 1980s of the last century have not lost their relevance at the present time. Each of these directions at the present stage includes even a wider range of tasks.

The aim of the article is to analyze the historical aspects and the current state of scientific and practical directions of use of insects and their metabolic byproducts for human needs, as well as to evaluate the prospects for further development of methods of technical entomology, including in the West Siberian region.

[1]Tamarina N.A. Zoocultures as artificial populations. Abstracts of the First All-Union Meeting on Zoocultures. M., 1986. V. 1. pp. 69-72.

Production of live insects used for various purposes. Targeted breeding of insects and mites (which are also objects of technical entomology) involves the realization of various tasks. Bumblebees, honeybees, and leaf-cutter bees are bred as insect pollinators. Insect cross-pollination of crops multiplies the yield and the quality of seeds and fruits [3, 4]. In general, there are more than 100 species of crops that need cross-pollination by insects. These include buckwheat, sunflower, sainfoin, mustard, rapeseed, watermelons, melons, pumpkins, cucumbers, zucchini, cabbage seeds, onions, many fruit and berry crops. According to Sh. R. Suyarkulov[2], in Fergana Valley, the yield of almond fruit with additional pollination by bees increased by 17 times, apple and plum trees by 8 and 11 times respectively. The use of honeybees as pollinators allows farmers who grow fruit and berry products to increase their income by 10-12 times. In Western Siberia, employees of the Siberian Research Institute of Soil Management and Chemicalization of Agriculture (SibNIIZKhim) have developed a technique for the accelerated breeding of bumblebee families and their use, which allows to double the seed productivity of clover [5], and recommendations[3] for the protection and rational use of wild solitary bees nesting in the soil for pollination of alfalfa. Obtaining bee-pollinated hybrids of cucumber and tomato in modern greenhouse vegetable production becomes impossible without the use of specially bred bumblebees. Currently, they are used in almost all large greenhouse farms in Russia. Of the known 300 species of bumblebees in practice mainly one species is used - large ground bumblebee (Bombus terrestris L.)[4]. The leading producers of commercial bumblebees in the world are BioBest (Belgium), Koppert (Netherlands) and BioBee (Israel). In the Russian market, only Compass and Bumblebee Company remain active producing about 10 thousand and 30 thousand bumblebee colonies per year, respectively[5].

It should be noted that in Russia, as well as all over the world, frequent mass death of bee families in apiaries due to violations of technologies of insecticide use [6], reduction in the number of natural populations of bees and bumblebees under the influence of anthropogenic factors and changing climatic conditions has been recently recorded [7, 8]. In this regard, artificial breeding and the use of insect pollinators is one of the most important tasks in crop production.

Some species of insects are grown and used as food for animals. Domestic and exotic animal species - lizards, amphibians, some mammals, birds, fish - eagerly use insects as food, especially in a live form. Among forage species, representatives of direct-winged insects (crickets, grasshoppers, locusts), cockroaches (marbled, Turkmen and Madagascar cockroaches), hard-wings (large and small mealworms, zophobas), diptera (larvae of different fly species, ringed mosquitoes) and others are in greatest demand. [9-12]. Recently, these products are becoming more and more in demand in pet stores, zoos, breeders of exotic species of pets.

A large block in technical entomology is the breeding of insects for plant protection purposes. Phytophagous insects are bred as test objects to determine the effectiveness of insecticides, assess plant resistance to pests, genetic control methods (obtaining sterile insects), breeding entomophages and the development of entomopathogens. At present, both in our country and abroad, a large number of techniques and methods of breeding certain species of plant-eating insects, including par-

[2]Suyarkulov Sh.R. The role of pollinators in intensive agriculture. URL: http://asprus.ru/blog/rolopylitelej-v-usloviyax-intensivnogo-zemledeliya/

[3]Grebennikov V.S. Ground bees - pollinators of alfalfa in the Novosibirsk and Omsk regions: methodological recommendations. Novosibirsk: Siberian Branch of the Academy of Agricultural Sciences, 1983. 12 p.

[4]Technology of industrial bumblebee breeding. The use of bumblebees in modern greenhouse enterprises. URL: https://www.shmel.org/article/article.php?storyid=5

[5]Commercial bumblebee breeding. URL: https://zen.yandex.ru/media/pchelovod/kommercheskoe-razvedenie-shmelei5c626ef1ad73a000adfe2eaf

ticularly dangerous pests, are well known. In the laboratory of biomethod at the SibNIIZhim SB VASKhNIL, methods of breeding meadow moth[6] and other lepidopterous pests were developed to evaluate biological plant protection agents and to develop entomopathogenic viruses that serve as the basis for biopreparations. At present, the Laboratory of Biological Control of Phytophages and Phytopathogens of the Siberian Federal Scientific Center for Agrobiotechnology of the Russian Academy of Sciences - SFNCA RAS (a receiver of the Siberian Branch of VASKhNIL and RAAS) has developed a technique for mass reproduction of dimondback moth[7] and contains mother cultures of meadow moths and corn worms, several other plant eating insects and mites, and several species of forage insects (see figure).

Herbiphagous breeding in our country is extremely limited and is intended mainly for the biocontrol of quarantine weed species. These include, for example, *Phytomyza orobanchia* Wert. phytomyza fly that damages ovaries and immature seeds of the persistent weed broom rape, striped leaf beetle *Zygogramma saturalis* F. feeding on quarantine weed common ragweed for which breeding methods have been developed [8,9] [13]. In Western Siberia (Novosibirsk Region), insects feeding on weedy artichokes (Compositae family) were studied in 1966-1967 under the herbivore exchange program for biological weed control. Local phytophages were studied to identify the possibility of introducing promising species to Canada. In particular, a large species composition of insects damaging vegetative and generative organs of the yellow thistle, curled thistle, and scabiose centaury was identified, and their efficiency in natural conditions was determined [14, 15]. However, due to a lack of further funding, research in this area has ceased, and the possibility of developing a biomethod to regulate the number of weeds is still unrealized.

One of the most promising segments of the Russian market of biological plant protection products at present is the production of entomophages [10-12]. In particular, since the beginning of the XXI century the range of entomophages and acariphages used to protect agricultural, forest and ornamental crops from pests has significantly expanded. According to the data of L.P. Krasavina[13], as of 2013 the world market of entomophages used only in protected ground conditions is represented by more than 90 species of useful insects and mites, while in 1990 there were not more than 50, in 1985 - only 20. Every year the list of entomophages used in practice in the Russian Federation and other countries is updated with new species.

Under the conditions of the Siberian region in the 80s of the XXth century, entomophages were produced and used mainly in protected ground conditions. For example, in bio-laboratories at greenhouse complexes "Kirovets" and "Inya" (Novosibirsk) phytoseiulus was bred and used to regulate the number of spider mites, enkarsia - against greenhouse whitefly,

[6]Shternshis M.V., Ermakova N.I., Zurabova E.R., Isangalin F.S. Determination of biological activity of LEST (Lepidocide stabilized powder) on meadow moth: methodological recommendations. M., 1990.

[7]Andreeva I.V., Shatalova E.I., Ulyanova E.G. Method of cabbage moth *Plutella xylostella* L. breeding. Patent № 2735251 dated 29.10.2020.

[8]Bronstein Ts.G. Biological method of broomrape control (Orobanachacae). Patent No. 1136388/30-15, 1967.

[9]Shternshis M.V., Tomilova O.G., Andreeva I.V., Shpatova T.V. Biotechnology in plant protection: electronic tutorial. Novosibirsk: NSAU, 2015.

[10]The market for biological plant protection products. URL: http://биомедиа.рф/biznes/marketing/348-rynok-biologicheskihsredstv-zaschity-rasteniy.html

[11]Chelyabinsk "Churilovo" agroholding will invest 9 billion rubles in the production of entomophages. URL: http://greentalk.ru/ topic/4922/

[12]The use and replacement of biological protection agents for food and crops. IPPO report. URL: http://www.iobc-global.org/download /Executive_Summary_FAO_report_2009_Russian.pdf

[13]Krasavina L.P. Problems of mass breeding of entomophages in greenhouse complexes in Russia. Phytosanitary optimization of agroecosystems: proceedings of the 3rd All-Russian Congress on Plant Protection. SPb., 2013. pp. 68-70.

Виды кормовых насекомых: *а* – большой мучной хрущак *Tenebrio molitor* L.(имаго); *б* – *Tenebrio molitor* L. (личинки); *в* – зофобас *Zophobas morio* Fabr. (имаго); *г* – *Zophobas morio* Fabr. (личинки); *д* – таракан черный *Pycnoscelus nigra* Brun.; *е* – таракан мраморный *Nauphoeta cinerea* Oliver; *ж* – сверчок домовый *Acheta domesticus* L.; *з* – черная львинка (*Hermetia illucens* L.)

Species of feeder insects: *а* - yellow mealworm beetle *Tenebrio molitor* L. (adult insects); *б* – *Tenebrio molitor* L. (larvae); *в* – superworm *Zophobas morio* Fabr. (adult insects); *г* – *Zophobas morio* Fabr. (larvae); *д* – cockroach *Pycnoscelus nigra* Brun.; *е* – marble cockroach *Nauphoeta cinerea* Oliver; *ж* – cricket *Acheta domesticus* L.; *з* – black soldier fly *Hermetia illucens* L.

aphidius - against lice[14]. Currently, in such large greenhouse complexes as "Novosibirsk", "Tolmachevsky", the range of imported and domestically produced entomophages and pollinators has significantly expanded and includes more than 10 species.

Given the current realities due to climate change in Siberia, it becomes possible and appropriate to use entomophages in the regulation of pest populations not only in protected, but also in open ground conditions [15]. Especially relevant is the use of entomophages for organic agriculture products. More and more demand for biological means, including beneficial insects and mites, is shown by individual entrepreneurs (farmers) and private individuals.

In this context, we cannot avoid the problem of preserving rare and endangered insects. All over the world there are regularly registered cases of decline or extinction of certain species of insects, including predatory or parasitic ones, resulting in a significant increase in the number of pests. For example, in 1971, 1972 in Middle Priob'ye (Western Siberia) on the plants of yellow acacia, elm, and rose hips infested by the spider mite, up to 5-12 larvae of its specialized predator *Stethorus punctillum* Ws. were found on one leaf. [16]. The studies of recent years (2019) conducted in the same area showed that in the years with mass reproduction of spider mites on various cultivated and wild plants in the open ground Stethorus was found in limited numbers[16]. The reduction of *S. punctillum* abundance in different zones of its habitat was also reported by other researchers [17]. This situation leads to the need for intra-areal dispersal of coccinellids[17] or mass breeding followed by release into agro- and biocenoses.

Predatory bugs of the family Pentatomidae are of interest for biological control of phytophages. The efficiency of bed bugs *Podisus maculiventris* Say and *Perillus bioculatus* Fab. introduced into our country is known for the control of the Colorado potato beetle and some other pests [18, 19]. However, native species - the representatives of genera *Arma, Troilus, Rhacognathus, Jalla, Zicrona, Picromerus* - can become the source for obtaining new agents of biological plant protection.

Thus, Zicrona caerulea L. plays an important role in the bioregulation of phytophage numbers in agrocenoses of potato fields [20]. In particular, V.P. Petrova gave information that in May 1967, this species was rather numerous in the south of Siberia, and every 25 swings of the net had on the average 6 specimens of Zicrona caerulea[18]. In entomological collections in 2021, only single individuals of *Z. caerulea* were found in the eastern regions of Western Siberia. Also limited in our region is the two-toothed stinkbug *Picromerus bidens* L., whose victims include about 250 species of insects of different orders; in this connection, this species is extremely promising for mass breeding.

Given their undoubted role in regulating the number of pest arthropods, the above and many other entomophage species need protection and artificial breeding to further enrich agro- and biocenoses. The unique experience

[14]Andreeva I.V. Microbiological control of common spider mite (*Tetranychus urticae* Koch.) in protected ground: PhD. Can. Sci. in Agriculture, Novosibirsk, 1996. 175 p.

[15]Andreeva I.V., Tsvetkova V.P., Zenkova A.A. Prospects of using entomoariphages for biological control of phytophages in the Siberian region. Actual problems of agroindustrial complex: collected works of scientific and practical conference of teachers, students, graduate students and postgraduate students, dedicated to the 80th anniversary of the Novosibirsk State Agrarian University. Vol. "Agricultural sciences. Biological sciences. Veterinary sciences". Novosibirsk: PC "Zolotoy Kolos", 2016. pp. 3-6.

[16]Andreeva I.V., Ulyanova E.G., Shatalova E.I. Common spider mite and its acariphages in the open ground biocenoses of Western Siberia. Agrarian science to agricultural production of Siberia, Mongolia, Kazakhstan, Belarus, China and Bulgaria: materials of the 22nd international scientific and practical conference Krasnoobsk: SFSCA RAS, 2019. pp. 77-78.

[17]Karbozova B.E. Economic importance of predatory cockcinellid entomophages. URL: http://www.rusnauka.com/1_NNM_2015/Biologia/7_185104.doc.htm

[18]Petrova V.P. Stinkbugs of Western Siberia (Hemiptera, Pentatomidae): a manual for students and teachers. Novosibirsk: NSPI, 1975. 235 p.

of preserving insect biodiversity in natural cenoses has been realized for the first time in the conditions of Siberia. At the initiative of the outstanding entomologist V.S. Grebennikov, our countryman, the first in the country micro-reserve for the protection of useful insects was created in the Omsk region in 1971. Later such micro-reserves were created near Novosibirsk on the lands of the Siberian Research Institute of Fodder Crops (1979) [5], in the experimental farm "Elitnoe" of the Novosibirsk region (1987)[19]. Unfortunately, at present these microreserves are not supported.

Processing of organic waste by insects to produce bio-fertilizers. Human life and the cultivation of farm animals leads to the accumulation of a huge amount of organic and inorganic waste requiring their disposal. One way of converting organic waste (food waste and meat production waste, bird droppings and animal manure, etc.) for reuse is their processing by insects to produce organic fertilizer, or zoohumus.

Scientists of the Novosibirsk Agricultural Institute (now NSAU) were the first in our country to start research on processing pig manure with the larvae of housefly (*Musca domestica*). The developed technology included breeding of selected population of "Novosibirskaya" fly and processing of substrate by larvae to produce zoohumus containing the whole set of macro- and microelements and protein larval flour. According to the developers' data, up to 80-90 kg of larvae and 400-450 kg of zoohumus were obtained from 1 t of pig manure or chicken droppings [21]. In the future, different regions of the country began to process chicken, quail droppings, manure of other animals, including the use of green blowflies (genus Lucilia).

Currently, one of the most effective species is the black soldier fly (*Hermetia illucens*). It is bred in many countries of the world [22, 23], but the leader in the processing of food and organic waste is currently recognized by China, where the program of construction of plants for breeding this insect species is supported by government agencies and is included in the list of the priority areas[20].

In Russia, the A.N. Severtsov Institute of Ecology and Evolution (IPEE RAS) and other scientific institutions are engaged in the study of the bioecological characteristics of *H. illucens*. The results of the studies confirmed that the advantages of this species of flies of tropical origin include the fact that they are not transmitting agents of infections and cannot survive outside biolaboratories in our climate [24, 25]. Mass breeding of the black soldier fly in Russia is carried out by several companies geographically located in the European part of the country: Entoprotek LLC (International Biotechnology Company), EcoBelok LLC (Moscow), and Biogenesis LLC (Moscow).

The company "Entoprotek" patented a unique technology for processing organic waste using *H. illucens* larvae and built a plant in the Penza region, where only in 2021 5.5 thousand tons of organic waste were processed, which allowed not only to obtain useful products, but also to significantly reduce greenhouse gas emissions compared to other methods of processing. In the future, the company is considering the possibility of expanding the production capacity of organic waste processing, as well as scaling the project both in Russia and abroad[21].

In addition to the larvae of two-winged insects, recycling of organic waste is possible with some species of cockroaches, beetles, larvae of lepidopterous insects.

More recently, facts of feeding of some insects with plastic have been documented[22]. Biotechnologists from Yakutia conducted an

[19]Museum of Agroecology and Environmental Protection (Prospectus). Novosibirsk, 1988. 18 p.

[20]China's national program for recycling agricultural waste using *Hermetia illucens* fly larvae. URL: http://www.nasadki.net/index/kitaj_stanovitsja_mirovym_liderom_po_razvedeniju_oparysha_na_pishhevykh_otkhodakh/0-593

[21]"Entoprotek" recycled 5.5 thousand tons of organic waste with the help of a black soldier fly. URL: https://www. agroxxi.ru/stati/-yentoprotyek-pererabotala-5-5-tysjachi-tonn-organicheskih-othodov-pri-pomoschi-chernoi-lvinki.html

[22]Carrington D. Microplastics can spread via flying insects, research shows. URL: https://www.theguardian.com/environment/2018/sep/19/microplastics-can-spread-via-flying-insects-research-shows#img-1

experiment in which they found that beetles *Zophobas morio* Fabr. can eat and decompose plastic. Using the method of gas chromatography, they determined that both in the larvae that ate plastic and, in their feces, it is virtually absent, as it is broken down into secondary metabolites and octacosan. Based on these findings, the researchers created portable mini stations for the disposal of plastic by beetles in the home and office environment[23].

Somewhat earlier, the discovery of the ability of the large wax pyralide moth *Galleria mellonella* L. to eat polyethylene was reported[24]. However, this fact was long known to scientists who conducted experiments with Galleria as test objects: keeping caterpillars of this insect implied the use of glass containers and metal covers, because polyethylene covers were easily gnawed by caterpillars of older ages. At the same time, this ability of larvae was not considered as a possibility to use them for recycling plastic waste due to small quantities of recyclable raw materials.

Production of insect metabolic byproducts. This direction has been known for a long time due to the development of beekeeping and silkworm breeding. In addition to traditional raw materials (honey, wax, silk, varnish, etc.), many other products obtained from insects are in demand nowadays. High-quality protein meal containing a number of valuable substances is obtained from dried (or lyophilized) insects. The scientists of the Novosibirsk Agricultural Institute were at the origins of this direction in Russia. The biotechnology developed in the problem laboratory of the institute of organic waste processing with the help of house fly larvae allowed to obtain not only organic fertilizer (as noted above), but also a highly valuable protein-lipid concentrate containing essential amino acids and biologically active substances. The feed enriched with insect protein meal provided high productivity of animals, poultry, fish, insects, microorganisms and plant resistance to diseases. 18-20 kg of protein-lipid meal was produced from 100 kg of house fly larvae [21].

At present, the Lipetsk company "New Biotechnologies" is producing feed protein from the larvae of the *Lucilia Caesar* fly population by processing ground meat waste[25]. The company "InAgroBio" (the Yaroslavl Region), which specializes in aquaculture, breeds house flies (*Musca domestica*) to provide baby fish with farm-produced feed[26].

The companies “Entoprotein”[27], “Biogenesis”[28], “EcoBelok”, and “Arkhangelsk NordTechSad” also produce animal feed protein using the black soldier fly. The larvae of this fly contain about 40% protein and about 40% fat; they are rich in calcium and phosphorus. According to the results of the tests of the Stavropol and Belgorod interregional veterinary laboratories of Rosselkhoznadzor (Russian Federal Service for Veterinary and Phytosanitary Surveillance), the flour obtained from them is not toxic and does not contain conditionally pathogenic fungi and bacteria[29].

[23]Bugs eat plastic - they have learned to breed them in Yakutia. URL: https://goarctic.ru/news/zhuki-edyat-plastik-ikh-nauchilisrazvodit-v-yakutii/

[24]Barinova A. Caterpillars Will Save the World from Plastic. URL: https://nat-geo.ru/nature/gusenitsy-spasut-mir-ot-plastika/ National Geographic Russia, 2017.

[25]The processing of organic agricultural waste by fly larvae to produce protein for animals, poultry and fish, and to produce organic fertilizers. URL: https://www.zooprotein.com/

[26]Protein of the twenty-first century: crickets, cockroaches, and fly larvae. URL: https://agrarii.com/protein-xxi-veka-sverchki-tarakany-ilichinki-muh

[27]Maksimov A.N., Zorin G.V. The method of growing fly larvae and processing of organic waste - Entoprotein. Patent 2 734 522 C1, 2020.

[28]Babaev N.A., Bastrakov A.I., Sokolov I.V. The method of processing of organic waste by fly larvae *Hermetia illucens* with obtaining animal protein and biohumus. Patent 654 220 C1, 2017.

[29]Protein of the 21st century: crickets, cockroaches, and fly larvae. URL: https://agrarii.com/protein-xxi-veka-sverchki-tarakany-ilichinki-muh

Protein meal is also used for inclusion in artificial nutrient medium (NM) for mass breeding of insects themselves. It is known that NM for breeding useful species of arthropods, as a rule, includes scarce and expensive components, and their replacement with a more accessible flour from insects can significantly reduce the cost of the medium, while maintaining its nutritive value. The Novosibirsk State Agrarian University has developed a nutrient medium for phytophagous insects including dried fly larvae. Replacing soybean meal with larval meal in the nutrient medium for bee flies resulted in a 10% increase in average imago weight and a 34% increase in female fecundity[30]. The same larval meal is also required for inclusion of entomopathogenic fungi, producers of insecticidal preparations, in NM. It is known that to increase the virulence of strains of fungal pathogens, they resort to passaging them through an insect host, which is a time-consuming, rather long and expensive process. Inclusion of insect larval meal into the nutrient medium makes it possible to obtain highly virulent strains, significantly reducing and decreasing the cost of this procedure[31]. Also, Siberian scientists developed a nutrient medium for the cultivation of entomopathogenic fungi consisting of a mixture of crushed larvae of synanthropic flies, sawdust and millet[32].

Protein meal and food additives produced on the basis of insect biomass are currently being considered for inclusion in the human diet [26]. The main players in the market of insect biomass products in the world include Entomotech (Spain), Meertens (Netherlands), Agriprotein (UK-SAR), Ynsect (France), Proteinsect (Netherlands), Protix (Netherlands), Enterra (Canada), Big Criket Farms (USA). FAO predicts the growth of the market of edible insects by 2023 to $ 1.2 billion. However, not all experts in this field are so optimistic. There is an opinion that the production and use of food products derived from insect biomass in Russia is unpromising due to a number of reasons. In particular, it is noted that the possible negative impact of insect products on humans is still poorly studied[33]. Nevertheless, such protein supplements started to be produced in our country. For example, LLC "Kormilitsa" (Moscow) offers a protein-lipid concentrate (BLK) of dried black soldier fly larvae containing 46-50% protein and 14-28% fat for athletes[34].

Some biologically active substances of insects have an important practical value. Chitin and its derivatives - chitosan, complex of fatty acids, organic forms of minerals, melanins, antimicrobial peptides, hormones, etc. are in demand on the world market.

At present more than 70 directions of practical application of chitin (chitosan) and their various modifications and composites are known. According to a number of researchers, insect chitin is 20-50 times better in quality than crustacean chitin [27-29].

In medicine and veterinary medicine such properties of chitosan and its derivatives as high wound healing and sorption ability, antitumor, antiviral, antibacterial and antioxidant activity, ability to reduce blood cholesterol levels, immunomodulatory and calming effect on the central nervous system are used, due to that these biopolymers are widely used in

[30]Shternshis M.V., Tomilova O.G., Andreeva I.V., Shpatova T.V. Biotechnology in plant protection: electronic tutorial: Novosibirsk: NSAU, 2015.

[31]Tomilova O.G., Usova O.N., Sternshis M.V. Modification of the medium for the cultivation of entomopathogenic fungi. Modern mycology in Russia: Abstracts of the First Congress of Mycologists of Russia. M., 2002. 214 p.

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[34]Feed protein for athletes (animal protein). URL: https://kormilitsa.com/kormovoj-belok-zhivotnyij-protein/

the development of new promising drugs, drug delivery means, wound coverings and suture materials for medicine, cosmetology and medicine. [28-35].

In the food industry, chitosan is used as a dietary fiber, emulsifier, thickener, etc. The work on creation of biohybrid packaging material based on chitosan with inclusion of various antimicrobial agents of animal origin is carried out on the basis of the V.M. Gorbatov Federal Research Center for Food Systems of the Russian Academy of Sciences. Such film materials exhibit a preservative effect, preventing microbial contamination and oxidative processes in meat, which allows to significantly increase its shelf life[35].

Chitin, chitosan and its derivatives can form strong chelate bonds with metals and selectively extract ions of mercury, cobalt, gold and other metals from wastewater and seawater. For example, the chitinmelanin complex, due to its high melanin content, can effectively bind heavy metals, radionuclides, and other pollutants and can be used as a sorbent for purifying water and soil from these anthropogenic pollutants [36, 37]. Having powerful antioxidant properties, melanin is used as a means to reduce the accumulation of radionuclides in animals and humans.

Chitosan-based preparations have also found applications in agriculture and plant protection. Due to good biodegradability and at the same time the presence of biological activity, chitosan is used for granulation of fertilizers, as an elicitor causing systemic and prolonged plant resistance to pathogens of various diseases [35, 36]. In recent years, based on the antifungal action of this biopolymer, scientists and practitioners are studying the possibility of its use as fungicides. It was found that chitosan and its derivatives suppress the development of such economically important fungal phytopathogens as *Botrytis cinerea* Pers., *Fusarium oxysporum*, *F. moniliforme*, *Colletotrichum lagenarium* (Pass) Ell. et Halst. [38-42], bacterial plant pathogens *Agrobacterium tumefaciens* and *Erwinia carotovora* [43], and also exhibit antiviral activity [44].

Fatty acids extracted from insect biomass during their processing are a valuable product [45]. A method of obtaining oil from the larvae of *Musca domestica* rich in omega-3 and omega-6, omega-7 and omega-9 has been developed for obtaining pure fractions of different types of fatty acids36. Black soldier fly larvae have a unique fatty acid composition, including high content of linoleic, oleic, lauric, and other acids intended for use in feed production, soap-making, cosmetology, and pharmaceuticals [22, 25, 26].

The information presented would not be complete without mentioning the importance of insects in science and technology. The list of discoveries made with the help of six-legged arthropods is quite extensive, the results of which are used by humans in agricultural production, medicine, chemical industry, engineering and many other areas of practical activity. This is the chromosomal theory of heredity, proved by Thomas Morgan in the experiments with the fruit fly Drosophila; construction of robots based on the "prototype" of insects and other arthropods; creation of effective coatings "Super Black" based on the study of diffraction gratings scales on the wings of butterflies able to act on light waves and capture light and much more. "Inventions" of insects are inexhaustible; all new facets and possibilities of their world are regularly discovered. In this regard, the prospects for further development of technical entomology are extremely relevant.

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ФУНГИЦИДЫ ДЛЯ ЗАЩИТЫ ЛЮПИНА УЗКОЛИСТНОГО ОТ АНТРАКНОЗА И ДРУГИХ БОЛЕЗНЕЙ

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Представлены результаты лабораторного и полевого изучения эффективности фунгицидов Абакус Ультра, СЭ (суспензионная эмульсия) и Оптимо, КЭ (концентрат эмульсии) против возбудителя антракноза и других болезней люпина. Работа проведена в 2019–2021 гг. в Брянской области. Объект изучения – проростки и посевы люпина узколистного сорта Витязь. В лабораторных условиях эффективность Абакус Ультра (пираклостробин 62,5 г/л + эпоксиконазол – 62,5 г/л) изучали при нормах 1,25; 1,5; 2,0 л/га и Оптимо (пираклостробин – 200 г/л) – 0,5; 1,0; 1,5 л/га. Биологическую эффективность защитных и лечебных свойств фунгицидов проводили по количеству пораженных проростков, выращенных в бумажно-полиэтиленовых рулонах в сравнении с контролем (без обработки). Наибольшую биологическую эффективность защитных и лечебных свойств Абакус Ультра (98,7 и 97,0%) и Оптимо (97,7 и 93,1%) против антракноза показали нормы 2,0 и 1,5 л/га. Полевые испытания Абакус Ультра и Оптимо при нормах 2,0 и 1,5 л/га соответственно проводили на опытном поле ВНИИ люпина при естественном проявлении антракноза. Опыт закладывали в 4-кратном повторении, площадь делянки 34 м^2. Норма высева – 1,2 млн всхожих семян/га. Предшественник – яровые зерновые культуры. Обработку посевов проводили ручным опрыскивателем из расчета рабочего раствора 200 л/га. Эффективность фунгицидов определяли в сравнении с контролем. Биологическая эффективность Абакус Ультра и Оптимо против антракноза составила соответственно 95,3 и 96,3%. К фазе блестящего боба в этих вариантах количество пораженных антракнозом бобов составило 1,7 и 1,2% при 18,7% в контроле. Поражение растений фузариозом снизилось от 20,2% в контроле до 10,9 и 9,3%. Распространение серой гнили на бобах сократилось в 1,7 раза. Фунгициды не оказали ингибирующего действия на рост растений. Достоверная ($НСР_{05}$ = 0,28) прибавка урожая семян составила 0,82 и 0,98 т/га, окупаемость затрат – 2,83 и 2,40 р.

Ключевые слова: люпин узколистный, болезни, антракноз, фунгициды, эффективность, урожайность

FUNGICIDES TO PROTECT NARROW-LEAFED LUPINE AGAINST ANTHRACNOSE AND OTHER DISEASES

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The results of laboratory and field studies of fungicide effectiveness of Abacus Ultra, SE (suspension emulsion) and Optimo, EC (emulsion concentrate) against anthracnose pathogen and other lupine diseases are presented. The work was conducted in 2019-2021 in the Bryansk region. The object of study were the seedlings and crops of narrow-leafed lupine of the Vityaz variety. Under laboratory conditions, the effectiveness of Abacus Ultra (pyraclostrobin 62.5 g/l + epoxiconazole - 62.5 g/l) was studied at the rates of 1.25; 1.5; 2.0 l/ha and Optimo (pyraclostrobin - 200 g/l) - 0.5; 1.0; 1.5 l/ha. Biological effectiveness of the protective and therapeutic properties of fungicides was carried out according to the number of affected seedlings grown in paper-polyethylene rolls compared with the control (no treatment). The highest biological effectiveness of protective and curative properties of Abacus Ultra (98.7 and 97.0%) and Optimo (97.7 and 93.1%) against anthracnose

showed the norms 2.0 and 1.5 l / ha. Field trials of Abacus Ultra and Optimo at the rates of 2.0 and 1.5 l/ha, respectively, were conducted in the experimental field of the ARLSRI under natural manifestation of anthracnose. The experiment was set in 4-fold repetition, the area of the plot was 34 m^2. The seeding rate was 1.2 million germinated seeds/ha. The forecrop was presented by spring cereal crops. Crops were treated with a hand sprayer at the rate of 200 l/ha of the working solution. The effectiveness of fungicides was determined in comparison with the control. The biological efficacy of Abacus Ultra and Optimo against anthracnose was 95.3 and 96.3%, respectively. By the shiny bean phase, the number of beans affected by anthracnose in these variants was 1.7 and 1.2%, compared to 18.7% in the control. Plant infestation with fusarium blight decreased from 20.2% in the control to 10.9% and 9.3%. The spread of blossom blight on beans was reduced by 1.7 times. Fungicides had no inhibitory effect on plant growth. Significant (LSD05 = 0.28) increase in seed yield was 0.82 and 0.98 t/ha, cost recovery was 2.83 and 2.40 rubles.

Keywords: narrow-leafed lupin, diseases, anthracnose, fungicides, effectiveness, yield

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INTRODUCTION

Narrow-leafed lupine (*Lupinus angustifolius* L.) is the most early ripening of the large-seeded species. It is of great interest for cultivation in the European part of our country as well as in Siberian regions and the Primorsky Territory. The optimum sum of effective temperatures for greening crop formation is 1280-1300°, and for seed maturation - 1600-1700° [1-3]. Narrow-leafed lupine is used for grain, herbage, and silage raw material. Seeds of modern varieties contain 32-37% crude protein, with 16-20% dry matter in the herbage. The percentage of fat in the dry matter of the grain is 4,06-5,10%, in the herbage - 1,31-1,63%. Unlike other legumes, lupine kernels contain considerably fewer anti-nutritive substances, which allows using them in their raw state for feeding animals. The seed yield of the modern varieties reaches 3-4 t/ha and the herbage 40-60 t/ha [3-5]. Despite these qualities, the areas sown with narrow-leafed lupine in the Russian Federation (RF) are rather small.

Disease infestation of this crop is one of the reasons preventing the expansion of sown areas. The most common and harmful diseases in narrow-leafed lupine crops are anthracnose, fusarium blight, rhizoctonia blight, gray mould, bacterial spot and viral prolification [6-8]. However, anthracnose remains the most dangerous disease on lupine for many years. The causative agent of the disease on lupin in the RF is the imperfect fungus *Colletotrichum lupini* var. *lupini* [8-10]. Ignoring this problem leads to significant losses of grain yield and herbage. Narrow-leafed lupine shows the highest ontogenetic resistance to this pathogen among lupine species cultivated in the Russian Federation. Anthracnose and many other diseases of this crop take their infectious origin from the seeds sown [10-12]. During vegetation, the fungus spreads from diseased seedlings by rain, wind, and in-

sects across the crop and affects young growing parts of plants. This peculiarity of the pathogen allows it to affect lupin plants during all phases of crop growth and development. In epiphytotic years, the disease reduces the seed yield of the narrow-leafed lupine by 83-100% and the herbage by 69-92% [11, 12].

This disease causes the greatest harm to narrow-leafed lupine crops in the years with warm (18-26°C) and damp weather conditions from mid-May to the end of July. Under such weather conditions, even if the seed material contains 0.01-0.05% of seeds infected with anthracnose pathogen, the disease becomes epiphytotic. One application of seed dressing does not save lupine crops from yield losses. Additional treatment with fungicides during vegetation is necessary to obtain high and stable yields of seeds of this crop.

Currently, a limited number of fungicides are permitted for lupine crops in the Russian Federation, which have weak activity against the anthracnose pathogen and many other pathogens. The search for new fungicides for application on lupine on green leaf against anthracnose and other diseases of narrow-leafed lupine is an urgent task. Chemical companies specializing in plant protection produce new fungicides with high efficacy against a wide range of pathogens that are not used for the treatment of narrow-leafed lupine crops every year. Acting substances from strobilurines and triazoles group are the base of chemical method of protection against diseases. Strobilurines are recommended to be applied first in the growing season because they sharply reduce the development of fungi forms resistant to triazoles on the leaves. Thus, breeding pressure is reduced because the level of pathogen inoculum is the lowest at the beginning of the growing season. On grain crops, the first treatment with these fungicides provides a disease-free crop, treatment during earing provides a large increase in yield, because in addition to the protective effect, they have a positive physiological effect on plants, which increases their productivity [13]. The BASF company fungicides Abacus Ultra, SE (pyraclostrobin 62.5 g/l + epoxiconazole 62.5 g/l) and Optimo, SC (pyraclostrobin 200 g/l) contain active substances of these chemical groups. Piraclostrobin belongs to a new generation of active substances from strobilurin group. Pyraclostrobin being absorbed by the waxy layer of plants, provides high resistance of the preparation to atmospheric precipitation. By inhibiting mitochondrial respiration of pathogens, pyraclostrobin inhibits germination of spores and growth tubes. Epoxiconazole inhibits the growth and development of the fungus mycelium within the plant. They are effectively used to protect seeds of grain crops, sugar beets, soybeans, peas and other crops from a wide range of pathogens at the consumption rate of 0.5-1.75 l/ha[1]. These fungicides are not used to protect lupine crops against anthracnose and other pathogens.

The purpose of the research is to study biological efficacy of fungicides Abacus Ultra and Optimo against anthracnose pathogen, to establish the necessary rate of consumption for treatment of narrow-leafed lupine crops, to identify the degree of influence on plant growth and development, seed yield, to determine the possibility of including the preparations in the technology of crop cultivation.

MATERIAL AND METHODS

Initial study of fungicide activity in suppression of anthracnose pathogen was performed under laboratory conditions on narrow-leafed lupine seedlings of the Vityaz variety. Abacus Ultra was studied at the rates of 1.25; 1.50; 2.0 l/ha, Optimo - 0.5; 1.0; 1.5 l/ha. Kolosal Pro fungicide (0.4 l/ha) served as a reference. The effectiveness of the fungicides against the disease was determined by the number of affected seedlings grown in paper-polyethylene rolls. The protective properties of fungicides were studied on 4-days-old healthy seedlings, therapeutic - on 3-days-old seedlings grown from the infected seeds in the rolls. The sample volume was 180 seedlings (6 bales with 30 seedlings

[1]Product catalog 2021 of chemical company plant protection products "BASF": URL: http//www. https:// www.agro.basf.kz/ru/Products/Overview/

per treatment). The toxic effect was determined by the presence of burns and the length of the hypocotyl of the seedlings[2,3].

Field trials of fungicides Abacus Ultra and Optimo at the rates of 2.0 and 1.5 l/ha, respectively, were conducted in 2019-2021 in the experimental field of the All-Russian Lupine Scientific Research Institute under natural manifestation of anthracnose. Experiments were laid in 4-fold replications on the plots with the area of 34 m2. Vityaz narrow-leafed lupine variety was used in the experiment. Infection of seeds by anthracnose ranged from 4 to 6% depending on the year of the study. Lupin disease and fungicide efficacy were determined in the different phases of crop development[4]. The toxic effect of fungicide on the plants was evaluated by measuring their height. The crops were treated with a hand sprayer at the rate of working solution consumption of 200 l/ha. Seed yield was counted from each plot by continuous threshing of beans with Sampo-500 combine. Statistical processing of the obtained data was carried out by variance analysis with determination of the smallest significant difference[5].

RESULTS AND DISCUSSION

Laboratory tests of fungicides Abacus Ultra and Optimo showed high protective and therapeutic properties against anthracnose pathogen. Depending on the rate of consumption, the efficiency of protective properties was 83.7-98.7%, therapeutic - 75.7-97.0% (see Table 1).

The highest protective effect against anthracnose was shown by maximum consumption rates of fungicides. The effectiveness of Abacus Ultra (application rate 2.0 l/ha) of protective properties was 98.7% and therapeutic - 97.0%, Optimo (1.5 l/ha) - 97.7 and 93.0% respectively.

Табл. 1. Токсичность и эффективность фунгицидов против антракноза на проростках люпина узколистного в лабораторных условиях

Table 1. Toxicity and effectiveness of fungicides against anthracnose for narrow-leafed lupin seedlings under laboratory conditions

Option	Consumption rate, l/ha	Action			
		protective		therapeutic	
		Hypocotyl length, mm	Effectiveness, %	Hypocotyl length, mm	Effectiveness, %
Control	–	62,1	–	57,3	–
Kolosal Pro (reference standard)	0,4	35,2	98,3	33,4	97,0
Abacus Ultra, EC	1,25	38,7	90,4	35,1	85,0
Abacus Ultra, EC	1,50	42,3	96,3	38,3	92,3
Abacus Ultra, EC	2,00	46,8	98,7	45,4	97,0
LSD_{05}	–	0,88	–	0,65	–
Control	–	60,7	–	58,6	–
Kolosal Pro (reference standard)	0,4	36,8	97,3	34,5	96,3
Optimo, SC	0,5	59,7	83,7	57,3	75,7
Optimo, SC	1,0	63,2	92,3	59,9	86,3
Optimo, SC	1,5	65,1	97,7	63,7	93,1
LSD_{05}	–	0,76	–	0,71	–

[2]Popkova K.V., Shmygli V.A. Methods of Determination of Diseases and Pests of Agricultural Plants. Translated from German. Moscow: Agropromizdat, 1987. 224 p.

[3]Kungurtseva O.V. Methods for monitoring of lupine anthracnose. St. Petersburg: All-Russian Research Institute for Plant Protection, 2002. 11 p.

[4]Methodological guidelines for registration tests of fungicides in agriculture. St. Petersburg, 2009, 378 p.

[5]Dospekhov B.A. Methodology of field experiment. Moscow: Agropromizdat, 1985.

The fungicides studied have different effects on the growth of narrow-leafed lupine seedlings. Optimo stimulates seedling growth. In relation to the control, the greatest increase in seedling hypocotyl length was observed in the variant with the maximum taken rate (1.5 l/ha). It significantly (LSD_{05} = 0.76, LSD_{05} = 0.71) increased the length of hypocotyl seedlings with a protective and therapeutic effect by 4.4 and 5.1 mm, respectively.

Abacus Ultra fungicide inhibits their growth. However, with an increase in the dose its inhibitory effect on lupine seedlings significantly (LSD_{05} = 0.88, LSD_{05} = 0.65) decreased. Therefore, the greatest length of hypocotyl seedlings was in the variant with the maximum taken dose (2 l/ha) of the fungicide. Abacus Ultra did not burn seedlings and they looked healthy with dark green color of cotyledons and true leaves (see Fig. 1).

Based on these results, the most acceptable rates of fungicides, which will allow effective control of anthracnose and other diseases in the field are 2.0 l/ha for Abacus Ultra and 1.5 l/ha for Optimo.

The development and spread of diseases in narrow-leafed lupine crops in the years of field studies of fungicides Abacus Ultra and Optimo were determined by meteorological conditions and the presence of infection in the seeds and in the soil. In general, weather conditions were favorable for the development and spread of many diseases, including the anthracnose pathogen in narrow-leafed lupine crops, which made it possible to evaluate the drugs for their activity against major diseases.

Vegetation conditions in May were cool and excessively wet. Air temperatures were 13.1°C, which was 0.4°C below the long-term average, while precipitation was 68.7 mm above average (121.7 mm). June was 3.6°C and 18.0 mm above the long-term average in terms of heat and moisture content. Mean daily air temperature was 20.2°C, and precipitation amounted to

Рис. 1. Защитное действие фунгицида Абакус Ультра против антракноза на проростках люпина узколистного: *1* – контроль (без обработки фунгицидом); *2* – Абакус Ультра при норме расхода 2,0 л/га

Fig. 1. Protection action of the fungicide Abacus Ultra against anthracnose for narrow-leafed lupin seedlings: *1* – reference (fungicide free); *2* – Abacus Ultra at dose 2.0 l/ha

97.0 mm. Weather conditions in July and August were warm and dry. Mean daily air temperatures exceeded the mean annual values by 1.6 and 1.3 °C, while precipitation deficit was 30.2 and 12.6 mm, respectively.

Seed dressing protects lupine plants only for a short time, which later may negatively affect the phytopathological state of crops. When warm weather with frequent precipitation in the early phases of lupine plant development sets in, preventive treatment with fungicide in the phase of shooting - beginning of budding is necessary [11, 12].

Anthracnose development in the crops depended on the amount of precipitation and air temperature. Favorable conditions for development and spreading of anthracnose in narrow-leafed lupine crops were formed in June. Optimum air temperature (20.2 °C) and abundant precipitation contributed to intensive development and spreading of the disease in crops. At this time, plants were in active growth phases (shooting-budding phase) and were vulnerable to anthracnose pathogen, since the pathogen actively affects and develops only on the young growing parts of lupine plants. Longitudinal brown ulcers appeared on the affected stems, later turning bright pink with sporulation of the fungus. Appearance of ulcers on the stems caused their curvature with subsequent breakage, which stood out noticeably against the background of healthy plants (see Fig. 2). On leaf petioles, anthracnose manifested itself as small dark spots turning into small brown ulcers. The petioles broke off at the lesion sites. Leaves fell off or were left hanging from the covering tissue. During the growing season of narrow-leafed lupine, the greatest anthracnose lesions were observed on the plants, but not on the seedpods.

On average, the number of plants affected by this pathogen was 32.1% in the control variant during the years of research. Reduced precipitation and sufficient heat (July-August)

Рис. 2. Поражение растений люпина узколистного антракнозом в фазу стеблевание – начало бутонизации

Fig. 2. Narrow-leafed lupin plants infestation by anthracnose during stemming-early budding phase

during seedpod formation and ripening significantly reduced bean lesions with anthracnose. Thus, during the shiny bean phase, the number of beans with anthracnose ulcers was 18.7%. From the shiny bean phase to their full ripeness, plant tissues become resistant to this pathogen.

In this experiment, fungicides were applied twice in the phase of shooting and the beginning of flowering on narrow-leafed lupine. Application of fungicides Abacus Ultra and Optimo at the above rates reduced the number of plants affected by anthracnose from 32.1% in the control to 1.9 and 1.7%, respectively (see Table 2).

At the same time, bean infestation in these variants decreased from 18.7% in the control to 1.7% and 1.2%, respectively, in the shiny bean phase. The effectiveness of fungicides against anthracnose was 95.3 and 96.3%, respectively. This is 3.8 and 4.8% more than the effectiveness of the reference fungicide Kolosal Pro.

Plants of narrow-leafed lupine are significantly affected by Fusarium oxysporum and gray mould. Under the conditions of 2020, in the study of 62 specimens and varieties of narrow-leafed lupine in the north-west of the Russian Federation, 43 of them were affected by fusarium wilt (*Fusarium oxysporum*) to varying degrees. Moderate spread of gray mould (*Botrytis cineria*) was observed on 42 studied samples of *L. angustifolius* [3]. In the conditions of Belarus, fusarium wilt of narrow-leafed lupine reduces grain yield by 17-50%; the grain yield loss due to gray mould is 20-30% [11].

The variants with fungicides Abacus Ultra and Optimo showed a lower number of diseased plants with Fusarium wilt and bean gray mould. Compared with the control, plant infestation with fusarium wilt decreased by 1.9 and 2.2 times, respectively, and bean disease with gray mould by 1.7 times. Moreover, in comparison with the reference variant bean infestation by gray mould decreased by 1.4 times.

Under field conditions, the studied fungicides had no inhibitory effect on the plant growth. The average plant height of narrow-leafed lupine before harvesting in the variant with fungicide Abacus Ultra was at the control level, with fungicide Optimo - by 1.2 cm significantly (LSD_{05} = 1.15) higher than in the control. At the same time, the reference fungicide Kolosal Pro reduced the plant height by 2.2 cm.

The application of fungicides Abacus Ultra and Optimo to protect the narrow-leafed lupine crops significantly reduced the seed yield losses by 0.82 and 0.98 t/ha, or 54.3 and 58.7%, respectively (LSD05 = 0.28). In the variant with the reference fungicide Kolosal Pro, the seed yield losses were reduced by 0.66 t/ha, or 48.9%. Cost recovery for the application of fungicides Abacus Ultra and Optimo was 2.83 and 2.40 rubles for each additional ruble invested.

Thus, the use of fungicides Abacus Ultra and Optimo at the rate of 2.0 and 1.5 l/ha, respectively, to protect the crops of narrow-leafed lu-

Табл. 2. Токсичность и эффективность фунгицидов против антракноза для защиты люпина в вегетацию (полевой опыт 2019–2021 гг.)

Table 2. Toxicity and effectiveness of fungicides against anthracnose for lupin protection during the vegetation period (field experiment 2019–2021)

Option	Consumption rate, l/ha	Plant height, cm	Desease infestation, %				Effectiveness, %	Seed yield, t/ha	Yield increase to control, t/ha	Return on costs, rubles
			plants		beans					
			anthracnose	fusariosis	anthracnose	grey rot				
Control	–	45,8	32,1	20,2	18,7	3,0	–	0,69	–	–
Kolosal Pro (reference standard)	0,4	43,6	2,8	11,8	2,4	1,9	91,5	1,35	0,66	3,89
Abacus Ultra	2,0	45,6	1,9	10,9	1,7	1,8	95,3	1,51	0,82	2,83
Optimo	1,5	47,0	1,7	9,3	1,2	1,7	96,3	1,67	0,98	2,40
LSD_{05}	–	1,15	–	–	–	–	–	0,28	–	–

pine significantly reduces the damage by harmful diseases, including anthracnose, promotes the realization of the seed yield potential of this high-protein crop.

ЗАКЛЮЧЕНИЕ

Application of fungicides Abacus Ultra (2.0 l/ha) and Optimo (1.5 l/ha) to protect narrow-leafed lupine from anthracnose and other diseases significantly reduces the infestation of plants and beans by various pathogens, has a positive effect on growth, development and productivity of the crop.

Over the years of research, the biological efficacy of Abacus Ultra and Optimo against the anthracnose pathogen was 95.3 and 96.3%, respectively. This significantly reduces the infectious load of the pathogen in crops. The spread of anthracnose across plants was 1.9 and 1.7%, compared to 32.1% in the control. The bean infestation with this pathogen was 1.7 and 1.2% with 18.7% in the control. Fungicides showed high efficiency against *Fusarium* fungi and gray mould. Plant infestation with Fusarium decreased by 1.9 and 2.2 times respectively, bean infestation with gray mould by 1.7 times.

The studied fungicides had no inhibitory effect on the plant growth. The plant height of narrow-leafed lupine before harvesting in the variant with fungicide Abacus Ultra was at the control level, and with fungicide Optimo was significantly (LSD_{05} = 1.15) higher than in the control by 1.2 cm.

The obtained significant (LSD05 = 0,041) increases of the seed yield (0,82 and 0,98 t/ha) paid back the expenses on the application of the studied fungicides in the amount of 2,83 and 2,40 rubles for each additional ruble invested. Since the experimental preparations are not registered in the Russian Federation for application on lupine, this work is experimental in nature.

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МОНИТОРИНГ И ХАРАКТЕРИСТИКА КУЛЬТУР *MYCOBACTERIUM AVIUM* SUBSP. *PARATUBERCULOSIS,* ВЫДЕЛЕННЫХ НА ТЕРРИТОРИИ ЗАПАДНОЙ СИБИРИ

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Представлены результаты микробиологических исследований стандартизированного штамма и изолятов, относящихся к *Mycobacterium avium* subsp. *paratuberculosis* (*MAP*), выделенных на территории Западной Сибири. Воспроизведена экспериментальная паратуберкулезная инфекция на нелинейных белых мышах с использованием внутрибрюшинного и внутривенного способов заражения опытными дозами 0,1; 0,25; 0,5 и 1,0 мл суспензии стандартизированного штамма и изолятов. Микробиологические исследования штамма и изолятов включали микроскопический, культуральный и биохимические методы: окраска мазков по Цилю – Нильсену; посевы суспензии микобактерий на плотную яичную питательную среду Левенштейна – Йенсена с фактором роста микобактином, предпосевной обработки биоматериала, полученного от лабораторных животных, с последующим посевом полученного осадка на яичные питательные среды с микобактином. Биохимические тесты: рост патогенов при 30, 37 и 42 ºС, определение амидазной активности; наличие роста колоний или его отсутствие на среде с салицилатом натрия, определение каталазной и арилсульфатазной активности, редукция нитратов, гидролиз твин-80, устойчивость к 5%-му хлориду натрия. По результатам проведенных исследований изученные культуры отнесены к 3-й группе микобактерий по классификации Раньона. У мышей, зараженных 0,1; 0,25; 0,5 и 1,0 мл суспензии стандартизированного штамма и изолятами внутрибрюшинно, выявлены увеличение легких, селезенки и печени, единичные гнойные очаги на печени, селезенке и брыжейке. Индекс высеваемости составил (++)2 – (+++)3 – (++++)4. У мышей, зараженных 0,1; 0,25; 0,5 и 1,0 мл суспензии стандартизированного штамма и изолятами внутривенно, выявлены увеличение легких, селезенки и печени, печень мраморной окраски, гнойные очаги в печени. Индекс высеваемости составил (++)2 – (+++)3 – (++++)4. Получены научные данные о культуральных, биохимических и биологических свойствах изолятов паратуберкулезных микобактерий, совпадающие с идентичными показателями стандартизированного штамма *Mycobacterium avium* subsp. *paratuberculosis*, что позволяет отнести их к микобактериям паратуберкулеза. Биологический метод исследования на нелинейных белых мышах с использованием внутрибрюшинного и внутривенного способов заражения опытными дозами суспензий, содержащих стандартизированный штамм и изоляты возбудителя паратуберкулеза, позволил установить эффективность данных способов и доз для воспроизведения экспериментальной паратуберкулезной инфекции на нелинейных белых мышах.

Ключевые слова: паратуберкулез, изолят, микобактерии, биохимические тесты, биологическая проба, биоматериал

MONITORING AND CHARACTERIZATION OF *MYCOBACTERIUM AVIUM* SUBSP. *PARATUBERCULOSIS* CULTURES ISOLATED ON THE TERRITORY OF WESTERN SIBERIA

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The results of microbiological studies of a standardized strain and isolates related to *Mycobacterium avium* subsp. *paratuberculosis* (MAP) isolated in Western Siberia are presented. Experimental paratuberculosis infection was reproduced on nonlinear white mice using intraperitoneal and intravenous methods of infection with experimental doses of 0.1;0.25; 0.5 and 1.0 ml of suspensions of standardized strains and isolates. Microbiological studies of strains and isolates included microscopic, cultural and biochemical methods: Ziehl-Neelsen staining of smears; inoculation of mycobacteria suspension on thick egg culture medium Lowenstein-Jensen with mycobactin growth factor; pre-sowing treatment of biomaterial obtained from laboratory animals with subsequent inoculation of the resulting sediment on egg culture medium with mycobactin. Biochemical tests: pathogen growth at 30, 37 and 42 ºC, determination of amidase activity; presence of colony growth or its absence on medium with sodium salicylate, determination of catalase and arylsulfatase activity, nitrate reduction, hydrolysis of tween-80, resistance to 5% sodium chloride. According to the results of the studies, the cultures studied were classified as mycobacteria group 3 according to Runyon's classification. Mice infected with 0.1; 0.25; 0.5 and 1.0 ml of standardized strain suspension and isolates intraperitoneally showed enlargement of lungs, spleen and liver, single purulent foci on liver, spleen and mesentery. The isolation rate index was (++)2 to(+++)3 to(++++)4. Mice infected with 0.1; 0.25; 0.5 and 1.0 ml of standardized strain suspension and intravenous isolates showed enlargement of lungs, spleen and liver, marbled liver, suppurative foci in liver. The isolation rate index was (++)2 to(+++)3 to(++++)4. Scientific data on the cultural, biochemical and biological properties of isolates of paratuberculous mycobacteria coinciding with identical parameters of the standardized strain *Mycobacterium avium* subsp. *paratuberculosis* (MAP) were obtained, which allows to refer them to mycobacteria of paratuberculosis. Biological method of research on nonlinear white mice using intraperitoneal and intravenous methods of infection with experimental doses of suspensions containing a standardized strain and isolates of the paratuberculosis pathogen, allowed to establish the effectiveness of these methods and doses for reproduction of experimental paratuberculosis infection on nonlinear white mice.

Keywords: paratuberculosis, isolate, mycobacteria, biochemical tests, biological sample, biomaterial

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INTRODUCTION

Paratuberculosis (paratuberculous enteritis, Ione's disease) is a chronic enteropathy of ruminants and some non-ruminants caused by Mycobacterium avium subsp. paratuberculosis. The disease mainly occurs without marked clinical symptoms and can have different forms of manifestation: from forms with high prevalence and significant mortality to cases with very low prevalence and low morbidity and rare mortality [1, 2].

Transmission of the pathogen to young animals is mainly through the feces of infected adult animals, many of which have no clinical signs of the disease. In this regard, paratuberculosis has been and remains one of the difficult to control and diagnose infections due to the fact that the incubation period can last from 6 months to 15 years. In addition, the pathogen is extremely resistant to environmental factors, where it can survive for up to a year or more [3, 4].

Despite the fact that veterinary science and practice are mainly focused on paratuberculosis in cattle, sheep and goats, many wild animals (deer, ermines, antelopes, foxes, ibexes, bisons, camels, llamas, weasels) also suffer from this infection. In addition, *M. paratuberculosis* persists in horses, mules, and pigs, which, when infected, become bacterial carriers that actively release the pathogen into the external environment. The importance of an infected or sick animal as a source of the paratuberculosis pathogen is due to the peculiarities of its excretion at different stages of the infectious process. This makes it necessary to conduct a detailed study of various properties of the paratuberculosis pathogen, which are essential in the development of the pathogenesis of the disease and in carrying out effective anti-epizootic measures [5, 6].

Allergic and serological methods of in vivo diagnosis as well as microbiological methods of isolation and identification of the pathogen, including bacteriological and biochemical methods based on the fact that during the process of metabolism some species of mycobacteria exhibit different enzymatic activity are used to identify paratuberculosis patients. There is also a biological method of paratuberculosis diagnosis, which is based on modeling the infection on laboratory animals (mice, rats, rabbits, hamsters, gerbils, guinea pigs) and birds (pigeons) due to their ability to replicate *M. paratuberculosis* during experimental infection. It should be noted that *M. avium* is pathogenic for chickens and rabbits, whereas *M. paratuberculosis* is not pathogenic for these animal species [7-9].

Modern diagnostic tests are not able to recognize all stages of the disease, which makes it difficult to diagnose and control the manifestation of this infection. Consequently, the insufficient efficiency of methods for identifying the pathogen and reproducing the disease in laboratory and naturally susceptible animals is an obstacle to studying the pathogenesis as well as developing effective diagnostic methods and control measures for this disease [10, 11].

All of the above indicates that paratuberculosis remains one of the serious problems for the livestock industry for the next few decades. Despite the implementation of veterinary routine preventive and health measures, it continues to cause significant economic damage to livestock production (see Fig. 1, 2) [12].

Рис. 1. Корова, больная паратуберкулезом
Fig. 1. A cow suffering from paratuberculosis

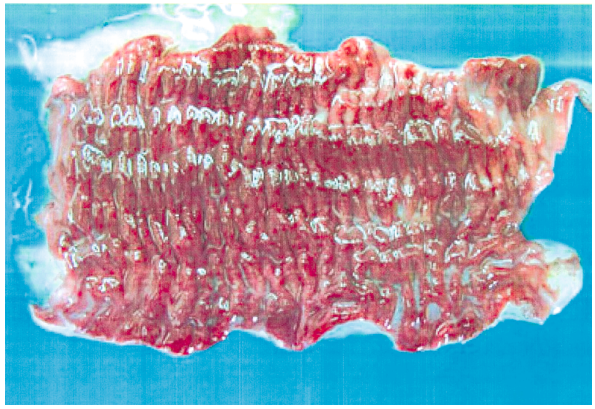

Рис. 2. Патологоанатомические изменения слизистой оболочки тонкого отдела кишечника у крупного рогатого скота при паратуберкулезе

Fig. 2. Pathological anatomical changes in the mucosa of the small intestine in bovine animals suffering from paratuberculosis

In this connection there is a necessity to improve highly specific and sensitive diagnostic methods of bovine paratuberculosis, especially the detection of animals in the initial stage of the disease, as well as in the period of excretion of the pathogen with feces into the external environment, taking into account the world experience. Using the whole complex of diagnostic methods of detection of paratuberculosis pathogen will allow to plan and carry out effective anti-epizootic measures in time, which will enable to prevent uncontrolled spread of this disease in cattle herds, as well as among other domestic and wild animal species.

The purpose of the study was to examine the cultural, biochemical and biological properties of mycobacteria isolated from animals and birds belonging to *Mycobacterium avium* subsp. *rabetricusliosis* (MAP).

MATERIAL AND METHODS

Microscopic method of staining smears by Ziehl-Neelsen; cultural method, including inoculation of mycobacterial suspension on dense egg culture medium Lowenstein–Jensen with growth factor mycobactin, as *M. paratuberculosis* are mycobactin-dependent, and presowing treatment of biological material obtained from laboratory animals with subsequent inoculation of the resulting sediment on egg culture medium with mycobactin were used to conduct the research. Biochemical tests: pathogen growth at 30, 37 and 42 ºC, determination of amidase activity; presence of colony growth or its absence on the medium with sodium salicylate, determination of catalase and arylsulfatase activity, nitrate reduction, hydrolysis of tween-80, resistance to 5% sodium chloride. Nitrate reductase activity was determined by the Tsukamura method; catalase activity was determined according to the method of G. Weyne (1962), hydrolysis of tween-80 by the modified method of G. Weyne (1964), amidase activity of Mycobacterium paratuberculosis - by the Taequet method[1] [13]. The biological method consisted in infecting non-linear white mice with different doses of the studied cultures suspension intraperitoneally and intravenously. A total of 32 experimental and 8 control groups of laboratory animals were formed, each group contained 5 mice with an average weight of 23 g.

Mice were infected with a suspension containing 1 mg of bacterial mass of pathogen cultures dissolved in 1 ml of physiological solution. Mice were infected once intravenously into the tail vein and intraperitoneally by injecting 0.1; 0.25; 0.5 and 1.0 ml of the suspension. The duration of the experiment was 4 months (120 days), after which the animals were routinely euthanized, followed by autopsy and biomaterial sampling (lungs, liver, spleen). The internal organs were treated by A.P. Alikaeva's method[2] followed by inoculation of the obtained suspensions on egg culture medium with mycobactin. Appearance of colony growth was recorded every 2 days during the first week, then once a week.

[1]New methods for the study of anthropozoonosis pathogens. Tuberculosis: guidelines. MOSCOW: RAAS, 2003. 50 p.

[2]Agricultural animals and poultry. Methods of laboratory diagnosis of tuberculosis: GOST 26072-89 (ST SEV 3457-81). Moscow: Publishing house of standards, 1989. 13 p.

RESULTS AND DISCUSSION

The standardized strain Central Lyubinsky (All-Russian Scientific-Research Institute of Brucellosis and Tuberculosis of Animals) and three isolates extracted from biological material of animals and birds in different natural and geographic zones of Western Siberia were selected for the complex of studies.

Results of cultural and biochemical studies. The Central Lyubinsky strain was isolated from the small intestine of cattle with changes characteristic of paratuberculous enteritis in the form of pronounced folding and thickening of the mucosa. The appearance of growth of this strain on Lowenstein-Jensen medium with mycobactin was observed on day 8 in the form of light-colored (beige) colonies located separately from each other, of medium size with a depression in the center (R shape). The mycobacterial strain showed no growth at 30 °C, abundant growth at 37 °C, and scanty growth at 42 °C. Amidase activity of the pathogen was negative, catalase activity was negligible. Positive growth on medium with sodium salicylate and hydrolysis of tween-80 (day 6) was observed. Arylsulfatase activity and nitrate reduction were negative, resistance to 5% NaCl was absent.

Isolate № 1 was isolated from the mandibular lymph nodes of a pig with the presence of caseous foci. In passages on Lowenstein-Jensen medium with mycobactin, the appearance of pathogen growth was noted on the 5th day. The colonies were light beige in color, confluent and separate from each other, of rough consistency (R shape). There was no colony growth at 30 °C, intense at 37 °C, and scanty at 42 °C. Amidase activity was absent, and the isolate had weakly expressed catalase activity. Growth on the medium with sodium salicylate was observed. Hydrolysis of tween-80 was positive (day 5). Arylsulfatase activity and nitrate reduction were negative, resistance to 5% NaCl was absent. Based on the diagnostic tests performed, the isolate was classified as mycobacterial group 3 according to the Runyon classification.

Isolate № 2 was isolated from the small intestine of cattle with pathological changes characteristic of paratuberculous enteritis in the form of pronounced folding and thickening of the mucosa. In passages on Levenstein-Jensen medium with mycobactin, the appearance of pathogen growth was noted on the 8th day. The colonies were light colored, large and medium-sized, separated from each other, rough and mucousy consistency (R and S shape). There was no colony growth at 30 °C, intensive growth was observed at 37 °C, and growth was scanty at 42 °C. Amidase activity was absent, catalase activity was weak, and colony growth on the medium with sodium salicylate was observed. Hydrolysis of tween-80 was positive (day 5), arylsulfatase activity and nitrate reduction were negative, resistance to 5% NaCl was absent. Based on the diagnostic tests performed, the isolate was classified as mycobacterial group 3 according to the Runyon classification.

Isolate №. 3 was isolated from the internal organs of crows. In passages on Levenstein-Jensen medium with mycobactin, the appearance of primary growth of the pathogen was noted on the 6th day, the colonies were light beige in color, small and medium in size, fused together, of rough consistency (R shape). There was no growth of the pathogen at 30 °C, abundant growth at 37 °C, and scanty growth at 42 °C. Amidase activity was absent and catalase activity was weakly expressed. Pathogen growth was positive on medium with the addition of sodium salicylate. Hydrolysis of tween-80 was positive (day 6), arylsulfatase activity and nitrate reduction were negative, resistance to 5% NaCl was absent. Based on the diagnostic tests performed, the isolate was classified as mycobacterial group 3 according to the Runyon classification. (see Table 1, Fig. 3).

Microscopic examination of strain cultures and pathogen isolates showed the presence of acid-fast granular rods in smears stained by Ziehl–Neelsen, arranged in clumps as a "palisade", which is a characteristic feature of MAP.

The shortening of the appearance of primary growth of the studied strains and isolates of the paratuberculosis pathogen during multiple passages on dense egg nutrient media is due to their adaptation to favorable cultivation conditions, leading to a variation in the quantitative

Табл. 1. Результаты культурального и биохимических исследований стандартизированного штамма и изолятов паратуберкулезного патогенов

Table 1. Results of cultural and biochemical studies of a standardized strain and isolates of the paratuberculosis pathogen

Cultural properties	Growth, ºC			Amidase activity	Catalase activity	Growth on salicylate medium Na	Hydrolysis of tween-80	Arylsulfatase activity	Nitrate Reduction	Growth on the medium with 5% NaCl
	30	37	42							
Standardized strain: light-colored (beige) colonies, separated from each other, medium-sized with a depression in the center (R shape)	–	+	+/–	–	+/–	+	+	–	–	–
Isolate № 1: colonies of light beige color, merged and separate from each other, rough consistency (R form)	–	+	+/–	–	+/–	+	+	–	–	–
Isolate № 2: light colored, large and medium-sized colonies, separate from each other, rough and slimy consistency (R and S shape)	–	+	+/–	–	+/–	+	+	–	–	–
Isolate № 3: colonies of light beige color, small and medium in size, merged with each other, rough consistency (R form)	–	+	+/–	–	+–	+	+	–	–	–

content of mycolic acids on the surface of bacterial cells, which causes changes in the thickness and permeability of their membranes. This process is reflected, in turn, in an increase or decrease in the hydrophobicity of the cell wall and, consequently, leads to an increase in the level of nutrient supply to the cell, which affects the rate and intensity of growth of their cultures. It should be noted that after the third and subsequent passages on dense egg nutrient media, R-subcultures of the studied pathogens acquired the ability to grow on Pavlovsky potato medium even without mycobactin growth factor [14].

The biological studies performed showed that the mice of the experimental groups had a lower body weight than those of the control groups. Autopsies of mice infected with 0.1; 0.25; 0.5 and 1.0 ml of suspension of the standardized strain of the paratuberculosis pathogen intraperitoneally showed slight enlargement of lungs, spleen and liver, single suppurative foci on the liver. The isolation rate index was ++(2) – ++++ (4).

Infection of white mice with identical doses of the standardized pathogen strain intravenously resulted in the enlargement of the lungs, liver, and spleen, and the liver was marbled

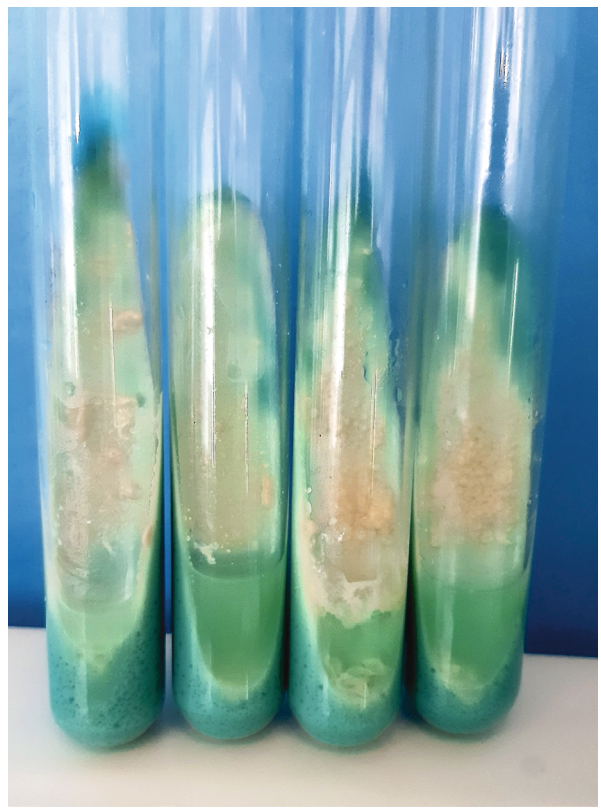

Рис. 3. Рост культур штамма и изолятов возбудителя паратуберкулеза на яичной питательной среде Левенштейна – Йенсена с фактором роста микобактином

Fig. 3. Growth of cultures of paratuberculosis strains and isolates on Lowenstein-Jensen egg culture medium with growth factor mycobactin

with purulent foci. The isolation rate index was ++(2) – ++++ (4).

In mice infected with 0.1; 0.25; 0.5 and 1.0 ml of suspension of isolate № 1 of the paratuberculosis pathogen intraperitoneally, the autopsy revealed enlargement of lungs, liver and spleen with purulent foci on the liver and spleen. The isolation rate index was ++(2) – +++(3). When infected intravenously, mice showed enlargement of the lungs, liver, and spleen. The isolation rate index was ++(2) – +++(3).

In infected white mice, 0.1; 0.25; 0.5 and 1.0 ml of suspension of isolate № 2 of the paratuberculosis pathogen intraperitoneally, enlargement of the lungs, liver and spleen, as well as single purulent foci on the mesentery were noted at the autopsy. The isolation rate index was ++(2) – +++(3).

Infection of white mice with identical doses of isolate № 2 of the paratuberculosis pathogen intravenously revealed increased liver and spleen. The isolation rate index was ++(2) – +++(3).

Pathological autopsy of white mice infected with 0.1; 0.25; 0.5 and 1.0 ml of suspension of isolate № 3 of the paratuberculosis pathogen intraperitoneally revealed slight enlargement of lungs, liver and spleen with purulent foci on liver and mesentery. The isolation rate index was ++(2) – +++(3). Autopsy of mice infected intravenously revealed enlarged liver and spleen with purulent foci in the liver. The isolation rate index was ++(2) (см. табл. 2).

Bacterioscopic examination of smears of paratuberculosis pathogens isolated from the internal organs of white mice in all experimental groups, stained by Ziehl-Neelsen, showed the presence of single acid-fast granular rods, arranged in groups or in the form of "palisades", which is typical for the pathogen of paratuberculosis.

CONCLUSION

A set of laboratory methods of investigation of isolates of Mycobacterium paratuberculosis isolated in Western Siberia from animal and bird biomaterial allowed to obtain scientific data on their cultural, biochemical and biological properties coinciding with identical indicators of the standardized strain *Mycobacterium avium* subsp. *paratuberculosis*, which allows to refer them to mycobacteria of the same pathogen. Biological method of research on nonlinear white mice using intraperitoneal and intravenous methods of infection with experimental doses of suspensions containing the standard-

Табл. 2. Результаты биологической пробы на нелинейных белых мышах, зараженных различными способами и дозами штамма и изолятов паратуберкулезных патогенов

Table 2. Results of biological assay on nonlinear white mice infected in different ways and with doses of strains and isolates of paratuberculosis pathogens

Strain and isolates	Method and dose of infection	
	Intraperitoneal (0,1; 0,25; 0,5; 1,0 ml)	Intravenous (0,1; 0,25; 0,5; 1,0 ml)
	Pathological anatomical changes. The isolation rate index.	
Standardized strain	Slight enlargement of the lungs, spleen and liver, single suppurative foci on the liver. The isolation rate index ++(2) – ++++ (4)	Enlarged lungs, liver and spleen, marbled liver with suppurative foci. The isolation rate index ++(2) – ++++ (4)
Isolate № 1	Enlarged lungs, liver, and spleen with suppurative foci on the liver and spleen. The isolation rate index ++(2) – +++(3)	Enlarged lungs, liver, and spleen. The isolation rate index ++(2) – +++(3)
Isolate № 2	Enlargement of the lungs, liver, and spleen, as well as single suppurative foci on the mesentery. The isolation rate index ++(2) – +++(3)	Enlarged liver and spleen. The isolation rate index ++(2) – +++(3)
Isolate № 3	Slight enlargement of the lungs, liver, and spleen with suppurative foci on the liver and mesentery. The isolation rate index ++(2) – +++(3).	Enlarged liver and spleen, suppurative foci in the liver. The isolation rate index ++(2)

ized strain and separated isolates of the paratuberculosis pathogen allowed to establish the effectiveness of these methods and doses for reproduction of experimental paratuberculosis infection on nonlinear white mice.

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ВЛИЯНИЕ РАЗНОГО УРОВНЯ КОРМЛЕНИЯ НА ПРОДУКТИВНОСТЬ БЫЧКОВ ЧЕРНО-ПЕСТРОЙ ПОРОДЫ

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Представлены исследования по регулированию уровня кормления молодняка животных в постэмбриональный период. Установлено влияние различных уровней кормления на скорость роста, развитие, мясную продуктивность, формирование мясности и соотношение важнейших тканей в туше молодняка черно-пестрой породы крупного рогатого скота в различные возрастные периоды. Схема выращивания молодняка была следующей: 1-я группа – повышенный уровень кормления до 14-месячного возраста, 1-я (а) – выращивание молодняка до 8 мес так же, как и животных 1-й группы (повышенный уровень кормления), от 8 до 14 мес – содержание на среднем хозяйственном кормлении; 2-я группа – хозяйственное среднее кормление до 14 мес, 2-я (а) – до 8 мес – хозяйственное (среднее) кормление, от 8 до 14 мес – повышенный уровень кормления. За 14 мес выращивания израсходовали на каждую голову в 1-й группе 2114,8 ЭКЕ, во 2-й (а) – 1888,1, в 1-й (а) – 1919,0, во 2-й – 1692,3 ЭКЕ, за 18 мес выращивания: в 1-й группе – 3673,2, во 2-й (а) – 3345,6, в 1-й (а) – 3197,4, во 2-й – 3240,0 ЭКЕ. У молодняка 1-й группы, находившегося на улучшенном кормлении, среднесуточный прирост за весь период составил 837 г, что на 124, 161 и 170 г ($p > 0,999$) больше, чем у молодняка 2-й (а), 1-й (а) и 2-й групп соответственно. При высоком уровне кормления молодняка крупного рогатого скота на мясо отмечено резкое увеличение мясной продуктивности и улучшение качества мяса. При этом снижались затраты кормов на производимую продукцию и повышалась экономическая эффективность выращивания скота. Уровень кормления оказывает дифференцированное влияние на развитие отдельных органов и тканей.

Ключевые слова: черно-пестрая порода, бычки, рост, мясные качества, уровень кормления, затраты кормов

INFLUENCE OF DIFFERENT LEVELS OF FEEDING ON THE PRODUCTIVITY OF BLACK-AND-WHITE BULL CALVES

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Studies on the regulation of the level of feeding of young animals in the post-embryonic period are presented. The effect of different levels of feeding on the growth rate, development, meat productivity, formation of meatiness and the ratio of the most important tissues in the carcass of young Black-and-White breed of cattle at different age periods has been established. The scheme of young animals rearing was as follows: Group 1 - increased level of feeding until 14 months of age, Group 1 (a) - rearing the young animals until 8 months in the same manner as in Group 1 (increased level of feeding), from 8 to 14 months - maintenance on medium farm feed; Group 2 - medium farm feed until 14 months, Group 2 (a) - until 8 months - medium farm (medium) feeding, from 8 to 14 months - increased level of feeding. For 14 months of rearing, 2114,8 EFU were spent per head in group 1, 1888,1 in group 2 (a), 1919,0 in group 1 (a), 1692,3 EFU in group 2; for 18 months of rearing: 3673,2 in group 1, 3345,6 in group 2 (a), 3397,4 in group 1 (a), 3240,0 EFU in group 2. Group 1 youngsters on improved feed had an average daily gain of 837 g for the whole period, which was 124, 161 and 170 g ($p > 0.999$) more than Group 2 (a), Group 1 (a) and Group 2 youngsters, respectively. At a high level of feeding young cattle for meat, a sharp increase in meat productivity and improved meat quality was noted. At the same time, the cost of feed for the products produced decreased and the economic efficiency of livestock breeding increased. The level of feeding has a differential effect on the development of individual organs and tissues.

Keywords: Black-and-White breed, bull calves, growth, meat qualities, nutritional level, feed costs

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INTRODUCTION

One of the elements of the promising model of development of domestic cattle breeding is to increase the level of animal productivity, which is directly dependent on the level of feeding, breeding work, rational use of the world and domestic gene pool of cattle [1-4].

Increasing demand for meat as a food product and the need to obtain it with the least expenditure of feed and funds put forward as the main task in cattle breeding to create animals with high growth energy, good payment for feed, capable of reaching 15-18 months age large live weight with a high slaughter yield and good quality meat indicators [5-9].

Currently, the main amount of beef is supplied by dairy and dairy-meat production farms. Studying the influence of the level of feeding on growth, development and beef productivity of cattle is one of the important tasks of zootechnical science and practice. Feeding serves as a powerful factor in the formation of the animal. Works of many scientists are devoted to the influence of nutrition on growth, development and meat productivity [10-14]. By regulating the level of feeding of young animals in the post-embryonic period, it is possible to change the growth rate of animals, the formation of meatiness and the ratio of the most important tissues in the carcass (muscle, bone, fat).

The purpose of the work is to establish the effect of different levels of feeding on growth, development, meat productivity of young black and white cattle breeds at different age periods.

MATERIAL AND METHODS

The experiment on growing young cattle of black-and-white breed up to 18 months was conducted in 2019, 2020 in the APC breeding farm "Zarya-1" of the Karachay-Cherkess Republic. Based on the analogue method, the test bulls were distributed into groups of 15 animals each. The scheme of growing young animals was as follows:

– Group 1: Increased level of feeding until 14 months of age;

– Group 1 (a): young animals are reared up to 8 months of age the same way as in Group 1 (increased level of feeding), from 8 to 14 months - kept on medium farm feed;

– Group 2: economic average feeding up to 14 months;

– Group 2 (a): up to 8 months - economic (average) feeding, from 8 to 14 months - increased level of feeding.

At the age of 14 to 16 months the young cattle of all groups were put under the same conditions of grazing, from 16 to 18 months - on intensive fattening.

Bulls were castrated at 3 months of age. The growth and development of the animals were recorded by individual weighing at the beginning of the experiment and at 9-, 12-, 16- and 18-months of age. The absolute, average daily and relative gain in live weight were calculated based on the weighing for the periods of the experiment and for the whole cycle of growing and fattening.

To study meat productivity, three steers from each group were slaughtered at 14- and 18-months of age according to the methodology of the VIZh (The All-Russia Research Institute for Animal Husbandry), VNIIMP (The

Gorbatov's All-Russian Meat Research Institute). The slaughter was performed at the meat processing plant OJSC RAPE (republican agro-industrial enterprise) "Caucasus Meat". The pre-slaughter live weight, carcass and internal raw fat weights, relative carcass yield, and slaughter yield were established during control slaughtering.

The morphological composition was determined by boning the half-carcass chilled for 24 hours at a temperature of 0 to 4 °C. Based on the boning and desinewing, the absolute and relative content of bones, flesh, tendons and cartilage were calculated, as well as the meat index (yield of flesh per 1 kg of bones), weight and yield of natural anatomical parts of the carcass (VNIIMS - Russian Research Institute for Metrological Service).

To study the qualitative indicators of beef, average samples of the fleshy part of the carcass weighing 400 g, the longest muscle of the back and fat from three carcasses of each group of different localization of 200 g were taken.

The chemical composition of muscle and fat tissue was determined according to the methods of zootechnical analysis.

The experimental data were processed using the mathematical method of variation statistics. Significance of the difference was determined by the Student's test.

RESULTS AND DISCUSSION

There were significant differences between the groups in the amount of feed fed and its nutritive value. Thus, for 8 months the young cattle of the 1st group spent 870.9 EFU, or 26% more than the young cattle of the 2nd group. At the age of 8-14 months the bulls of groups 1 and 2 (a) received 195.8 EFU more in feed than the bulls of groups 2 and 1 (a).

For 14 months of breeding 2114,8 EFU were spent per head in the 1st group, 1888,1 in the 2nd group, 1919,0 in the 1st group and 1692,3 EFU in the 2nd group. During the period young animals of the 1st group were fed 422,5 EFU or 24,9 % more than young animals of the 2nd group. Cattle of the "transfer" groups (1-st (a) and 2-st (a)) received by 195,8 and 226,7 EFU or 11-13% more than the young of the 2nd group. Thus, the "transfer" groups occupied an intermediate position between the bulls of groups 1 and 2 in terms of the amount of feed. In summer, animals of all groups were transferred to grazing. For 60 days of fattening, on average, 17 cwt of grass was fed per steer in Group 1, 18.5 cwt in Group 2, 20.4 cwt in Group 1 (a) and 19.2 cwt in Group 2 (a).

For 18 months of rearing, the fodder was spent per head, EFU: in group 1 - 3673.2, 1 (a) - 3197.4, in group 2 - 3240.0 and 2 (a) - 3345.6.

It was found that the live weight of young animals changed in different periods depending on the level of feeding (see Table 1, Fig. 1).

Analysis of the growth pattern shows that when reared at the first 8 months after birth on reduced feeding with subsequent transfer to improved feeding, steers grow well and their growth retardation is significantly compensated. However, the growth retardation in the young bulls of the 2nd group (a) at the age of 8 months after transfer to increased feeding was

Табл.1. Изменение живой массы молодняка с возрастом, кг (n = 15)
Table 1. Change in live weight of young animals with age, kg (n = 15)

Group	Age, months						
	at birth	6	8	12	14	16	18
1-st	32 ± 0,34	156 ± 0,39	208 ± 0,32	312 ± 0,32	364 ± 0,73	406 ± 0,37	484 ± 0,42
1-st (a)	30 ± 0,36	158 ± 0,51	209 ± 053	265 ± 0,56	292 ± 0,60	341 ± 0,38	395 ± 0,87
2-nd	29 ± 0,52	126 ± 0,40	159 ± 0,32	220 ± 0,35	241 ± 0,54	317 ± 0,76	389 ± 0,72
2-nd (a)	30 ± 0,58	121 ± 0,54	158 ± 0,62	238 ± 0,72	268 ± 0,64	339 ± 0,56	415 ± 0,82

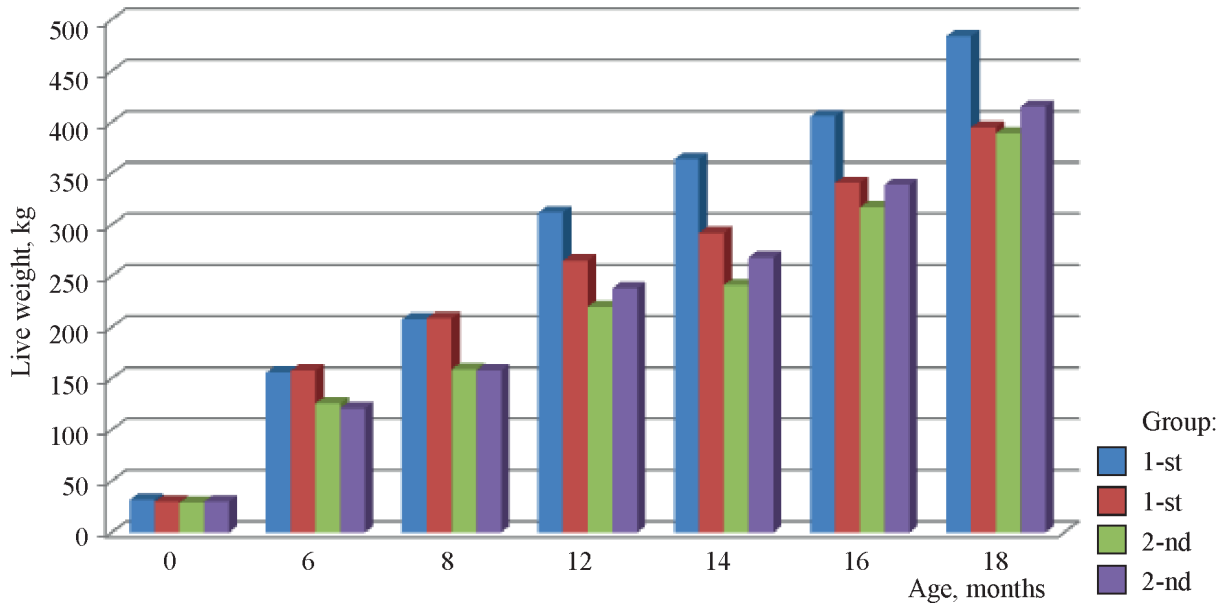

Рис. 1. Динамика среднего значения живой массы бычков, кг
Fig. 1. Dynamics of the average live weight of bulls, kg

not completely compensated even at the age of 18 months. Obviously, the level of increased feeding applicable in this experiment did not provide a complete recovery of live weight during this period.

The question arises: how do young animals grow when transferred from a higher level of feeding to a lower one? Analysis of growth in the "transferred" group 1 (a) has quite a different picture. After transfer to the reduced level of feeding, the young animals showed lower growth rates than their counterparts raised at the average level of feeding. Thus, at the same feeding level from 8 to 14 months of age, the average daily gain in bulls of group 1 (a) was 442 g, in bulls of group 2 - 690 g, or 36% more ($p > 0,999$) (see Fig. 2). It should be noted that the average daily gain in bulls of group 1 on improved feed was 837 g for the whole period. This index was 124, 161 and 170 g ($p > 0,999$)

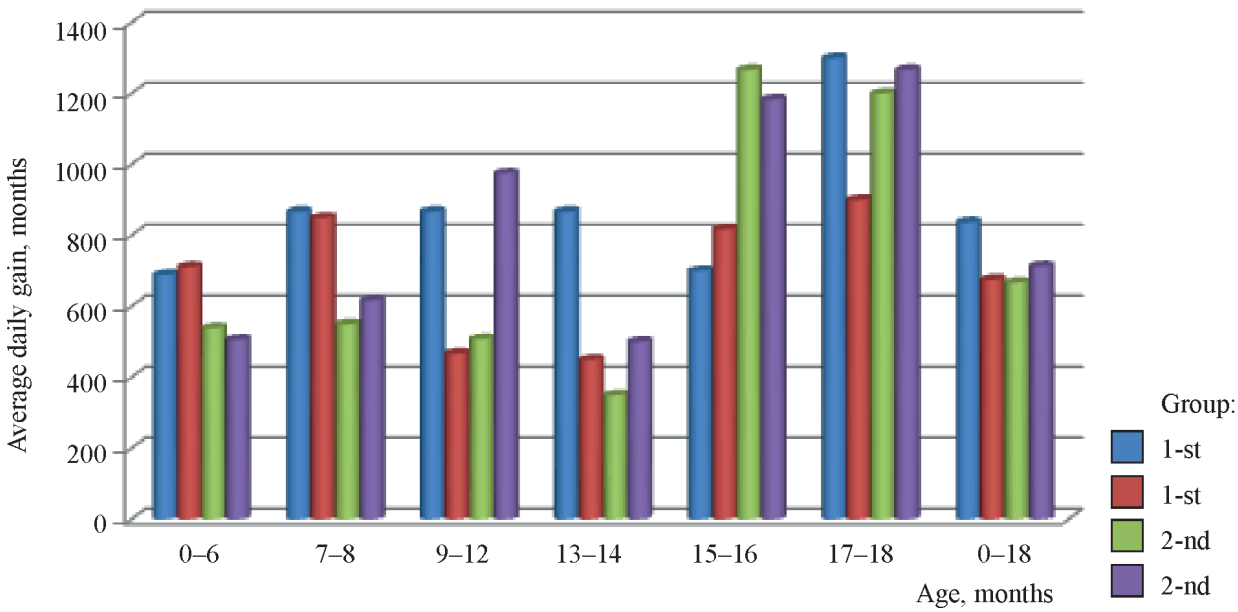

Рис. 2. Динамика среднесуточного прироста живой массы бычков, г
Fig. 2. Dynamics of the average daily increase in live weight of bulls, g

higher than the values of group 2 (a), group 1 (a) and group 2, respectively.

In youngsters transferred at 8 months of age from improved feeding to farm feed (group 1 (a)), the average daily gain in winter was 248 g ($p > 0.99$) less than in group 2 youngsters and 428 g, 478 g ($p > 0.999$) less than in groups 1 and 2 (a).

Subsequently, young animals of all groups were transferred to pasture feeding. During the fattening period the difference was small. The young animals of group 1 used the pasture worse and were much inferior to the animals of all other groups: their daily gain was lower (700 g). The experimental group 1 turned out to be more demanding to feed. Obviously, the digestive system of these animals was less prepared to use vegetable bulky fodder. However, during the final fattening period, Group 1 bulls had high average daily gains of live weight (1300 g) and outperformed their peers of Group 2 (a), Group 1 (a), Group 2 by 20, 400, 100 g, and during the whole growing period by 124, 161, 170 g, respectively.

A one-factor analysis of variance was carried out to determine the effect of bulls belonging to one or another group on the average daily gain in different life periods. The formulated null hypothesis of the analysis of variance states that the average value of the average daily gain of live weight of steers does not depend on the factor of belonging of animals to one or another group. The analysis of variance was conducted separately for each measurement period (6, 8, 12, 14, 16, 18 months).

The standard value of Fisher's criterion (Fk) for the considered one-factor dispersion complexes is Fk =2,769. If the factor effect strength (Fη) and ρ-value obtained as a result of the analysis correspond to the condition

$\{ F\eta > Fk \; \rho\text{-value} < 0{,}05$,

then it can be stated with a significance level of 0.05 that the null hypothesis must be rejected.

The results of the analysis of variance are presented in the table 2.

Despite the deviation of the null hypothesis for the entire variance complex, it makes sense to test the significance of differences in the values of average daily gain of live weight in separate groups of animals. As a result of such analysis, it was found that in certain periods for some groups of animals there is no significant difference in the mean values of the average daily gain of live weight (see Table 3).

Feed costs per 1 kg of live weight from birth to 14 and 18 months in separate groups are shown in the table 4.

The best feed payment was in the young animals of group 1, which were on improved feed. Feed use in the "transfer" groups (1-st (a) and 2-nd (a)) varied considerably. When steers

Табл. 2. Результаты однофакторного дисперсионного анализа

Table 2. Results of one-factor analysis of variance

Period, months	Power of influence of the factor η^2	Reliability index of the power of influence of the factor F_η	ρ-value	Acceptance/ rejection of the null hypothesis
0–6	0,982 ± 0,001	1006,6	$1{,}16 \cdot 10^{-48}$	Rejected
6–8	0,922 ± 0,004	221,7	$4{,}87 \cdot 10^{-31}$	The same
8–12	0,982 ± 0,001	998,5	$1{,}44 \cdot 10^{-48}$	»
12–14	0,982 ± 0,001	993,9	$1{,}64 \cdot 10^{-48}$	»
14–16	0,966 ± 0,002	534,2	$3{,}73 \cdot 10^{-41}$	»
16–18	0,896 ± 0,006	161,1	$1{,}65 \cdot 10^{-27}$	»

Note. ρ-value – the "viability" of the null hypothesis, which we estimate using the available data.

Табл. 3. Группы животных без существенной разницы в средних значениях среднесуточного прироста живой массы (n = 15)

Table 3. Groups of animals with no significant difference in the average values of the average daily live weight gain (n = 15)

Period, months	Compared groups	Average daily live weight gain	
		Group	Value, g/days
6–8	1-st and 1-st (a)	1-st	867 ± 1,82
		1-st (a)	850 ± 2,37
8–16	1-st (a) and 2-nd	1-st (a)	1314 ± 20,21
		2-nd	1263 ± 18,06
16–18	2-nd and 2-nd (a)	2-nd	1201 ± 24,08
		2-nd (a)	1263 ± 17,06
	1-st and 2-nd (a)	1-st	1299 ± 16,13
		2-nd (a)	1263 ± 17,06

were reared up to 14 months of age, feed expenses per 1 kg of gain were lowest in group 1 steers (6.39 EFU). They surpassed their peers of groups 2 (a), 1 (a) and 2 by 1.51, 1.88 and 1.59 EFU in feed expenses. During rearing until 18 months of age, this tendency persisted, but the differences between the groups decreased slightly. Thus, in terms of payment for feed by live weight gain, Group 1 animals exceeded their counterparts in Group 2 (a), Group 1 (a) and Group 2 by 0.67; 0.74 and 0.98 EFU.

The first slaughter of steers of groups 1, 2, 2 (a) (3 animals from each group) was conducted at the age of 14 months, before going out to pasture. Data on the slaughter results are given in table 5.

In terms of the slaughter weight, Group 1 and the "transfer" group (2 (a)) animals significantly, by 114 and 94 kg ($p > 0.999$), outperformed Group 2 steers.

Of particular interest is the change in the morphological composition of the carcasses of animals depending on the nature of growth. Data on morphological composition of carcasses of 14-month-old steers are given in table 6.

There was no difference in the relative bone content in the carcasses of steers of groups 1 and "transfer" group 2 (a). In the carcasses of steers of group 2 there were significantly more bones ($p > 0.99$) than in the animals bred at the increased level of feeding.

From the above data we can see that the transfer of 8-month-old young animals from a reduced to an increased level of feeding provided not only an increase in live weight, but also contributed to the growth of muscle, which led to a decrease in the relative weight of the bones in the carcass.

A study of the chemical composition of meat showed that the fat content in the meat of steers of group 1 was 1.4 times ($p > 0.999$) higher than in young steers of group 2; the caloric content of meat was 12% ($p > 0.999$) higher (see Table 7).

The bulls of the "transfer" group 2 (a) in terms of fat content and meat caloric content occupied an intermediate position.

At the age of 18 months after fattening, all remaining steers were killed. Three animals were taken from each group to register slaughter products and study the morphological composition of carcasses. The data on slaughter results are given in table 8.

It was found that the higher slaughter yield of carcass and fat was given by the animals of groups 1 and 2 (a), the lower - by groups 1 (a) and 2. Indicators of the relative weight of the main organs: heart, liver and lungs in the steers of all groups were close to each other.

Табл. 4. Оплата корма приростом живой массы бычков, ЭКЕ

Table 4. Payment for feed by the increase in live weight of bulls, EFU

Group	Age, months	
	up to 14	up to 18
1-st	6,39	8,02
1-st (a)	8,27	8,76
2-nd	7,98	9,00
2-nd (a)	7,90	8,69

Табл. 5. Мясные качества подопытных бычков в возрасте 14 мес ($n = 3$)

Table 5. Meat qualities of experimental bulls aged 14 months (n = 3)

Indicator	Group					
	1-st		2-nd (a)		2-nd	
	kg	%	kg	%	kg	%
Live weight before slaughter	344,0 ± 1,15	100	250,0 ± 5,77	100	230,0 ± 1,05	100
Carcass weight	211,0 ± 0,58	61,3	141,3 ± 0,46	56,5	116,6 ± 0,12	50,7
Internal fat	5,60 ± 0,15	2,7	3,40 ± 0,15	2,4	2,5 ± 0,20	1,09
Carcass and internal fat	216,60 ± 0,31	62,9	144,67 ± 0,19	57,9	119,10 ± 0,06	51,8
Heart	3,35 ± 0,03	0,97	2,05 ± 0,02	0,82	2,05 ± 0,01	0,89
Lungs	7,05 ± 0,02	2,18	6,35 ± 0,03	2,54	6,15 ± 0,03	2,67
Liver	6,70 ± 0,10	1,95	5,10 ± 0,05	2,04	4,61 ± 0,01	2,00
Hide	29,50 ± 0,29	8,58	25,00 ± 0,58	10,0	19,80 ± 0,15	8,61

Табл. 6. Морфологический состав туш 14-месячных бычков, % (n = 3)

Table 6. Morphological composition of carcasses of 14-months-old bulls, % (n = 3)

Indicator	Group		
	1-st	2-nd (a)	2-nd
Flesh	74,2 ± 0,20	73,7 ± 0,15	70,3 ± 0,12
Bones	23,1 ± 0,24	23,3 ± 0,22	27,0 ± 0,58
Tendons and cartilage	2,7 ± 0,10	3,0 ± 0,06	2,7 ± 0,10

To study the morphological composition of the carcasses from each group, three half-carcasses were boned (see Table 9).

The highest relative number of bones was in the carcasses of bulls of the 2nd group, the lowest - in animals of the 1st group; animals of the "transfer" groups (the 2nd (a) and the 1st (a)) occupied an intermediate position. According to the yield of flesh, the main mass of which is muscle, the carcasses of steers of the 1st group were in the first place, the carcasses of steers of the 2nd group - in the last place. Animals of the "transfer" groups occupied an intermediate position. The level of feeding had the greatest influence on the absolute weight of flesh (muscle and fat) and much less influence on the weight of bones of carcasses.

Taking the carcass weight of the 1st group young animals as 100%, the carcass weight of bulls of the 2nd group (a) was 80,3%, of the 1st group (a) - 75,5 and of the 2nd group - 70,0%. Correspondingly the weight of the flesh of bulls of the 1st (a), 2nd (a) and 2nd groups was 80,2; 75,6 and 69,8% to the weight of the flesh of

Табл. 7. Химический состав мяса бычков в 14-месячном возрасте (n = 3)

Table 7. Chemical composition of meat of bulls at 14 months of age (n = 3)

Group	Content, %				In 1 kg of meat, Kkal
	water	protein	fat	ash	
1-st	74,65 ± 0,03	20,30 ± 0,26	4,10 ± 0,15	0,95 ± 0,08	1547 ± 27,82
2-nd	76,50 ± 0,20	19,74 ± 0,22	2,69 ± 0,08	1,07 ± 0,01	1380 ± 20,72
2-nd (a)	75,22 ± 0,15	20,48 ± 0,04	3,23 ± 0,02	1,07 ± 0,01	1491 ± 13,79

Табл. 8. Мясные качества бычков в 18-месячном возрасте (n = 3)

Table 8. Meat qualities of bulls at 18 months of age (n = 3)

Indicator	Group							
	1-st		2-nd (a)		1-st (a)		2-nd	
	kg	%	kg	%	kg	%	kg	%
Live weight before slaughter	463,0 ± 0,88	100	397,0 ± 3,61	100	387,0 ± 1,53	100	373,0 ± 1,75	100
Carcass weight	298,6 ± 0,31	64,5	239,8 ± 0,26	60,4	225,6 ± 0,20	58,3	208,9 ± 0,22	56,0
Internal fat	5,80 ± 0,12	1,25	4,3 ± 0,12	1,08	4,4 ± 0,21	1,13	3,6 ± 0,06	0,96
Carcass and fat	304,4 ± 0,27	65,7	244,1 ± 0,12	61,48	230,0 ± 1,15	59,4	212,5 ± 0,20	57,0
Heart	3,91 ± 0,01	0,84	2,40 ± 0,20	0,60	2,32 ± 0,02	0,59	2,28 ± 0,02	0,61
Lungs	6,98 ± 0,02	1,50	6,09 ± 0,02	1,53	6,15 ± 0,03	1,58	5,85 ± 0,03	1,56
Liver	7,88 ± 0,05	1,70	6,85 ± 0,03	1,72	6,57 ± 0,06	1,69	6,00 ± 0,06	1,60
Hide	34,00 ± 0,16	7,34	31,50 ± 0,26	7,93	25,00 ± 1,53	6,45	23,60 ± 0,10	6,32

Табл. 9. Морфологический состав туш в возрасте 18 мес, %

Table 9. Morphological composition of carcasses at the age of 18 months, %

Indicator	Group			
	1-st	2-nd (a)	1-st (a)	2-nd
Flesh	77,20 ± 0,12	75,60 ± 0,19	75,23 ± 0,13	72,78 ± 0,21
Bones	20,46 ± 0,06	21,60 ± 0,12	22,55 ± 0,24	23,99 ± 0,07
Tendons and cartilage	2,34 ± 0,18	2,80 ± 0,50	2,22 ± 0,10	3,23 ± 0,20

the 1st group animals. The values of the carcass bone mass of the animals of groups 1, 2 (a) and 1 (a) were similar, and only the young animals of group 2 had the bone mass by 3,53 abs. % higher than the 1st group.

In terms of muscular and fat tissue development, the young animals of the "transfer" groups occupy an intermediate place between groups 1 and 2.

The given data show that when steers were transferred from a medium to a high level of feeding, more growth was obtained than in young steers that were at a high level of feeding until 14 months of age. However, by 18 months of age, the lag in live weight had not yet been compensated. At the same time, steers kept at a high level of feeding until 8 months of age had lower gains on winter rations and on pasture after transfer to a medium level of feeding compared to the group of steers bred at a medium level of feeding.

The different growth pattern of steers was also observed when they were slaughtered with similar live weight and the same fatness category, which ultimately resulted in obtaining carcasses with different tissue ratio and chemical composition of meat. At 18 months of age, steers bred at high and medium feed levels contained relatively less water and protein and more fat than steers of the "transfer" group. The fat-to-protein ratio in the meat of steers of high and medium-fed groups was 2.4-2.2, and 1.8-1.9 in the meat of steers of 'transferable' groups, resulting in a 14% higher caloric value of the meat of the first two groups.

Thus, the degree of live weight compensation depends on the duration and size of growth retardation of young animals, as well as the level of feeding, to which animals are transferred after a low level of feeding.

CONCLUSIONS

1. Feeding level can enhance or retard the growth of young cattle, significantly affect the ratio of tissues in the carcass, as well as the quantity and quality of meat productivity.

2. At a high level of feeding young cattle marked a sharp increase in meat productivity and meat quality, while reducing the cost of feed for products and increasing economic efficiency of breeding.

3. Malnutrition most delays the deposition of body fat, reduces muscle growth, and decreases skeletal mass.

4. The degree of underdevelopment in growing cattle at different feed levels can vary, so the potential for partial or full compensation and the time required will vary. It is undesirable and unacceptable to severely underweight young cattle in the first year of life, when the animal should be prepared for slaughter at 16-18 months of age. In addition to the fact that it reduces the number of products manufactured, its quality decreases sharply. As our experience has shown, the low level of feeding of young animals delays the growth of the most valuable tissues and parts of carcasses to a greater extent.

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ПРОФИЛАКТИКА ТЕХНОЛОГИЧЕСКОГО И КОРМОВОГО СТРЕССА ПОРОСЯТ С ИСПОЛЬЗОВАНИЕМ КОРМОВОЙ ДОБАВКИ ЦЕОДО

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Представлены результаты изучения свойств кормовой добавки цеодо при технологическом и кормовом стрессе у поросят. Для профилактики стресс-факторов у поросят нами ранее разработана кормовая добавка цеодо на основе облученных CO^{60} древесных опилок и природного цеолита сахаптин. Для проведения опытов по определению эффективности кормовых добавок в рационе поросят сформировали четыре группы по восемь поросят-аналогов. Контрольная группа получала основной рацион, 1-я опытная к основному рациону – 7,5% цеодо, 2-я опытная – 2,5% цеолита сахаптин, 3-я опытная – 2,5% микосорба. Установлено, что применение кормовой добавки цеодо способствует приросту живой массы у поросят при кормлении их не проверенными на качество кормами в стрессовый период отъема и содержания. При изучении свойств цеодо и испытания различных схем с целью профилактики стрессов у поросят установлено, что кормовая смесь, состоящая из 92,5% дробленой кормовой смеси и 7,5% кормовой добавки цеодо, оказала положительное влияние на прирост живой массы поросят в течение 91 дня опыта. Прирост поросят в этой группе был выше на 18,4% по сравнению с контрольной. При сравнении с показателями 3-й опытной группы, получавшей микосорб, отмечено повышение среднесуточного прироста живой массы в группе с цеодо на 2,5%, с сахаптином – на 2,8%. Сделан вывод, что цеодо снижает синергическое действие стресс-факторов и обладает профилактическим свойством при стрессах. Результаты опытов по применению кормовой добавки цеодо дают основание для ее производственного испытания.

Ключевые слова: стресс, поросята, корма, кормовая добавка цеодо, микосорб, прирост

PREVENTION OF TECHNOLOGICAL AND FEED STRESS IN PIGS WITH ZEODO FEED ADDITIVE

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The results of studying the properties of the feed additive zeodo under technological and feed stress in piglets are presented. To prevent stress factors in piglets, we previously developed a feed additive zeodo based on CO-60 irradiated sawdust and natural sakhaptin zeolite. To conduct experiments to determine the effectiveness of feed additives in the diet of piglets, four groups of eight peer piglets were formed. The control group received the basic diet, the 1st experimental group received 7.5% zeodo to the basic diet, the 2nd experimental group received 2.5% sakhaptin zeolite, the 3rd experimental group received 2.5% mycosorb. It has been established that the use of zeodo feed additive promotes live weight gain in piglets when feeding them with unproven feed during the stressful period of weaning and keeping. When studying the properties of zeodo and testing various schemes to prevent stress in piglets it was found that a feed mixture consisting of 92.5% crushed feed mix and 7.5% zeodo feed additive had a positive effect on the live weight gain of piglets within 91 days of the experiment. The growth of piglets in this group was 18.4% higher than in the control group. When comparing with the indicators of the 3rd experimental group receiving mycosorb, there was an increase in the average daily gain of live weight in the group with zeodo by 2.5%, with sakhaptin - by 2.8%. It is concluded that zeodo reduces the synergistic effect of stressors and has a preventive effect on stress. The results of experiments on the use of zeodo feed additive give grounds for its production testing.

Keywords: stress, piglets, feed, feed additive zeodo, mycosorb, gain

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INTRODUCTION

Currently, the problem of feed quality for farm animals and poultry remains acute. Many scientists are of the opinion that feed is not completely free of mycotoxins [1-3]. Continuous long-term exposure to several stressors has a negative effect on the animal body: immune status decreases, susceptibility to diseases increases, growth and development, digestive, immune, reproductive, nervous system and kidney functions are impaired[1] [4-8].

To prevent feed stress caused by poor quality feed and technological conditions of pig breeding, various methods of animal organism sanitation using natural and modified zeolites are used. It is possible to preserve and maintain the health of animals against the background of almost constant stresses using different methods of sanitation of the body, including the use of various feed additives such as natural and modified zeolites [2-4] [9-12]. Literature data and the results of our studies on the use of the unique properties of natural zeolites have served as the basis for work on the enhancement of these properties [1].

In January 2020, an international forum on etiopathogenesis, prevention, diagnosis and treatment of mycotoxicoses was held in Bangkok. Scientists highlighted the basic strategy of mycotoxin elimination by adsorption, their binding in the gastrointestinal tract of animals by special adsorbent substances[5] [13-15].

Taking into account the causes of stresses, the nature of their course in the body and hereditary conditionality of a number of individual manifestations, we provide one of three directions of stress prevention - the use of biologically active substances-adaptogens, which mitigate the course of stresses and increase the resistance and adaptogenic properties of the body.

The purpose of the research is to study the schemes of stress factor prevention in piglets using the feed additive (adsorbent) zeodo.

MATERIAL AND METHODS

To prevent stress factors in piglets previously a feed additive zeodo based on CO^{60}-irradiated wood sawdust and natural sahaptin zeolite was developed. The process of treatment of plant fibers (softwood sawdust) was carried out at the ILU-8 facility at the Institute of Nuclear Physics SB RAS (Novosibirsk) using their technology at a dose of 20 mrad [15].

After sawdust irradiation they contained crude protein 0,35%, moisture - 60,56, crude fat - 1,48, crude fiber - 17,85, ash - 0,95 and NFES (nitrogen-free extractive substances) -

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[4]Bityutsky V.S. Influence of zeolite complex and biologically active substances on the metabolic parameters and productivity of broiler chickens: Ph. D. in Biology, abstract, Lvov, 1990, 16 p.

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18,81%; metabolic energy was 0,36 kJU, their nutrition increased by 33%. The study according to GOST R 52397-2005 showed that sawdust is not toxic. The content of man-made radionuclides in the sample of irradiated sawdust did not exceed the control level. The composition of the plant fibers was supplemented with sahaptin zeolite.

To carry out the experiments to determine the effectiveness of feed additives in the diet of piglets, four groups of eight piglets each with an average live weight of 12.75-13.32 kg were formed. Irradiated wood (pine) sawdust was mixed in mixers with natural zeolite of 0.01-2.0 mm fraction in certain ratios. Experiments were carried out according to the scheme:

Control Experimental Group:	Composition of feed mix Basic diet (BD)
1-st	100%
2-nd	92,5% BD + 7,5% zeodo
3-rd	97,5% OP + 2,5% zeolite sahaptin 97,5% OP + 2,5% mycosorb

When testing the feed additives zeodo and sahaptin, a commercial feed additive mycosorb was taken for comparison. The experimental animals were fed with a grain mixture (crushed feed) prepared at the farm and not tested for quality and safety indicators. During the experiment period (91 days) the health status of the piglets was monitored.

Experimental studies were carried out in the conditions of the experimental production farm "Borovskoe" (Novosibirsk Region). Whole blood stabilized with heparin was used for morphological studies, and blood serum was used for biochemical studies. The amount of hemoglobin was determined in the blood according to Sali, the number of erythrocytes and leukocytes in the Goryaev chamber. Total protein in the blood serum was determined by refractometric method, protein fractions - by nephelometric method. Toxicity of zeodo and its components was performed on protozoa and mice.

RESULTS AND DISCUSSION

Each head was weighed 3 times during the experiment period (see Table 1).

During the first 20 days of the experiment (during the adaptation of piglets to the conditions of feeding and housing), gastrointestinal distress of the young animals was observed. During this period, the fractured particles were examined and found to contain mycotoxins within the MAC limits (aflatoxin, zearalenone, T-2 toxin).

From the 45th day of the experiment instead of the fractured particles mixed fodder SK-3, SK-4 began to be used.

During this period, fluctuations in the average daily live weight gain of piglets between the groups were observed. Feed additives had a positive effect on the average daily gain of live weight. Thus, during the whole period of experiment the indicators of growth in the 1st experimental group (with zeodo) were higher by 18,4% (411,53 g), in the 2nd experimental group (with sahaptin) by 20,55% (418,9 g), in the 3rd experimental group (with mycosorb) by 16,09% (403,4 g) compared to the control group (347,47 g). There was an increase in the average daily live weight gain in the group with the feed additive zeodo by 2.5%, with sahaptin zeolite by 2.8% compared with the indices of the 3rd experimental group.

When calculating the economic efficiency, it should be noted that while there was insignificant difference in growth between the 1st and 2nd experimental groups (by 2,5-2,8%), income was 6,4 times higher in the 1st group (with zeolite) (26,28 rubles) than in the 3rd experimental group receiving mycosorb (4,09 rubles); in the 2nd group (with sahaptin zeolite) it was 14,76 times higher (60,4 rubles).

Табл. 1. Содержание микотоксинов и предельно допустимые уровни их в корме

Table 1. The content of mycotoxins and their maximum permissible levels in feed

Mycotoxin, mg/kg	Mycotoxin content in the crush	MAC
Ochratoxin A	0,005	0,01
T-2 toxin	0,065	0,1
DON	0,500	1,0

The addition of 7.5% zeodo (5% CO^{60}-irradiated wood (pine) sawdust and 2.5% sahaptin zeolite) to the feed mixture resulted in feed savings (see Table 3).

Total protein in all groups was within the age norm. Decreased albumin combined with β- and γ-globulin levels indicate functional disorders of the liver.

During the experimental period of 50 to 90 days no changes in the clinical condition were observed in piglets of all groups when fed with high-quality forage.

Total protein was within the physiological norm. Protein fractions were reduced, albumin was most pronounced compared to the norm in the groups with sahaptin zeolite and mycosorb. There was an increase in γ-globulin in the 1st experimental group with zeodo. In 1979 and 1980 in the USSR similar experiments with the use of radiolabeled fodder preparation (RADUPR) were performed [16]. The results of the studies, irradiation doses were taken into consideration when testing the zeodo feed additive on piglets in our study.

Табл. 2. Показатели прироста живой массы поросят и эффективность кормовых добавок в течение 91 дня при 100%-й сохранности (n = 8)

Table 2. Live weight gain indicators of piglets and the effectiveness of feed additives for 91 days at 100% livability (n = 8)

Indicator	Group			
	control	experimental		
		1-st	2-nd	3-rd
Weight of piglets, kg:				
start of the experiment	102	106	102	106,6
end of the experiment	354,96	405,60	406,98	403,36
Live weight gain for the experiment, kg	252,96	299,60	304,96	293,68
Average daily live weight gain, g	347,47	411,53	418,9	403,4
% to the control	100,00	118,40	120,55	116,09
Additional growth obtained, g	–	46,64	52,00	40,72
The cost of additional growth, rbl.	–	3264,8	3640,0	2850,4
Gross feed consumption without feed additives, rbl.	600	555	585	585
The cost of gross feed expenses, rbl.	1800	1665	1755	1755
Feed savings, kg	–	135	15	15
The cost of the saved feed, rbl.	–	405	45	45
Feed additives consumption, kg	–	45	15	15
The cost of feed additives, rbl.	–	135,0	60,0	568,4
Net income from the saved feed	–	+270	–15	–523,4
Total net income, rbl.	–	3534,8	3625	2327
Total net income per 1 rbl. of the costs for feed additives	–	26,18	60,4	4,09

Табл. 3. Морфобиохимические показатели крови поросят на 20-й день эксперимента

Table 4. Morpho-biochemical blood parameters of piglets on the 20th day of the experiment

Indicator	Group			
	control	experimental		
		1-st	2-nd	3-rd
Hemoglobin, g/l	91,1 ± 0,12	115,4 ± 0,25*	95,3 ± 0,13*	102,0 ± 0,34*
Erythrocytes, 10^{12}/l	5,12 ± 0,23	6,81 ± 0,22*	5,34 ± 0,48**	6,47 ± 0,34**
Leukocytes, 10^{9}/l	15,32 ± 0,63	12,32 ± 1,43	12,2 ± 1,32**	12,10 ± 1,54**
Total protein, g/l	54,2 ± 0,10	64,3 ± 0,02	51,0 ± 0,12**	53,7 ± 1,88
Albumins, %	44,12 ± 10,56	25,58 ± 6,22*	26,57 ± 11,10*	49,12 ± 10,32*
Globulins, %:				
α	15,65 ± 6,15	30,21 ± 6,52*	28,16 ± 8,22**	31,18 ± 6,43**
β	22,54 ± 3,5	23,15 ± 3,34*	11,57 ± 2,44	23,11 ± 3,09**
γ	17,11 ± 4,43	23,18 ± 3,03*	10,13 ± 3,77**	23,16 ± 3,02**

*$p \leq 0,05$ compared to the control group.
**$p \leq 0,05$ compared to the 1st experimental group.

Табл. 4. Влияние цеодо, цеолита сахаптин и микособа на показатели крови поросят-отъемышей в возрасте 90 дней

Table 4. Influence of zeodo, zeolite sahaptin and mycosob on the blood parameters of weaned piglets at the age of 90 days

Indicator	Group			
	control (комбикорм СК-3)	experimental		
		1-st (zeodo)	2-nd (sahaptine)	3-rd (mycosorb)
Hemoglobin, g/l	110,4 ± 1,49	112,6 ± 1,72	113,5 ± 0,13	102,0 ± 0,34
Erythrocytes, 10^{12}/l	3,35 ± 1,02	5,06 ± 1,22*	3,01 ± 0,49**	3,54 ± 0,64**
Leukocytes, 10^{9}/l	8,45 ± 0,91	9,52 ± 1,03*	6,52 ± 1,35*	6,18 ± 1,54*
Total protein, g/l	56,8 ± 0,13	61,0 ± 0,52*	53,1 ± 1,12**	53,7 ± 0,88**
Albumins, %	31,5 ± 9,56	38,58 ± 6,22*	18.57 ± 7,10**	16,94 ± 8,32**
Globulins, %:				
α	21,85 ± 4,15	28,36 ± 4,51*	27,61 ± 6,25**	26,51 ± 5,45**
β	8,86 ± 3,55	8,96 ± 3,34*	5,55 ± 3,45**	5,91 ± 2,95
γ	44,28 ± 3,43	55,81 ± 3,03*	44,43 ± 5,77	40,24 ± 2,02**

*$p \le 0,05$ compared to the control group.
**$p \le 0,05$ compared to the 1st experimental group.

CONCLUSION

An experimental study of the properties of the feed additive zeodo and its use in the ration on unbalanced, not tested for quality feed found that it had a preventive effect on the body of piglets in the stressful period of weaning and contributed to a better assimilation of feed. As a result, the average daily gain of live weight of young pigs increased. The results of scientific and production testing of zeodo feed additive testify to its harmlessness and efficiency.

The results of the experiments on testing the feed additive adsorbent zeodo provide a basis for production tests.

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ПЛЕМЕННАЯ ЦЕННОСТЬ КОРОВ – МЕТОДЫ УЧЕТА И ОЦЕНКИ

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Проведено изучение показателя удоя коров как признака племенной ценности. Отмечено, что общепринятая методика оценки фактической племенной ценности коров по показателям продуктивности за первые 305 дней не отражает истинную племенную ценность животных, не показывает потенциал, не дает информацию о воспроизводительных качествах коров. Исследованы данные оценки 10 быков-производителей за 2020, 2021 гг. в племрепродукторном хозяйстве красной степной породы Кабардино-Балкарской Республики. Средний удой по стаду составляет 6600 кг. Оценка проведена по 545 дочерям по удою за первые 305 дней и за всю лактацию с учетом продолжительности лактации, а также вариабельности показателей. Сравнение результатов оценки определено путем ранжирования по продолжительности лактации, удою за первые 305 дней и всю лактацию. Из 10 групп дочерей быков ранги сохранились только по дочерям двух быков (Торпан 2739 и Иман 314), занявших первое и десятое места. Из 8 остальных быков ранг по удою за всю лактацию у дочерей 5 быков-производителей (Грильяж 6977, Кнор 45026 и Кулон 1237) повысился на один, у дочерей быка Арзамас 6815 – на два, быка Гир 1883 – на четыре порядка. Ранги оценки по дочерям быков Топаз 1239 снизились на один, быков Твист 76849 и Тибул 3728 – на четыре порядка. При средней продолжительности сервис-периода по всей выборке 144,3 дня она варьировала от 126,3 (дочери быка Топаз 1239) до 171,4 дня (дочери быка Кнор 45026), разница составила 45,1, или два полноценных половых цикла. Это свидетельствует о влиянии генотипа на продуктивность животных в одинаковых условиях кормления и содержания. Удой за всю лактацию всех 10 оцениваемых особей достоверно ($p \geq 0,95$) превышает их показатели за первые 305 дней и значительно меняет ранг оценки, что необходимо учитывать при выборе быков.

Ключевые слова: бонитировка, племенная ценность, изменчивость продуктивности, быки-производители, оценка животных

BREEDING VALUE OF COWS – METHODS OF RECORDING AND EVALUATION

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The study of cow milk yield as a sign of breeding value of cows was carried out. It is noted that the generally accepted method of evaluating the actual breeding value of cows by productivity indices for the first 305 days does not reflect the true breeding value of animals, does not show the potential, does not give information about the reproductive qualities of animals. The evaluation data of 10 stud bulls for 2020, 2021 in the breeding farm of the red steppe breed of the Kabardino-Balkarian Republic were studied. The average milk yield in the herd is 6,600 kg. The evaluation was performed on 545 daughters in terms of milk yield for the first 305 days and for the whole lactation, taking into account the duration of lactation as well as the variability of indicators. Comparison of evaluation results is determined by ranking the duration of lactation, milk yield for the first 305 days

and the whole lactation. Of the 10 groups of bull daughters, the ranks were retained only on the daughters of two bulls (Torpan 2739 and Iman 314) who took first and tenth places. Of the 8 remaining bulls, the daughters of 5 stud bulls (Grillage 6977, Knor 45026 and Kulon 1237) increased their milk yield rank for the whole lactation by one, daughters of the Arzamas 6815 bull increased by two, daughters of the Gir 1883 bull increased by four exponent parts. The rankings for the daughters of the bulls Topaz 1239 decreased by one, the bulls Twist 76849 and Tibulus 3728 decreased by four exponent parts. With an average service period of 144.3 days in the entire sample, it ranged from 126.3 (daughters of the bull Topaz 1239) to 171.4 days (daughters of the bull Knor 45026), with a difference of 45.1, or two full ovary cycles. This indicates the influence of genotype on the productivity of animals under the same feeding and housing conditions. The full-lactation yield of all 10 evaluated individuals significantly ($p \geq 0.95$) exceeds their performance in the first 305 days and significantly changes the evaluation rank, which should be taken into account when selecting bulls.

Keywords: valuation, breeding value, variability of productivity, stud bulls, evaluation of animals

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INTRODUCTION

In modern market conditions the development of cattle breeding is not only of socio-economic significance, but is also a stabilizer of the financial condition of the entire agro-industrial complex. In particular, dairy cattle breeding currently remains one of the leading sub-branches of livestock breeding and its development is of great importance not only in ensuring the country's food independence, but also in the social aspect [1].

Many authors emphasize that the increase in productive longevity of cows is one of the main factors contributing to the improvement of effective breeding[1] [2]. A.Y. Samuylenko et al. [3] point out that "at present, the availability of basic resources of agricultural products and raw materials, the saturation of the food market in Russia are such that the physical availability of food is mainly provided, at least at the minimum level of consumption".

To increase the competitiveness of domestic cattle breeding and the formation of a modern market of highly valuable breeding genetic material, it is necessary to create a sustainable structure that organizes and coordinates activities to improve the efficiency of livestock production by increasing the rate of genetic potential of animals in the overall system of reproduction of genetic resources[2]. Analysis of dairy productivity, research of exterior traits and measurement of cattle exteriors are necessary to increase the genetic potential of productive qualities of animals and to create high-productive herds [4].

Dairy cattle breeding in Russia is a promising branch of animal husbandry. More than 90% of agricultural enterprises in our country are engaged in milk production. At the same time, domestic dairy cattle breeding should be primarily profitable, competitive and highly productive [5].

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Improvement of labor and improvement of technology through the use of modern equipment create prerequisites for increasing animal productivity [6]. At present, the productive longevity of cows is decreasing in all constituent entities of the Russian Federation [7]. The economic efficiency of dairy cattle breeding is determined by the value of the milk yield. Of all the dairy cow breeds worldwide, the Holstein breed is the most efficient according to this indicator, so the interest in this breed is obvious [8].

V.V. Nogaeva, L.Kh. Albegova [9] note that "the main factors influencing the formation of high milk productivity of animals are their genetic potential and the conditions of feeding, housing and care. In this regard, the issue of dependence of productive indicators of cattle on heredity is relevant".

However, A.V. Bakai et al. [10] note that "the main difficulty faced by breeders in practical work is that the progeny of highly productive animals under appropriate conditions do not repeat the high productivity of their ancestors, and their quality is close to the average value characteristic in specific conditions for herd and breed".

O.K. Gogaev et al. [11], having studied the influence of maternal age and live weight of calves at birth on the indicators of milk productivity and reproductive ability of cows, note that "the indicators of reproductive ability of cows such as service-period, intercalving period, reproductive ability factor and calf yield per 100 cows depend primarily on the level of milk yield of the first heifer or the age of first calving, than on the live weight at birth". Pellinen A.V. et al. [12] note that "the probable possibility of increasing milk productivity in cows is an increase in their breeding value, which, along with the genotype of animals, is strongly influenced by paratypical factors: the age of first calving and the milk yield from first heifers".

Retention of cows is one of the main components of high profitability of dairy cattle breeding. The normal volume of culling is about 25% of the herd per year, which ensures regular renewal of the herd due to replacement cattle. In some farms up to 40% of cows are withdrawn from the herd annually [13].

To improve the Red Steppe breed, the semen of stud bulls of the Red-And-White Holstein breed was used on the farm for a long time. According to the research results, the duration of lactation of the first heifers reliably exceeds the daughters of purebred bulls of the Red Steppe breed and, accordingly, the yield for the first 305 days of lactation.

Recording the duration of lactation and productivity for the whole lactation makes it possible to estimate the reproductive qualities of the daughters of the bulls used, which is the main indicator. The lack of information on the value of milk yield during the whole lactation of both the bull mother and his daughters conceals the reproductive qualities of the bulls used, since the longer the lactation of daughters, the higher the milk yield during the first 305 days of lactation, respectively, the higher the breeding value. However, such evaluation sharply reduces the calf yield, which is no less important for breeding work.

The purpose of the research is to determine the correctness of establishing the breeding value of cows only by productivity indicators for the first 305 days of lactation without taking into account reproductive qualities. The research objectives are to study the extent to which the standard productivity indices reflect the potential of animals and the accuracy of genotype evaluation, as well as the need to increase the requirements for reproductive qualities recording.

MATERIAL AND METHODS

The results of the evaluation of 10 stud bulls of different genotypes on the productivity of daughters on the basis of the Red Steppe breeding multiplication farm "Lenintsy" of the Maisky district of the Kabardino-Balkar Republic were used as the material for the study. The average milk yield in the herd is 6600 kg. The evaluation was carried out on 545 daughters by the milk yield for the first 305 days of the first lactation and for the whole first lactation, taking into account the duration of lactation, as well as the variability of the indicators. Comparison of the evaluation results was determined by ranking the duration of lactation, the milk yield in

the first 305 days and the whole lactation. The obtained statistical material was processed using Microsoft Office Excel program pack.

RESULTS AND DISCUSSION

Valuation of dairy cattle is the main information base for individual evaluation of herd animals, which is used to annually set the valuation class of each individual who has reached the appropriate age (young cattle) and cows who have completed the next lactation. This information includes age, live weight, body measurements, milk yield, fat and protein content for the first 305 days or a shortened finished lactation (specifying the duration in days, but not shorter than 240 days). While the evaluation of cows with a lactation duration of up to 305 days is not questionable, for cows whose lactation lasts longer, such evaluation is not entirely correct. This is due to the fact that the longer the lactation, the higher the milk yield in the first 305 days, and the fat and protein content in milk is usually lower. There are questions about the reliability of identification of breeding value of cows for a part of lactation activity and also about inclusion of elite-record class cows in zootechnical marriage group because of relatively low level of productivity in high-productive herds.

The main indicator for determining the quality class of cows is still the milk yield. However, a number of important and really valuable traits that determine the economic efficiency of the industry and the profitability of dairy cattle breeding are included in the valuation, but are evaluated minimally.

Annual herd classification, a necessary basis for the improvement of breeding and productive qualities of animals, loses its significance in principle, especially in highly productive herds, when average herd indicators exceed standard requirements by 1.5-2.0 times and more.

At the present stage, reproductive capacity (fertileness) and the duration of productive use (viability) of cows have become one of the fundamental elements of selection along with milk productivity. Instruction on valuation (2010) includes these indexes evaluating their share by maximum 5 points from 100 which an animal can get accordingly with the duration of service-period not more than 90 days and at the age of six calvings and older. There are relatively few cows with such indicators in highly productive herds. The evaluation of the milk yield, in particular for the Red Steppe breed is limited by maximum 60 points: for the first heifers - 5030 kg in the first 305 days of lactation, 5869 kg in the second lactation and 6372 kg at the age of three calvings and older. Exceeding these indicators does not increase the class. Therefore, it is possible to assign high-productive cows as stud bulls of the corresponding categories A and B, which would contribute to the selection of mother cows of bulls.

Evaluation of productivity for the first 305 days of lactation does not reflect the real breeding value of highly productive cows and, to some extent, hides the costs of reproduction. It was noted that the longer the lactation, the lower the fat and protein content of milk in the first 305 days of lactation, which also reduces the value of animals.

Based on the results of the productivity of daughters- cows for the first 305 days and for the whole lactation, they were ranked according to the relevant indicators. Along with the milk yield, the value of variability of the milk yield during these periods was taken into account. The results are presented in the table.

The data of the table show that the ranks of evaluation of stud bulls by the productivity of daughters for the first 305 days of lactation and for the whole lactation change significantly. Of the 10 groups of bull daughters, the ranks were preserved only for daughters of bulls Torpan 2739 and Iman 314, who took the first and tenth places, respectively. Of the remaining 8 bulls, the daughters of 5 stud bulls (Grillage 6977, Knor 45026 and Kulon 1237) had their milk yield rank increased by one, the daughters of Arzamas 6815 bull increased by two, and Gir 1883 bull increased by four ranks. The rankings for the daughters of Topaz 1239 bulls decreased by one, and Twist 76849 and Tibulus 3728 bulls decreased by four ranks.

The average difference in the milk yield for the whole lactation and the first 305 days was 645.3 kg and ranged from 398.4 kg (daughters

of the bull Twist 76849) to 824.2 kg (daughters of the bull Grillage 6977). Such a difference in milk yield makes it possible to increase the class of cows by two ranks.

There is a significant difference in the variability of the main trait of evaluation and selection - milk yield. Thus, if the value of the mean square deviation of the milk yield for the first 305 days of lactation was 882,8 kg, then for the whole lactation it was 1678,7 kg, that is 1,9 times higher, and the variability of the trait is one of the indicators of selection efficiency.

With the same average minimum milk yield of daughters, the limit of all bulls was 2671.6 kg, the maximum for the first 305 days was 6918.4 kg, and for the whole lactation it was 10,795.7 kg, the difference counted for 3877.3 kg.

The main indicator of the state of herd reproduction is the duration of the service period. According to the results of our studies, the maximum duration of the service period is observed after the first calving. With the age of animals, the duration of service period decreases insignificantly, but actually linearly.

The average length of the service period for daughters of first-born bulls was 144.3 days and ranged from 126.3 (daughters of the bull Topaz 1239) to 171.4 days (daughters of the bull Knor 45026).

The analysis showed that the evaluation ranks of stud bulls for the first 305 days of lactation of daughters changed in 8 out of 10 evaluated bulls, which confirms the increase in accuracy of evaluation. The evaluation for the whole lactation allows us to significantly increase the amount of information on productivity and reproductive ability of the of stud bull daughters.

CONCLUSIONS

1. With an average service period of 144.3 days in the entire sample, it ranged from 126.3 (daughters of the bull Topaz 1239) to 171.4 days (daughters of the bull Knor 45026), a difference of 45.1, or two complete sexual cycles. This indicates the effect of genotype on animal productivity under the same feeding and housing conditions.

Влияние оценки за первые 305 дней и всю лактацию на племенную ценность дочерей быков-производителей
Influence of the evaluation for the first 305 days and the entire lactation on the breeding value of the stud bulls' daughters

Item No. n/a	Name	Number of daughters	Duration of lactation		Calving interval		Service-period		Milk yield size				Difference in milk yield, kg	Mean square deviation (σ)				Fluctuation limit		
			Days	Rank	Days	Rank	Days	Rank	for 305 days, kg	Rank	for the entire lactation, kg	Rank		for 305 days, kg	Rank	for the entire lactation, kg	Ранг	minimal	maximum for 305 days	maximum for the entire lactation
1	Arzamas 6815	41	345,3	5	405,3	4	128,8	2	4594,9	9	5223,9	7	629,0	997,4	1	1891,3	3	2479	6750	11 566
2	Gir 1883	65	368,8	8	428,8	10	143,9	6	4633,2	8	5441,6	4	808,4	859,6	6	1926,5	2	2672	7136	11 744
3	Grilyazh 6977	51	372,1	9	432,3	8	153,3	8	4925,0	3	5749,2	2	824,2	834,8	8	1622,1	8	2813	6937	10 713
4	Iman 314	59	352,9	6	413,1	5	138,4	4	4361,7	10	4991,9	10	630,2	927,4	5	1743,9	5	2357	7059	9968
5	Knor 45026	82	372,2	10	432,4	9	171,4	10	4861,4	4	5650,9	3	789,5	847,7	7	1641,3	7	2013	6763	11 137
6	Kulon 1237	21	359,8	7	419,6	7	149,8	7	4641,8	6	5375,4	5	733,6	972,1	3	1839,6	4	3140	6527	10 542
7	Tvist 76849	21	342,6	4	413,5	6	162,2	9	4936,8	2	5335,2	6	398,4	797,8	9	2151,8	1	3461	6555	11 429
8	Tibul 3728	74	332,3	2	332,2	1	138,5	5	4759,6	5	5165,3	9	405,7	720,1	10	1206,1	10	3024	6793	9296
9	Topaz 1239	28	327,9	1	388,0	2	126,3	1	4635,6	7	5183,5	8	548,3	947,4	4	1575,2	9	2603	6219	10 008
10	Torpan 2739	103	339,3	3	399,1	3	132,6	3	5167,2	1	5783,9	1	616,7	976,6	2	1696,7	6	2157	8445	11 534
	Total average			–	404,4	–	144,3	–	4802,8	–	5444,1	–	641,3	882,8	–	1678,7	–	2671,6	6918,4	10 795,7

2. The full-lactation milk yield of all the 10 evaluated stud bull daughters significantly ($p \geq 0.95$) exceeds their performance in the first 305 days and significantly changes the rank of evaluation, which should be considered when selecting bulls.

3. Mean square deviation of the milk yield (σ) of daughters during the first 305 days of lactation (882.8 kg) was actually 2 times lower than during the whole lactation (1678.7 kg), which indicates the lack of effectiveness and accuracy of breeding evaluation of cows during this part of lactation.

The existing system of evaluation of the breeding value of cows according to the current instructions significantly lags behind the achieved indicators in dairy cattle breeding and insufficiently takes into account the issues of reproduction and duration of productive use, which influence the profitability of the industry. Market economy and related pricing system do not take into account many elements of breeding, without which further improvement of animal breeds and technological elements of their operation is impossible. In high-productive herds the evaluation of cows by productivity for the first 305 days of lactation does not take into account the reproductive qualities and does not reflect the true breeding value of animals, as evidenced by the significant difference in the indicators of variability of the main selection traits.

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РОСТ И РАЗВИТИЕ БЫЧКОВ, ПОЛУЧЕННЫХ РАЗНЫМИ МЕТОДАМИ РАЗВЕДЕНИЯ

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Научно-хозяйственные опыты проведены на молодняке крупного рогатого скота в производственных условиях Магаданской области в соответствии с планом научных исследований 2020, 2021 гг. Проанализированы рост и развитие бычков, полученных разными методами разведения. Для эксперимента сформированы три группы бычков различных генотипов. В 1-ю группу вошли бычки герефордской породы третьего поколения (F_3), полученные в результате поглотительного скрещивания голштинской породы герефордской, во 2-ю – полукровные помеси герефордской и абердин-ангусской пород, полученные в результате промышленного скрещивания абердин-ангусских телок с герефордскими быками, в 3-ю – чистопородные голштинские бычки. На протяжении всего изученного периода выращивания (от рождения до 17-месячного возраста) животные находились в одинаковых условиях кормления и содержания. Анализ полученных данных свидетельствует о том, что помесные бычки, полученные в результате поглотительного скрещивания голштинской породы герефордской (F_3) и промышленного скрещивания животных герефордской и абердин-ангусской пород, имели преимущество над своими сверстниками голштинской породы на протяжении всего периода выращивания по живой массе, среднесуточному, абсолютному приросту. Лучшими по этим показателям отмечены бычки герефордской породы третьего поколения. Они были тяжелей в 17-месячном возрасте полукровных бычков на 2,9% и тяжелей чистопородных голштинов на 12,5%. Помеси обеих групп имели явно выраженные мясные формы, глубокую и широкую грудную клетку, хорошо развитую мускулатуру тазобедренной области, спины и поясницы. Относительная скорость роста помесных бычков от рождения до 17-месячного возраста была выше голштинских на 3,5–4,1%.

Ключевые слова: рост и развитие, поместные бычки, поглотительное и промышленное скрещивание

GROWTH AND DEVELOPMENT OF YOUNG BULLS OBTAINED BY DIFFERENT BREEDING METHODS

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Scientific and economic experiments were conducted on young cattle in the production conditions of the Magadan region in accordance with the 2020, 2021research plan. Growth and development of young bulls obtained by different methods of breeding were analyzed. Three groups of steers of different genotypes were formed for the experiment. The first group consisted of the third generation (F_3) Hereford bulls obtained as a result of the accumulation cross breeding of the Holstein breed by the Hereford breed, the second group consisted of half-blood crossbreeds of Hereford and Aberdeen-Angus crosses obtained as a result of commercial cross breeding of Aberdeen-Angus heifers with Hereford bulls, the third group - purebred Holstein bulls. Throughout the entire rearing period studied (from birth to 17 months of age) the animals were under the same feeding and keeping conditions. The analysis of the obtained data shows that crossbred young bulls obtained as a result of the accumulation cross breeding of the Hereford Holstein breed (F_3) and industrial cross breeding of the Hereford and Aberdeen-Angus breeds had an advantage over their counterparts of the Holstein breed throughout the whole period of cultivation in live weight, average daily and ab-

solute gain. The best in these indicators were the young bulls of the third generation Hereford breed. At the age of 17 months, they were heavier than half-blood young bulls by 2.9% and heavier than purebred Holstein bulls by 12.5%. Crossbreeds of both groups had pronounced meat shapes, deep and wide chest, well developed musculature of hips, back and loin. The relative growth rate of crossbred young bulls from birth to 17 months of age was 3.5-4.1% higher than that of Holstein bulls.

Keywords: growth and development, crossbred bulls, accumulation and commercial cross breeding

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INTRODUCTION

The Magadan Region is not an agricultural region, the products of agricultural producers account for about 1.5% of the gross regional product. Particular dependence on imported meat and meat products is observed in the region. The share of domestic production in the consumed meat products is less than 10%.

In the north-east of Russia, agricultural production is not only economically but also socially important, because the stabilization of the socioeconomic situation and further development of the territories are impossible without keeping the population there, for which purpose food security problems must be solved. One of the main tasks is to provide residents with affordable and high-quality locally produced food. This is especially important in the context of foreign sanctions and the need for accelerated import substitution of livestock products.

In order to meet the needs of the population in chilled meat, in 2014, the government of the Magadan Region recognized the development of meat cattle breeding as a priority in the territory of the region along with the production of poultry and pork. In the same year, for the first time in the history of cattle breeding development in Kolyma, the seed of specialized meat breed bulls started to be used for artificial insemination of the Holstein breed pedigree stock. [1].

Experiments of the Russian scientists have proved that cattle of many breeds can achieve high meat productivity under intensive and well-organized breeding. However, under equally good feeding and housing conditions, beef cattle and hybrids obtained by crossing different cattle breeds are fattened faster, give a higher carcass slaughter yield, process feed into products more economically, and give beef of better quality than peers of dairy and dairy-meat breeds [2-7]. Quality beef production involves cost-effective breeding of animals adapted to specific climatic conditions, with high productivity.

At the first stage, for insemination of dairy Holstein cows and heifers in the Magadan Region, semen of beef bulls of Hereford and Aberdeen Angus breeds was used. Herefords and Angus are among the three most popular meat breeds in our country used for interbreeding and purebred breeding. Prolonged purebred breeding of cattle of these breeds has led to a strong consolidation of heredity. Therefore, cattle of these breeds steadily pass their economically useful traits to the offspring in any crosses [8-15]. Since the research on identifying specialized beef breeds that are competitive in the conditions of the region has not been carried out before, they are relevant and in demand. In 2018, the employees of the Magadan Research Institute of Agriculture initiated such research [16, 17]. Currently, research in this direction continues.

The purpose of the research is to study the economic and biological characteristics of mixed bred cattle for identifying desirable genotypes when creating a population of beef cattle under the conditions of the Magadan Region. The research objectives are to do a comparative analysis of the growth and development of steers bred by different methods of interbreeding.

MATERIAL AND METHODS

Scientific and economic experiments were carried out on young cattle in the production conditions of the peasant farm "Komarova" (Magadan). To study the growth and development of the experimental animals three groups of bull-calves obtained from first-calf cows were formed, 10 animals in each group. The first group included bulls of the Hereford breed of the third generation (F3),

received as a result of the accumulation cross breeding of the Holstein breed with the Hereford one; the second one includes half-blooded mixed crosses of the Hereford and Aberdeen-Angus breeds, bred as a result of crossing of Aberdeen-Angus heifers with Hereford bulls; the third group includes purebred Holstein steers. During the whole period under study, the animals were kept under the same feeding and housing conditions.

From birth to 6 months of age, the animals were raised according to the technology adopted in dairy cattle breeding. The diet was designed to produce 750-800 g average daily gain in steers (economic level of feeding). Calves were kept in individual cages up to the age of 15 days, in groups of 4 animals up to the age of 6 months. Further, up to the age of 17 months the animals were kept in groups of 10-20 heads using the silage-concentrate type of feeding and economic diet designed to produce 900 g of live weight gain per day. Evaluation of the origin of crossbred cattle of different genotypes was made on the basis of zootechnical and pedigree recording data. To conduct research, generally accepted methods [1,2] were used. The growth and development of young animals were studied by the indicators of live weight on the basis of monthly weighings and exterior measurements. Average daily and absolute growth were calculated based on the results of weighings and measurements, and the body mass indices were calculated. Relative growth rate was calculated according to the formula of S. Brody

$$B = [(W_1-W_0) \times 100]: [(W_1+W_0) \times 0,5],$$

where W1 and W0 are final and initial live weight, respectively.

Mathematical analysis of experimental data was performed on the basis of generally accepted modern methods using Microsoft Office Excel programs[3].

RESULTS AND DISCUSSION

Data analysis shows that bulls of different genotypes exhibited different growth intensity during the whole period studied. At birth, the highest live weight was recorded in group 3 bulls, which exceeded the live weight of group 1 and 2 bulls by 4.4 and 9.9%, respectively. This difference was due to the breed peculiarities of the test bulls. During the whole period, the advantage in the live weight was recorded in the bulls of groups 1 and 2 (see Table 1).

The average daily gain for the period from birth to 6 months was higher in the groups of crossbred

Табл. 1. Динамика живой массы и среднесуточный прирост подопытных бычков
Table 1. Dynamics of live weight and average daily gain of experimental bulls

Age, months	Group		
	1-st	2-nd	3-rd
	Live weight, kg		
At birth	29,70 ± 0,47	28,2 ± 0,33	31,00 ± 0,26
1	51,30 ± 0,68	48,8 ± 0,48	47,70 ± 0,21
3	95,90 ± 2,04	90,8 ± 0,82	85,50 ± 0,21
6	167,75 ± 1,35	165,85 ± 0,97	152,90 ± 0,66
12	316,18 ± 1,04	311,10 ± 1,44	284,14 ± 1,09
17	443,81 ± 1,71*	431,33 ± 1,91*	394,52 ± 1,71
	Average daily gain, g		
0–6	766,69 ± 10,44	764,72 ± 6,21	675,40 ± 2,30
6–12	824,60 ± 4,68	806,90 ± 3,70	729,50 ± 3,00
0–17	812,20 ± 2,91*	791,20 ± 2,79*	712,73 ± 3,18
	Relative growth rate, %		
6–12	61,36 ± 0,53	60,91 ± 0,23	60,10 ± 0,12
0–17	174,96 ± 0,35	174,51 ± 0,31	170,86 ± 0,21

*$p < 0,05$.

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[2]Methodological guidelines for scientific research on growing, graziery and fattening of cattle. MOSCOW: VNIIZH. 1958. 38 p.

[3]The system of applied statistical and mathematical methods of processing experimental data in agriculture. MOSCOW: MSKHA, 1992. 160 p.

Табл. 2. Промеры отдельных статей подопытных бычков в возрасте 4 мес, см
Table 2. Measurements of individual parameters of experimental bulls at the age of 4 months, cm

Measurement	Group		
	1-st	2-nd	3-rd
Height at the withers	83,6 ± 0,59	81,6 ± 0,62	83,2 ± 0,53
Height at hips	88,2 ± 0,54	86,9 ± 0,47	89,8 ± 0,69
Oblique body length	95,3 ± 1,05	92,4 ± 0,74	94,9 ± 0,73
Chest girth	108,4 ± 1,05*	105,2 ± 0,88*	99,5 ± 0,89
Chest depth	37,5 ± 0,60*	36,1 ± 0,79*	33,3 ± 0,37
Chest width	22,4 ± 0,69	21,4 ± 0,60	20,0 ± 0,41
Hook bone width	24,5 ± 0,62	23,6 ± 0,38	23,4 ± 0,22
Cannon bone girth	13,1 ± 0,17	12,7 ± 0,17	12,4 ± 0,11

Here and in Table 3. *p <0,01.

Табл. 3. Промеры отдельных статей подопытных бычков в 17-месячном возрасте, см
Table 3. Measurements of individual parameters of experimental bulls at 17 months of age, cm

Measurement	Group		
	1-st	2-nd	3-rd
Height at the withers	121,7 ± 1,7	117,1 ± 3,1	122,2 ± 1,9
Height at hips	125,1 ± 1,9	122,7 ± 1,9	126,8 ± 1,9
Oblique body length	147,7 ± 2,5	141,0 ± 2,2	149,1 ± 2,9
Chest girth	189,0 ± 2,7*	180,9 ± 2,5*	170,1 ± 2,2
Chest width	47,4 ± 1,9*	46,1 ± 1,8*	37,8 ± 1,5
Chest depth	68,3 ± 2,2*	66,4 ± 2,3*	62,4 ± 1,5
Hook bone width	39,5 ± 0,7*	39,0 ± 0,43*	35,6 ± 0,36
Cannon bone girth	20,2 ± 0,2	20,0 ± 0,18	17,8 ± 0,14

Табл. 4. Индексы телосложения подопытных бычков, %
Table 4. Body indexes of experimental bulls, %

Index name	Group					
	1-st		2-nd		3-rd	
	17 months	4 months	17 months	4 months	17 months	4 months
Long-legged	43,9	55,1	43,8	55,8	48,9	60,0
Bone	16,6	15,7	17,1	15,6	14,6	14,9
Lengthiness	121,4	114,0	120,4	113,2	122,0	114,1
Chest	69,3	59,7	69,4	59,3	60,6	60,1
Blockiness	128,0	113,7	128,3	113,9	114,1	104,8
Overgrowth	102,8	105,5	104,8	106,5	103,8	107,9

steers. Thus, the difference in the indicators of groups 1 and 2 as compared to group 3 was 91.29 g ($p < 0.05$) and 89.32 g ($p < 0.05$), respectively. The relative gain of crossbred steers of groups 1 and 2 from birth to 6 months of age was higher than that of purebred peers by 7.26-9.29%, respectively. The highest absolute gain of live weight from 6 to 17 months was observed in Hereford steers of the third generation (276.06 kg). It was reliably ($p < 0,05$) more than in half-breeds by 10,58 and 34,44 kg more than in the Holstein breed. The relative growth rate in the bulls of the 1st group for this period was 90,3%, in the 2nd group - 88,9, and in the 3rd group - 88,3%.

At 17-months of age, Group 1 animals were the heaviest by 2.9% and 12.5% heavier than Group 2 steers and Group 3 steers. The average daily gain for the period from birth to 17-months of age was reliably ($p < 0,05$) greater in Group 1 and 2 bulls than in Group 3 bulls by 99,5 g (14,0%) and 78,5 g (11,1%) respectively. The highest absolute and live weight gain for this period was recorded in Group

1 bulls (414.1 kg), which is more than in Group 2 and Group 3 by 11.6 and 50.6 kg, respectively. The relative growth rate of crossbred steers was higher than that of the Holstein steers in groups 1 and 2 by 4.1 and 3.5%, respectively.

Throughout the study, crossbred steers differed significantly from their Holstein counterparts in body shape. The mongrels had pronounced meat shapes, deep and wide chest, well developed muscles of hips, back and loins.

When studying the linear growth of the experimental young animals at 4 months of age, no significant differences in height measurements were found. The greatest differences between dairy and crossbred steers were in chest girth and depth. Thus, the animals in groups 1 and 2 exceeded the animals in group 3 in breast girth by 8.9 and 5.7% ($p < 0.01$), and in breast depth by 12.6 and 8.4% ($p < 0.01$), respectively (see Table 2). At 17 months of age, there was a difference in latitudinal measurements. The hybrids in groups 1 and 2 reliably ($p < 0,01$) exceeded the Holstein peers in breast girth by 11,1 and 6,3%, in breast width by 25,4 and 22,0%, in breast depth by 9,5 and 6,4%, in width in hips by 11,0 and 9,6% respectively. According to the height measurements the animals of the 1st group stood out among the mixed males. They exceeded Group 2 bulls in the height at the withers by 3.9%, in the height at hips by 2%, and in the oblique body length by 4.8% (see Table 3).

For a more detailed study of the development of experimental steers, some body indices were calculated at the age of 4 and 17 months (see Table 4). Development of the calves of all groups was normal. With age there was a decrease in the long leggedness index and an increase in the index of format (elongation). The increase with age of the blockiness index testifies to the development of the meat type of physique in bulls. Throughout the whole period of breeding the thoracic index and the blockiness index were higher in comparison with Holstein, which is characteristic for the development of steers of meat type of productivity. There was no significant difference in the physique indices of crossbred steers of the studied genotypes in groups 1 and 2.

CONCLUSION

The research results prove the successful use of accumulation and industrial crossbreeding with producers of specialized meat breeds in the conditions of commercial livestock enterprises of the Magadan Region. This makes it possible to obtain young animals characterized by high growth rate and live weight, with pronounced meat forms at the age of 17 months. The application of these breeding methods will have a positive impact on the dynamics of development of meat cattle breeding in the region.

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ВЛИЯНИЕ ЭНДОФИТНЫХ ГРИБОВ НА РОСТ И РАЗВИТИЕ КОРМОВЫХ БОБОВ (*VICIA FABA* L.)

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Представлены результаты изучения влияния энтомопатогенных грибов *Metarhizium robertsii* и *Beauvéria bassiana* на рост и развитие кормовых бобов сорта Сибирские. Исследования проведены в 2019, 2020 гг. Предпосевная обработка семян кормовых бобов (*Vicia faba* L.) эндофитными грибами *M. robertsii* и *B. bassiana* с последующим выращиванием в полевых условиях способствовала ускорению ростовых процессов, формированию большей биологической массы и увеличению урожайности. Эффективность энтомопатогенных грибов *M. robertsii* и *B. bassiana* оценивали в полевом опыте в условиях лесостепной зоны Западной Сибири на черноземе выщелоченном. Использование на кормовых бобах *M. robertsii* достоверно увеличивало урожайность зерна на 2,0–4,2 ц/га (Man–W, p = 0,01565), высоту растений на 6–16 см, а также облиственность и массу 1000 зерен. Использование *B. bassiana* не привело к увеличению урожайности. Установлено достоверное увеличение числа активных клубеньков на корнях растений кормовых бобов, на которых применяли обработку *M. robertsii*. В фазу цветения отмечены существенные различия между контролем и вариантом с применением *B. bassiana* (Fisher, p = 0,000085). Обработка семян бобов энтомопатогенными грибами *M. robertsii* и *B. bassiana* перед посевом позволяет повысить урожайность культуры и стимулировать ростовые процессы. В перспективе этот прием может использоваться в сельскохозяйственной практике на других бобовых культурах. Настоящая работа является первым исследованием влияния энтомопатогенных грибов на кормовые бобы при выращивании в условиях континентального климата Западной Сибири.

Ключевые слова: эндофит, урожайность, устойчивость, стимуляция роста, *Metarhizium robertsii*, *Beauveria bassiana*

EFFECT OF ENDOPHYTIC FUNGI ON THE GROWTH AND DEVELOPMENT OF FODDER BEANS (*VICIA FABA* L.)

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The results of studying the effect of entomopathogenic fungi *Metarhizium robertsii* and *Beauvéria bassiana* on the growth and development of fodder beans of the Siberian variety are presented. The studies were conducted in 2019, 2020. Presowing treatment of fodder beans (*Vicia faba* L.) seeds with endophytic fungi *M. robertsii* and *B. bassiana* with subsequent cultivation in the field conditions contributed to the acceleration of the growth processes, the formation of a greater biological mass and an increase in the yield. The efficiency of entomopathogenic fungi *M. robertsii* and *B. bassiana* was evaluated in a field experiment in the forest-steppe zone of Western Siberia on leached chernozem. The use of *M. robertsii* on fodder beans significantly increased grain yield by 2.0-4.2 c/ha (Man-W, p = 0.01565), the plant height by 6-16 cm, as well as foliage and weight of

1000 grains. The use of *B. bassiana* did not result in an increase in yield. A significant increase in the number of active nodules on the roots of fodder bean plants where *M. robertsii* treatment was applied was observed. During the flowering phase, significant differences between the control and the variant with *B. bassiana* application were noted (Fisher, p = 0.000085). Treatment of bean seeds with entomopathogenic fungi *M. robertsii* and *B. bassiána* before sowing can increase crop yield and stimulate growth processes. In the future, this technique can be used in agricultural practice on other legume crops. The present work is the first study of the effect of entomopathogenic fungi on fodder beans when grown in the continental climate of Western Siberia.

Keywords: endophyte, yield, stability, growth stimulation, *Metarhizium robertsii*, *Beauveria bassiana*

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INTRODUCTION

Soil fungi form close symbiosis with more than 90% of all vascular plant species [1]. These interactions have evolved over 400 million years and are of great ecological importance because they contribute to plant nutrient uptake [2]. Nitrogen is considered a critical nutrient limiting plant growth and usually must be fixed by nitrogen-fixing bacteria for plant consumption [3]. The soil lacks easily usable carbon for many microorganisms, hence there is a huge competition between them for this resource [4, 5]. Plants often produce an excess of photosynthetic products, especially in the presence of sufficient nitrogen, some of which enters the rhizosphere [6]. These nutrients provide an opportunity for a potential symbiotic exchange of nutrients between plants and endophytic fungi. Plants need nitrogen and fungi need available carbon. The study of these relationships opens up great opportunities for the use of this group of organisms in agriculture and arouses great interest in them from the scientific community.

In contrast to microorganisms inhabiting the surface of the root system and the aboveground vegetative organs of plants, representatives of symbiont communities (endophytic microorganisms) are capable of entering into closer relationships with the host plant. In some cases, they strongly influence its phenotype as a whole, as well as such processes as growth and development regulation, phytoimmunity and adaptation to changing conditions of existence, without forming any specific structures [7].

The interaction of legume plants with *Metarhizium robertsii* and *Beauveria bassiana* is predominantly mutualistic. These endophytes stimulate vegetative development and reproduction as well as increase host resistance to environmental stresses and have a suppressive effect on phytopathogens [8].

Metarhizium is also capable of forming endophytic associations under laboratory and field conditions with many plant species [9]. At present, it has been proved that entomopathogenic fungi from the genera *Metarhizium* and *Baeuveria* can enter into mutualistic interactions with various plant species and suppress infections caused by fungal phytopathogens *[10-12].*

The study of biodiversity of endophytic microorganisms is a new direction in biology. However, it can already be noted that endophytic fungi have been identified in most agricultural plants. Such microorganisms have been found in cereals and legumes, single- and

perennial plants, sugar beets, corn, sorghum, potatoes, and many other crops [13-15]. The interaction of endophytic fungi with perennial cereal crops has been proved.

Forage beans (*Vicia faba* L.) are one of the most important crops in this family and are now traditionally used as food in several countries such as India, the Philippines, Nigeria, Ghana, Brazil and Malawi [16]. Forage bean yields are affected by a number of external factors that can significantly reduce this figure. One way to level out adverse environmental impacts is to integrate beneficial microbiota that can influence plant growth and development, increase nutrient utilization efficiency and build resistance to abiotic stresses and diseases.

It should be noted that most studies on the interaction between endophytic entomopathogenic fungi, plants and phytopathogens were performed under laboratory conditions. However, the results obtained under laboratory conditions do not always agree with the data of field experiments due to the influence of a large number of environmental factors [17]. Studies on the effect of entomopathogenic fungi on the growth and development of forage beans under field conditions have not been conducted.

The purpose of the study was to determine the effect of endophytic fungi *Metarhizium robertsii* and *Beauveria bassiana* on the growth processes and the yield of forage beans of Siberian variety.

MATERIAL AND METHODS

The studies were carried out in 2019, 2020 at the field station of the Siberian Research Institute of Fodder Crops, SFSCA RAS, located in the northern forest-steppe of the Priob'ye region of Novosibirsk (Russia). The soil of the experimental plot is medium-powered medium-loamy leached chernozem with a humus content of about 6% in the layer 0-20 cm. The soil is relatively well provided with mobile forms of phosphorus and exchangeable potassium. The reaction of soil solution is close to neutral. The total amount of absorbed bases is 58-61 mg/equivalent per 100 g of soil. Thus, the soil is characterized by good physico-chemical indicators.

In terms of climatic resources, it is a moderately warm, insufficiently humid agroclimatic region. Average annual precipitation is 350-450 mm, of which 254 mm falls in the warm period of the year (April - September). During June - August 113-130 mm precipitation falls. Hydrothermal coefficient according to Selyaninov in the period with air temperature above 10 °C is 1.0-1.2. The coldest month is January with an average daily temperature of 19.4 °C, the hottest month is July with 18.4 °C. The sum of positive temperatures above + 10 ° C averages 1880 °, with year-to-year deviations from 1500 to 2250 °. Spring frosts may occur until 20 May and ground frosts until 17 June. The beginning of autumn frosts is at the end of August.

Treatments and seeding. The field experiment included three variants. Conidia of fungi *B. bassiana* and *M. robertsii* were suspended in water-Tween 20 solution (0.04%) at a concentration of 5 × 107 conidia/ml. Grains of fodder beans were treated with the suspension and allowed to dry just before sowing. The control variant was treated with 0.04% Tween. The volume of suspension applied was 2.5 L per 20 kg of forage bean grain. Strains of entomopathogenic fungi *M. robertsii* (P-72) and *B. bassiana* (Sar31) obtained from the collection of microorganisms from the Institute of Systematics and Ecology of Animals, Siberian Branch of the Russian Academy of Sciences were used. Conidial mass was produced by the two-phase cultivation method.

Variants were placed consecutively in one tier in fivefold replications. Sowing was carried out on May 16 in 2019 and on May 19 in 2020, when the soil temperature at a depth of 6-8 cm reached 8-10 ° C. When sowing, the distance between the rows was 70 cm, the seeding rate - 400 thousand germinated grains/ha. The plot length in the experiment is 10 m, the width is 3.9 m, the accounting area is 39 m^2. Seed harvesting was carried out on October 10, 2019 and September 18, 2020.

Plant growth phases were evaluated during the growing season. In addition, the characteristics of bean yield from fungi treatment variants were analyzed. After sowing on days 12, 26, 41, 59, 79, and 98, the growth and develop-

ment characteristics of forage bean plants were evaluated. To determine the main parameters of plant growth in the field, 10 plants (n = 50 plants in each variant) were randomly selected at each repetition. Plants were dug up and records and observations were made. Yield parameters were evaluated after harvesting. Several main phases are distinguished during vegetation of the crop. All of them have certain duration. Conditions of each of phases influence the crop yield and its quality differently. The duration of the interphase periods in forage bean plants was determined by the following phases: full sprouts, 5-6 leaves, branching, flowering, bean formation, seed filling and maturation.

Rhizobial nodules were counted in 2019 and 2020. For this purpose, 10 fodder bean plants from each replicate (n = 50) were randomly selected on days 41, 59, and 79 after sowing. Plants were washed thoroughly and nodule counts were performed on each.

Statistical analysis. Analysis of the data set was performed using Statistica 8 (StatSoft Inc., USA) and PAST 3 [18]. Normality of data distribution was checked using Shapiro-Wilk W test. Normally distributed data were analyzed using one-way analysis of variance followed by Fisher's LSD test. Abnormal data were analyzed using the Kruskal-Wallis test followed by the Dunn test or the Mann-Whitney test.

Weather conditions during the growing season.

The growing season 2019 can be characterized (HTC May - September = 1.2) as close to the climatic norm for the study site, but with variable precipitation by months and a lack of moisture in June (HTC = 0.5) and August (HTC = 0.4).

At sowing on May 16, stocks of productive moisture in a meter layer of soil were 103 mm. The ten-day distribution of moisture resources for the period III ten-day period of June - III ten-day period of July is of particular importance for fodder bean plants, which undergo at this time the phases of flowering - seed filling - ripening. Thus, in 2019, from the third ten-day period of June to the third ten-day period of August, the amount of precipitation was 123 mm, or 94% of the average annual norm, but with an uneven distribution. Air temperatures were 0.2-0.5°C below the long-term average in June and July and 2.2°C above average in August. On average, the maximum air temperature reached 29.3-29.8 °C in the first ten-day period of July (see Fig. 1).

Development of fodder beans in the growing season 2019 took place under the deficit of precipitation in the phase of flowering - seed ripening (III ten-day period of June, III ten-day July and all August) with average daily air temperature in August by 2.2 °C above the climatic norm, average maximum daytime air temperature to 29.8 °C, and relative air humidity in this period lower than the norm by 5-11%. According to the amount of precipitation the summer period of 2020 can be characterized (HTC May - September = 1.29) as close to the climatic norm for the place of research, but with uneven distribution of precipitation, lack of moisture in June (GTC = 0.4) and in the second ten-day period of July (GTC = 0.6).

The average air temperature in the first ten-day period of June was 13.9 ° C, while the norm was 15.0 ° C. This contributed to rapid emergence of seedlings and their good development. The second and third ten-day periods of June were characterized by absence of precipitation and high temperatures (air temperature was 1.1 °C higher than the mean annual rate). Dry and hot weather during this period had a negative impact on biomass accumulation and forage bean yield. In 2020, from the first ten-day period of July (after strong stress) to the third ten-day period of August, rainfall amounted to 167 mm, or 1280% of the average annual norm, with an even distribution. In the first ten-day period of July precipitation was 2000% of the norm (32 mm).

RESULTS AND DISCUSSION

Under the conditions of Western Siberia, treatment of forage bean seeds with the entomopathogenic fungus *M. robertsii* was found to stimulate growth and increase the yield for the first time. Similar trends were observed after treatment of seeds with strain *B. bassiana*, but the resulting effect was weaker.

The period from sprouting to formation of

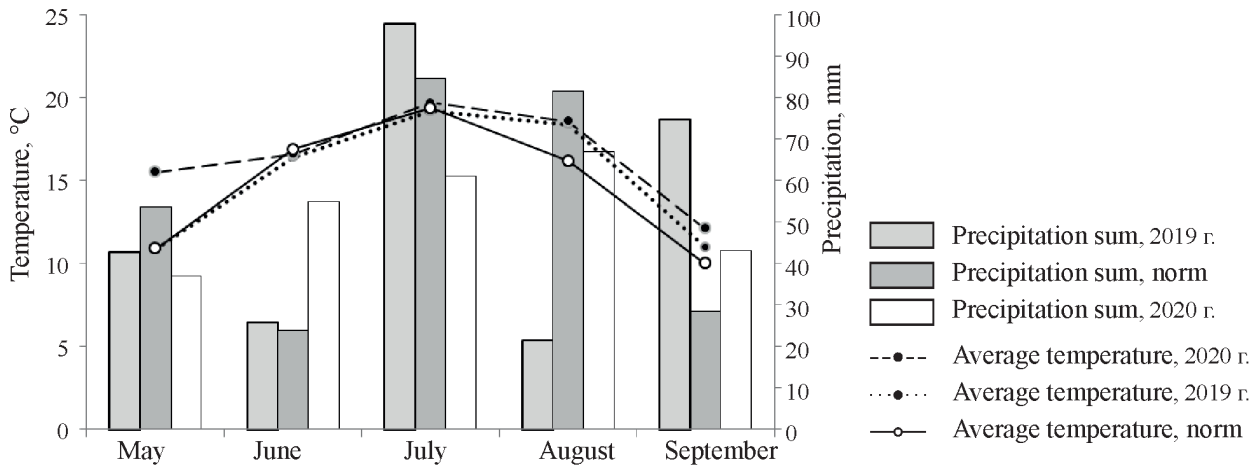

Рис. 1. Динамика температуры и осадков в течение вегетации 2019, 2020 гг. Метеостанция Огурцово

Fig. 1. Dynamics of temperature and precipitation during the growing season of 2019 and 2020. MS Ogurtsovo

5-6 leaves was characterized by successive processes of stem, leaf, scale leaf bracts and the formation of nodules on the plant roots. Friendlier and stronger sprouts provide high foliage of the agrocenosis and are the key to the subsequent development of the crop.

Research data indicate that seed treatment with fungal strains had a significant effect on the growth processes of forage bean plants (see Table 1). The influence of *M. robertsii* is more pronounced and clearly seen in all the years of research, the duration of the growing season noticeably increased by 6-9 days compared to the control variant.

The effect of using fungi in the experiment was manifested already in the initial phases of forage bean development and persisted throughout the growing season (see Fig. 2).

Plant height depending on the strains used in 2020 varied from 6 to 16 cm in different phases of their development (see Fig. 3). In the phase of 5-6 leaves a reliable increase of 15% was obtained when treated with *M. robertsii* (Man-W, p = 0.01219) and *B. bassiana* (Man-W, p = 0.01597).

Treatment of seeds of forage beans with *M. robertsii* fungus significantly affected the growth of the aboveground mass of plants from the branching phase, since intensive consumption of elements from the soil begins from this moment, and there is a possibility that fungus *M. robertsii* created more favorable conditions for this in the rhizosphere of forage beans.

Treatment of forage bean seeds with entomopathogenic fungus *M. robertsii* promoted more powerful development of root system

Табл. 1. Длительность межфазных периодов растений кормовых бобов в зависимости от применяемых штаммов, сут

Table 1. Duration of interphase periods of fodder bean plants depending on the strains used, days

Option	Duration of the interphase period												Growing season length	
	Seedlings – phase 5–6 leaves		Phase 5–6 leaves – branching		Branching – flowering		Flowering – pod formation		Pod formation – seed filling		Seed filling – ripening			
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
K.	10	12	20	14	18	15	19	18	24	20	20	19	111	98
B. b	–	11	–	15	–	15	–	18	–	20	–	20	–	99
M. r	11	13	21	16	21	17	21	19	26	21	21	18	120	104

Note: K – control; *B. b – B. bassiana; M. r – M. robertsii.*

with more lateral roots and appearance of active nitrogen-fixing rhizobia nodules. On day 41 after the sowing, the number of active nodules on the roots of forage beans with *M. robertsii* was 2.4 times greater than on the control variant (Fisher, p = 0.000005). Insignificant development of rhizobial nodules in the phase of budding was associated with a severe drought that manifested itself in the late June 2020 (HTC = 0.4), the reserve of productive moisture in the soil layer 0-20 cm was 10.5 mm (see Table 2).

The most significant difference of *M. robertsii* with the control was noted in the phase of forage bean flowering 59 days after the sowing. After intensive precipitation and soil moistening, the number of nodules in all variants of the experiment increased 3-fold in relation to the phase of budding (Fisher, p = 0.00003). Differences in this period between the control and the variant with *B. bassiana* were also significant (Fisher, p = 0.000085).

Рис. 2. Растения кормовых бобов в фазы ветвления, цветения, полного созревания (слева направо): контроль, гриб *B. bassiana*, гриб *M. robertsii*

Fig. 2. Fodder bean plants in the phases of branching, flowering, full maturation (from left to right): control, mushroom *B. bassiána*, mushroom *M. robertsii*

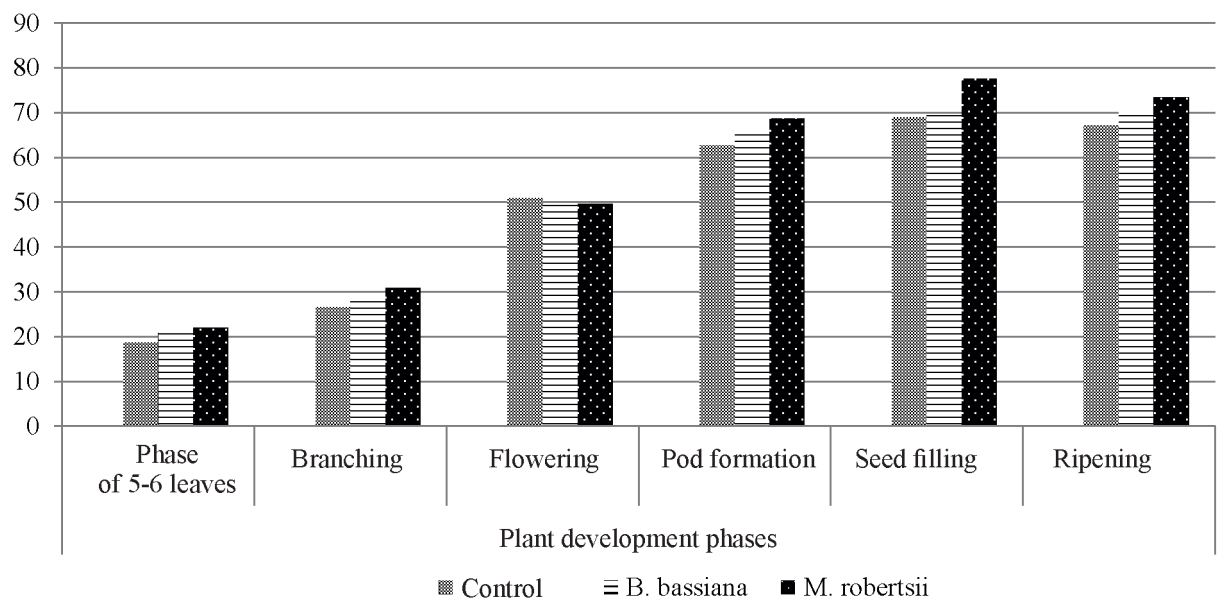

Рис. 3. Высота растений кормовых бобов в зависимости от применяемых штаммов, см
M. robertsii (Man-W, *p* = 0,01219) и *B. bassiana* (Man-W, *p* = 0,01597)

Fig. 3. Height of fodder bean plants depending on the strains used, cm
M. robertsii (Man-W, *p* = 0,01219) and *B. bassiana* (Man-W, *p* = 0,01597)

By the end of the forage bean vegetation 11 weeks after the sowing, the differences in the number of nodules smoothed, the difference was 1.7 between the control and *B. bassiana* (Fisher, p = 0.000176) and 1.4 times between the control and *M. robertsii* (Fisher, p = 0.027119). This is primarily due to natural aging of symbiotic nodule. Analysis of the data on yield structure shows that the studied species of fungi differently, but positively influenced the studied traits. The plant height in all variants of the experiment had a clear tendency to increase in relation to the control variant (up to 16%). Seed treatment with the conidial mass of *M. robertsii* contributed to the strengthening of growth processes and thereby the formation of more powerful in habitus plants of fodder beans, resulting in the formation of more reproductive organs and seeds of good quality.

Seed treatment with fungi had a significant impact on the weight of 1000 grains. The weight of 1000 grains in these variants was higher than the control from 8-10% to 14.8-16.2% (depending on the year of research). Still, the integral indicator of the effectiveness of one or another agricultural technique is the yield.

In 2020, seed treatment with conidial mass of *M. robertsii* increased the yield by 1.96 c/ha (11%) above the control (Dunn's test, p = 0.00460). Forage bean yields in 2020 were 8.4-11.2 c/ha lower than last year due to unfavorable meteorological conditions (see Table 3). The maximum yield of 29.27 c/ha was recorded in 2019 with *M. robertsii*, which is 4.26 c/ha higher than the control (Dunn's test, p = 0.00125).

Protein content in the grain of fodder beans most often depends on meteorological conditions. In 2019, there was no significant effect of the studied strains on the protein content - protein content was 35.9-36.2%. Fat in the seeds of fodder beans appeared in small amounts and, similarly to protein content, practically did not depend on the preparations used for seed treatment. The fat content in the grain of fodder beans was 12.3-12.6%.

After the research conducted, it was established for the first time that treatment of forage bean seeds with entomopathogenic fungus *M. robertsii* with subsequent cultivation under field conditions stimulated the vegetative development of plants, contributed to increased yield, resistance to some environmental stresses and had a suppressive effect on phytopathogens during vegetation in the forest-steppe zone of Western Siberia. Similar trends were observed after seed treatment with *B. bassiana* strain, but these effects were weaker. It can be assumed that entomopathogens affect forage beans directly (as an antagonist) or indirectly (through the activation of plant defense systems). Thus, the present work is the first study of the effect of entomopathogenic fungi on forage beans grown in the forest-steppe zone of Western Siberia.

CONCLUSION

This work is the first study of the effect of entomopathogenic fungi *Metarhizium robertsii* and *Beauveria bassiana* on fodder beans grown in the inhospitable conditions of Siberia. It has been revealed that pre-sowing treatment

Табл. 2. Количество активных клубеньков на корнях кормовых бобов в зависимости от применяемых штаммов, шт./растение

Table 2. The number of active nodules on the roots of fodder beans, depending on the strains used, pcs./plant

Option	Plant development phase					
	Budding		Flowering		Pod formation	
	2019	2020	2019	2020	2019	2020
Control	6,4	1,6	10,4	6,8	5,8	3,2
B. bassiana	–	2,4	–	14,0	–	5,4
M. robertsii	7,4	3,8	12,3	20,3	8,1	4,7

Note. *M. robertsii* (Fisher, *p* = 0,000005), *B. bassiana* (Fisher, *p* = 0,000085).

Табл. 3. Урожайность кормовых бобов сорта Сибирские в зависимости от применяемых штаммов, ц/га
Table 3. The yield of fodder beans of the Siberian variety depending on the strains used, c/ha

Option	Yield		Increase in control		Harvest in 2019		Harvest in 2020	
	2019	2020	2019	2020	Protein	Fat	Protein	Fat
Control	25,01	16,96	–	–	8,9	3,07	5,3	2,17
B. bassiana	–	15,93	–	– 1,03	–	–	4,8	2,15
M. robertsii	29,27	18,92	4,26	1,96	10,47	3,57	5,7	2,45

Note. Protein and oil content were determined by IR-analyzer FOSS, Denmark. *M. robertsii* (Dunn's test, $p = 0{,}00125$).

of seeds with conidia of entomopathogenic fungi *M. robertsii* and *B. bassiana* stimulates the vegetative development of plants and contributes to an increase in the yield of fodder beans. These endophytes can be used to increase the yield and control diseases on other plant species of the legume family. The findings represent a significant basis for posing further more detailed research questions aimed at improving the knowledge of the ecological role of endophytes in natural ecosystems. To accurately assess the ability of *Metarhizium robertsii* to colonize plant roots, it is crucial to quantify the endophytic association, which may depend on environmental factors, plant species and localization in the plant, as well as on the strain and species variability of fungi. The endophytic ability of *Metarhizium robertsii* and *Beauveria bassiana* is currently being evaluated along with their use in biological control and is potentially crucial for developing new and effective strategies for their control.

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АВТОМАТИЗИРОВАННЫЙ ВЫБОР АГРОТЕХНОЛОГИЙ И ТРАКТОРНОГО ПАРКА СЕЛЬХОЗПРЕДПРИЯТИЯ: СТРУКТУРА И АЛГОРИТМЫ WEB-ПРИЛОЖЕНИЯ

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Рассмотрены вопросы повышения эффективности и конкурентоспособности растениеводческого сельхозпредприятия путем информационного сопровождения производства с применением цифровых технологий. Исследован процесс выбора технологий и технических средств при возделывании зерновых культур. Изучены имеющиеся методы и программные средства, применяемые для решения этих задач. Обоснована целесообразность разработки web-ориентированного программного комплекса автоматизированного выбора агротехнологий и машинно-тракторного парка хозяйства, обеспечивающего учет и оперативную обработку разнообразной информации, характеризующей объективно существующее большое количество факторов, условий и особенностей производства в сельскохозяйственном предприятии. На основе анализа основных научно-методических составляющих технологий возделывания зерновых культур сформирована структурная схема web-приложения. Разработаны алгоритмы программных модулей как составных частей программного комплекса, имеющих общую базу данных и объединенных общим интерфейсом. Реализация программного комплекса в дальнейшем даст возможность автоматизировать процесс формирования годового планирования работ, расчет экономических показателей, позволит провести своевременные необходимые ремонтно-обслуживающие мероприятия для снижения потерь мощности, обусловленных неизбежным ухудшением технического состояния двигателей внутреннего сгорания машинно-тракторного парка в производственных условиях. Разрабатываемый программный комплекс может использоваться при производстве продукции растениеводства в системах поддержки принятия решений, построенных на базе цифровых технологий.

Ключевые слова: выбор технологий, алгоритм, программный комплекс, тракторный парк, диагностирование, энергетическая оценка

AUTOMATED SELECTION OF AGRICULTURAL TECHNOLOGIES AND TRACTOR FLEET OF AN AGRICULTURAL ENTERPRISE: WEB-APPLICATION STRUCTURE AND ALGORITHMS

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The issues of increasing efficiency and competitiveness of a crop farming enterprise through information support of production using digital technologies are considered. The process of selecting technologies and technical means in the cultivation of crops is investigated. The available methods and software tools used to solve these problems are studied. The expediency of developing a web-oriented software complex of the automated choice of agricultural technologies and MTF (machine

and tractor fleet), providing accounting and operational processing of a variety of information describing objectively existing large number of factors, conditions and characteristics of production in the agricultural enterprise is substantiated. Based on the analysis of the main scientific and methodological components of cereal crop cultivation technologies, a structural scheme of a web-application is formed. Algorithms for software modules as components of the software package, with a common database and a unified common interface are developed. The implementation of the software package in the future will automate the process of forming an annual work planning, calculation of economic indicators, will allow the timely implementation of the necessary repair and maintenance activities to reduce power losses due to the inevitable deterioration of the technical condition of the ICE of the machine-tractor fleet in production conditions. The software package under development can be used in crop production in decision support systems based on digital technologies.

Keywords: technology selection, algorithm, software package, tractor fleet, diagnostics, energy assessment

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INTRODUCTION

At present, the application of digital technologies in the agricultural sector makes it possible to significantly increase productivity, reduce costs and reduce labor requirements [1, 2]. The digitalization of all agricultural systems is carried out through the introduction of innovative (emergent) technologies (artificial intelligence, robotics, Internet of Things, drones, etc.) and new hardware, software, mobile applications, sensor technologies and big data processing systems [3-8].

In Russia, the degree of implementation of digital technologies in various sectors of agriculture is much lower than in the leading countries; for example, from 5 to 10% of arable land is cultivated using information technologies. In the countries most developed in terms of information technology equipment in agriculture (USA, Germany, Canada), the level of their use exceeds 30% (in Canada, up to 80%) [9-12].

In crop production, information and digital technologies can be implemented with great efficiency, since they meet the specific features of agricultural production due to the significant territorial distribution of production, the diversity of agricultural objects and processes with complex dynamics of changing their properties in the production process, the need for constant assessment of the current situation, the ambiguity of algorithms for strategic and tactical decisions [1, 13].

It is no less important to ensure the operability of the machine-tractor fleet (MTF) and to maintain the standard values of energy operating parameters of tractors (power, fuel consumption) when performing field works [14, 15]. For example, a 15% reduction in the power of the tractor internal combustion engine (ICE) from the standard value when carrying out sowing work leads to an increase in specific costs by 28.4%, which was determined by simulating the example of a seeding unit based

on a wheeled tractor with a 125 kW engine. It is known that if the actual state of MTF is continuously determined it is possible to reveal the hidden reserves of power within 6,0-15,6%, fuel consumption - 12,0-18,7% [16]. It is obvious that it is advisable to maintain the necessary level of energy supply of field works by monitoring the energy parameters of MTF, and information support of each unit of equipment in the farm [17-19].

Hence there is a need to develop flexible algorithms and create software for technology selection using modern means of computer-aided design and monitoring of technological and technical support based on the totality of data and knowledge in this subject area.

Numerous existing developments in the field of digital technologies and platform solutions to improve the efficiency of crop production make it possible to solve the problems facing agricultural producers in many areas of support for grain cultivation technologies. These developments use various methods of modeling, information search, data mining, creation of expert systems, evolutionary calculations [20-25].

The interest of these software products lies in the approaches to technology selection. One of them consists in comparing the actual level of natural and material resources of the enterprise with the normative ones calculated earlier in the relevant technology registers. To do this, a cumulative assessment of the available resources is carried out, and the function of compliance with the agro-technologies from the technology register is set. Another approach is to use a combination of mathematical (economic-mathematical model) and graphical (web graph) modeling methods. In addition, the presented software products take into account, to different degrees, natural and climatic conditions of agricultural producers.

At the same time, their direct application in a particular agricultural enterprise is difficult because of the large number of regional characteristics of agricultural production (soil, climate and production), a diverse range of MTF with varying degrees of wear, and the lack of control of energy operating parameters.

Due to the complexity of the task, it is reasonable to implement the program complex by developing a set of individual software components, for which it is necessary to determine the contribution of each of them to the overall algorithm already formed by the authors [26].

The purpose of the study is to develop a structural scheme of a web-application and the algorithms for the selection of agricultural technologies and technical means, taking into account the characteristics of the location of the farm and its production conditions.

These algorithms and structural scheme will form the basis of the software package (web-application) to support machine agro-technologies.

The object of the study is the process of selecting technologies and technical means in the cultivation of crops.

MATERIAL AND METHODS

At present, several methods of selecting agricultural technologies and optimizing the use of machine-tractor fleet are used. When developing the algorithms for planning agricultural work on grain crop production and creating software components for the web-complex, a method based on the assessment of the conditions of the natural-climatic zone of the farm location influencing the choice of technology and MTF, as well as taking into account phytosanitary and production conditions was used. In order to evaluate the technology options and technical means necessary for its implementation, a mathematical model with the evaluation of options according to the following criteria: fuel and lubricant materials (FLM) consumption, the number of mechanics, and production costs [27] was developed. To select the technology and technical means, it is necessary to specify the constant and variable factors affecting the object of study. Constant factors in this study include the agroclimatic zone of the farm location, its production orientation, configuration of fields and their areas, the composition of the machine and tractor fleet of the farm, crops, crop rota-

tion, etc. Variable factors include agroclimatic characteristics of the zone (amount of precipitation, temperature), crop varieties, the need for protection agents and fertilizers, etc. In the process of work, agro-technologies of grain crops cultivation in the Novosibirsk region were taken into account. Based on these technologies, the structural scheme of the software complex and algorithms of software modules for the selection of agro-technologies and technical means for their implementation were developed. The use of information technologies based on mathematical algorithms and information models is determined, since modern agriculture is focused on the precise measurement of processes occurring in the production of products [28].

RESULTS AND DISCUSSION

To determine the set of software modules of the automated program complex and to develop algorithms of their work, a structural diagram of web-application, reflecting the significant components of the considered process and their connections (see Fig. 1), was developed.

The structural scheme includes the following main blocks: input of initial information, selection of agricultural technologies, selection of equipment, power supply of field works, database (DB). The presence of a common database, which contains a variety of information: primary, reference, additional, results of work, etc. is an important unifying component of the model.

The process of technology and equipment selection at the initial stage consists in collecting initial information about constant and variable factors and factors affecting production, which are necessary when choosing agricultural technologies and tractor fleet of an agricultural enterprise to compare options and calculate economic indicators. Among them for agricultural producers are individual data on the structure of fields, phytosanitary situation, intensification level, crop rotations, workers, technologies, equipment available in the farm.

The process of determining technology options with an indication of the necessary technological operations, timing and multiplicity of their implementation is to select multiple options of agricultural technologies from the available ones in the database of the software package based on individual characteristics of the zone of agricultural enterprise location.

After choosing one of the technology options proposed by the system at the previous stage, the agricultural producer selects the options of rational use of the MTF, necessary for its implementation. Based on the mathematical model, economic indicators are calculated to assess the options obtained at this stage [27]. At the same time, the composition of the machine-tractor aggregate (MTA) is adjusted taking into account the results of the current monitoring of the MTA operational energy parameters, for example, when the parameter reaches the limit-allowable value. As a result of the operation of this unit, a list of equipment needed to perform a given amount of work in optimal agrotechnical terms is formed.

Assessment of deviations of power operating parameters of MTF ICE from normal values is based on monitoring of ICE diagnostic signals. When calculating the power parameters of ICE (power, fuel consumption) a dynamic model is applied using test effects on the engine [29].

All normative and technical data and reference data on crops, fertilizers, protection means, agricultural equipment (tractors and agricultural machines), types of technological works, technological operations and their characteristics, agroclimatic zones, intermediate variants of technology and technical means selection, calculated technological cards for the chosen variant, as well as the year-wise archive by farm are stored in the database.

The developed algorithm of the technology selection module provides the possibility of applying different technologies from the available basic technologies in the database according to the following criteria:

– determining the method of tillage, taking into account agroclimatic and phytosanitary conditions of the farm;

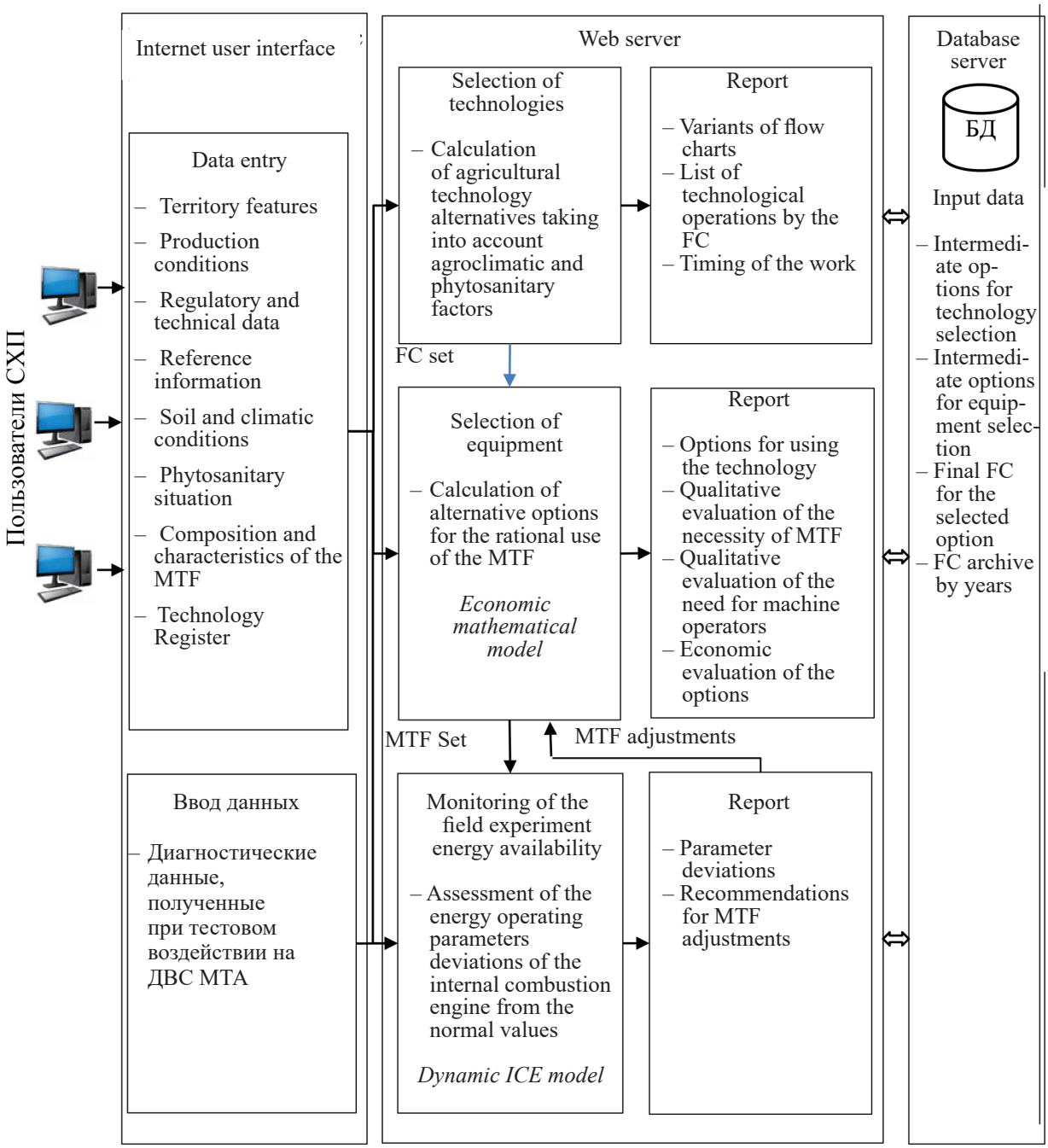

Рис. 1. Структурная схема работы web-приложения для автоматизированного подбора агротехнологий и тракторного парка

Fig. 1. Block diagram of a web application for automated selection of agricultural technologies and tractor fleet

– compliance of the technology with the given level of intensification;

– matching technology to crop rotation;

– applicability of technologies in a given climatic zone, taking into account the culture, topography and structure of the fields;

– determining the need for and frequency of mineral nutrition;

– determining the need and frequency of technological operations for crop care, formation of crop rotation (see Fig. 2).

The algorithm of the hardware selection software module provides the ability to select machinery based on the configuration of the

fields and the width of the machine-tractor aggregate by the following criteria (see Fig. 3):

– performing a given amount of work in optimal agrotechnical terms;

– minimum of mechanization;

– minimum consumption of fuel and lubricants;

– the possibility of using wide-cut machinery (field size and configuration);

– calculation of minimum direct costs and other economic indicators.

The algorithm of automated energy monitoring of the tractor fleet of an agricultural enterprise includes (see Fig. 4):

– measurement of crankshaft rotation speed during test dynamic influences on the internal combustion engine;

– synchronization of measurements with monitoring and ensuring in the test cycle the required number of full-fledged single test effects;

– construction of speed and control dynamic characteristics of internal combustion engine by power and torque according to measurement data;

– calculation of a set of diagnostic characteristics according to the velocity characteristic.

The developed algorithm was implemented in the creation of an automated digital technology for energy monitoring of the tractor fleet of an agricultural enterprise based on the diagnostic device "MOTOR-TESTER SibFTI". [30]. Experimental testing of the technology in production conditions confirmed the possibility of energy monitoring of the tractor fleet during field work. Analysis of the obtained monitoring data made it possible to perform operative repair and adjustment actions, increase the energy supply of the field works, prevent overuse of fuel and increased costs, and increase the efficiency of agricultural production.

The algorithms were tested on the example of a farm in the southern taiga-forest zone of the Novosibirsk region in the selection of spring wheat cultivation technologies. As a result of the work of the software component based on the developed algorithms, technology options are formed with regard to natural (aerial landscape region, agro-ecological group of lands) and production conditions (crop, forecrop in the rotation, the level of intensification). The registers of technological operations and conditions of their application serve as the initial material for the formation of variants. As a result, two alternative technologies with the list of operations were formed. These technologies serve as the basis for further selection of agricultural equipment and economic assessment of the options.

It is planned to develop a software package based on the presented algorithms in the future, which will automate the process of annual work planning, calculation of economic indicators, conduct timely necessary repair and maintenance activities to reduce power losses caused by the inevitable deterioration of the technical condition of the tractor engine in the production conditions. The software package can be used in crop production in decision support systems based on digital technologies.

CONCLUSIONS

1. The application of the method of graphical representation of algorithms as the most adaptive tool for holistic and formalized description of the process of automated choice of agricultural technologies and technical means has been justified. The structural scheme of web-application containing the blocks of initial information, technology and equipment selection, as well as energy supply of field works on the basis of monitoring of energy parameters of machine-tractor units has been developed.

2. The algorithms of the software modules as components of the software complex with a common database and a common interface have been developed using the structural diagram.

3. The developed structural scheme and algorithms of the software package will allow to automatically carry out the selection of agricultural technologies and machine-tractor fleet for the conditions of a particular farm, reduce

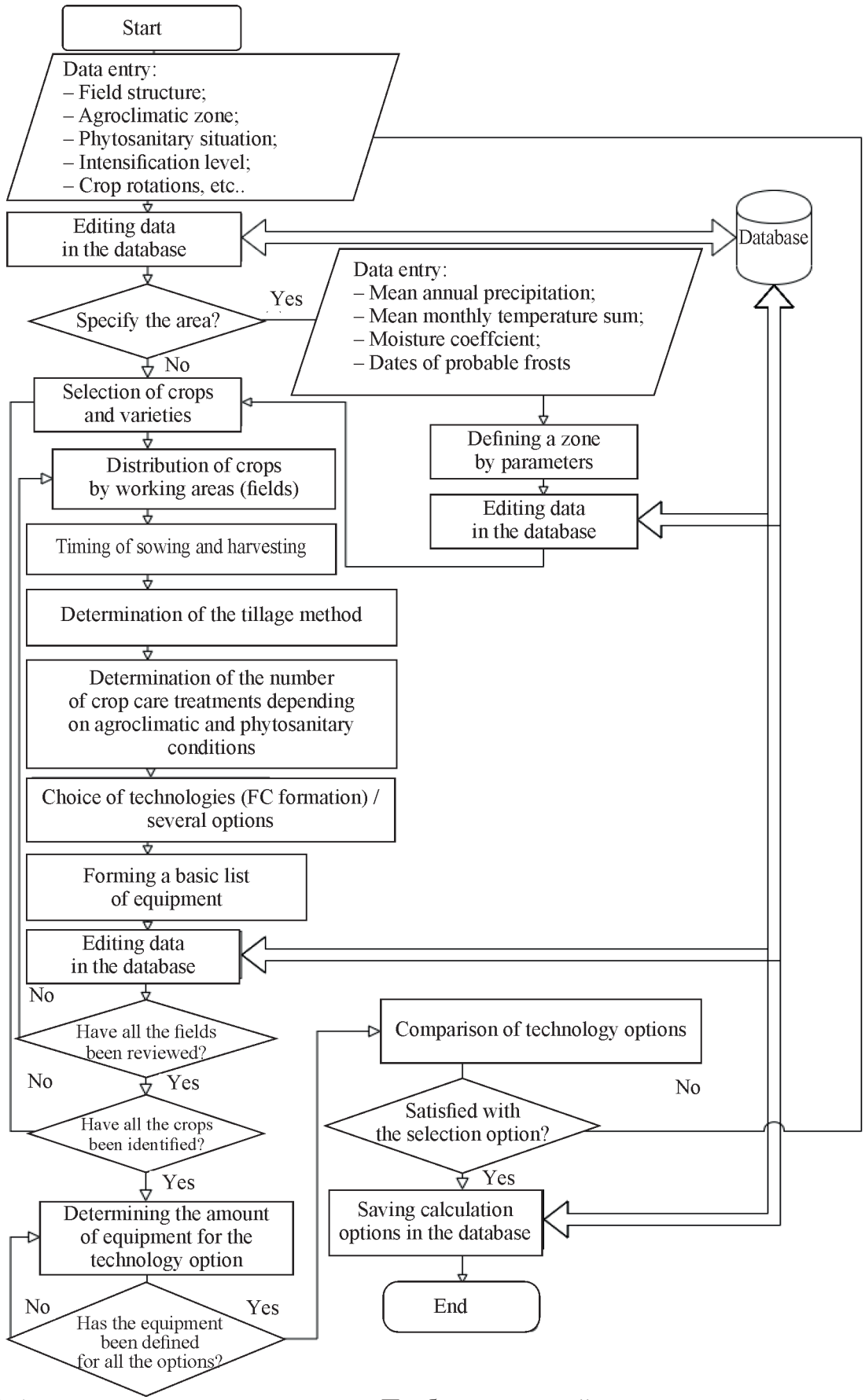

Рис. 2. Алгоритм программного модуля «Подбор технологий»

Fig. 2. Algorithm of the software module «Selection of technologies»

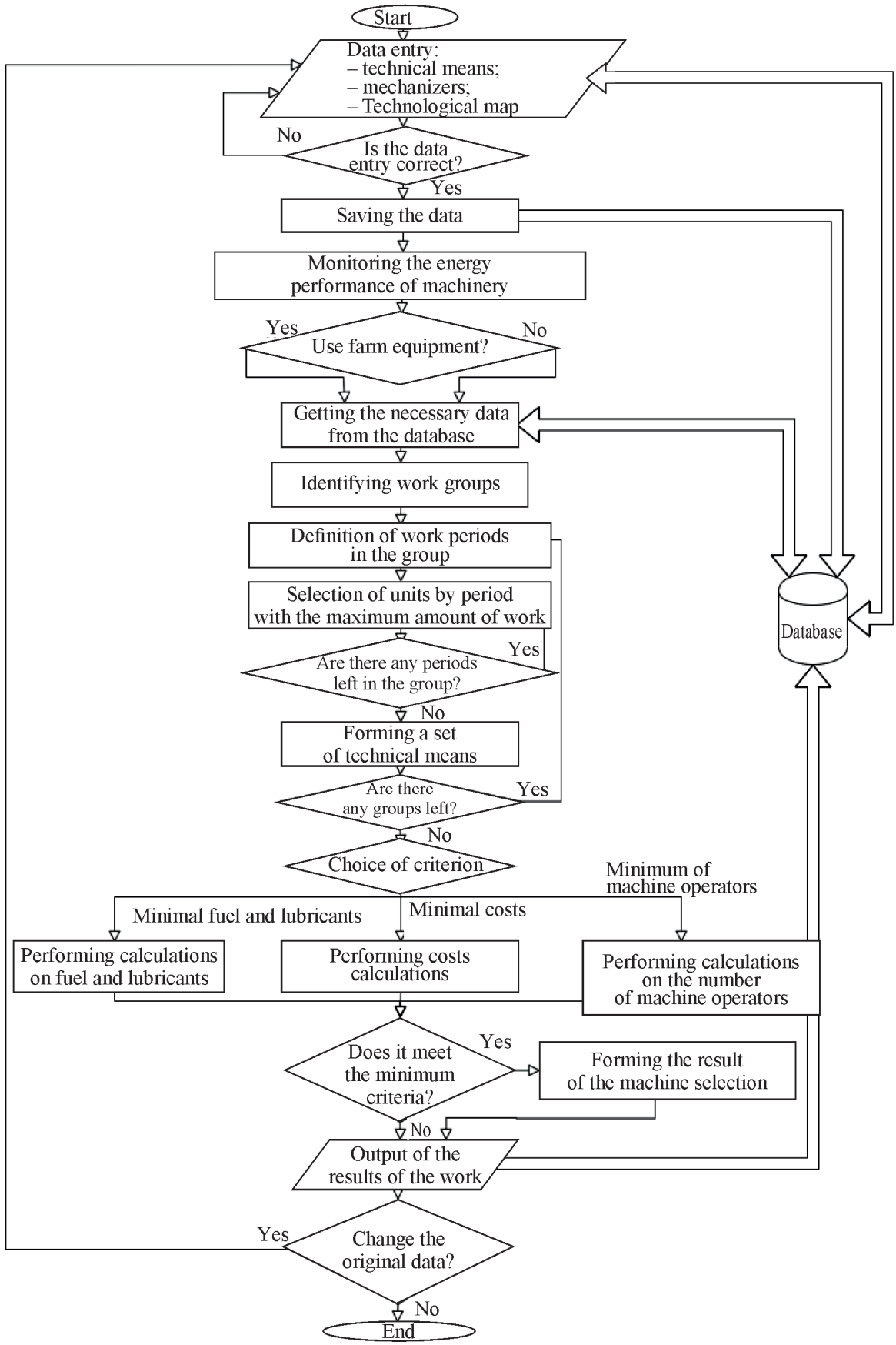

Рис. 3. Алгоритм программного модуля «Подбор техники»

Fig. 3. Algorithm of the software module «Selection of equipment»

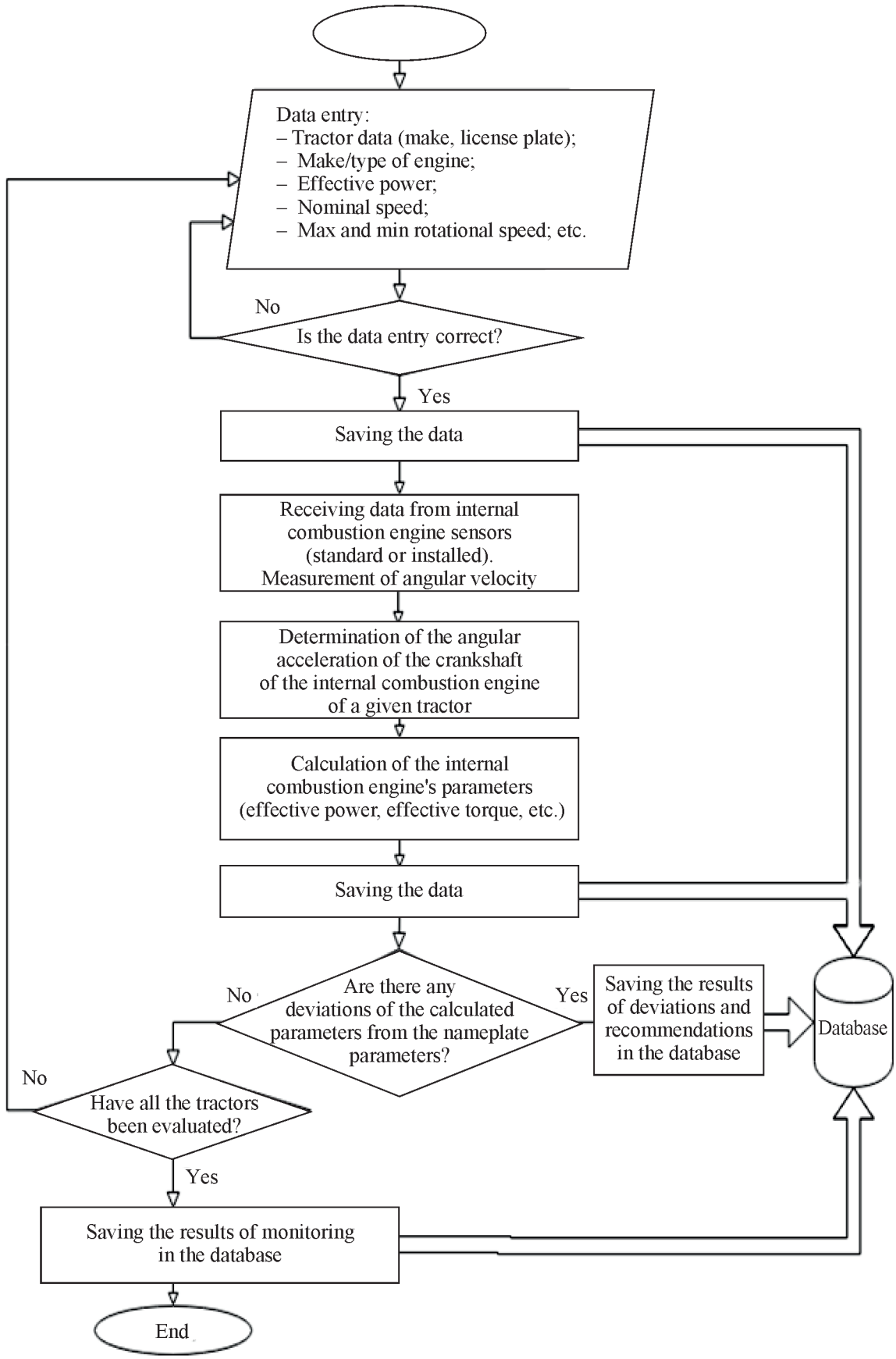

Рис. 4. Алгоритм мониторинга энергетических показателей тракторного парка

Fig. 4. Algorithm for monitoring the energy indicators of the tractor fleet

costs and increase the efficiency of agricultural production.

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ОЦЕНКА БОКОВОГО ОТКЛОНЕНИЯ КОЛЕСНОЙ МАШИНЫ ОТ ЗАДАННОЙ ТРАЕКТОРИИ ДВИЖЕНИЯ

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Колесная машина при криволинейном движении всегда находится под действием боковой силы и вследствие бокового увода отклоняется от заданной траектории движения. Известные методы и способы изучения криволинейного движения колесной машины, особенно при неустановившихся режимах, на высоких скоростях и с малыми радиусами поворота, дают достоверную информацию лишь для ограниченных условий эксплуатации машины на твердом опорном основании. Предложена методика расчета бокового отклонения колесной машины при движении по деформируемому основанию от теоретической криволинейной траектории как разность между действительным минимальным и теоретическим минимальным радиусами поворота. Данная методика представляет ее как единый объект, а не описывает ввиду сложности качение отдельного колеса. При этом исключен трудоемкий и материально затратный процесс определения эмпирических коэффициентов и зависимостей. При аналитических исследованиях кривых траекторий использованы экспериментальные данные и описание этих траекторий методом нелинейной аппроксимации кусочно-гладкой функцией. Получена действительная аналитическая траектория путем сдвига теоретической траектории и минимального теоретического радиуса на величину бокового отклонения. Представленная методика аналитического описания действительной траектории криволинейного движения колесной машины по деформируемому опорному основанию с использованием экспериментальных данных и нелинейной аппроксимации их кусочно-гладкой функцией, а также методика определения ее бокового отклонения с учетом изменения расчетной и экспериментальной траекторий позволяют достаточно точно описать различные режимы неустановившегося движения по фактической траектории и решать необходимые для рационального использования колесных машин задачи по оптимизации их конструктивных свойств и эксплуатационных качеств.

Ключевые слова: боковое отклонение, колесная машина, траектория, поворот, аппроксимация

EVALUATION OF THE LATERAL DEVIATION OF A WHEELED VEHICLE FROM A GIVEN TRAJECTORY

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A wheeled machine in a curved movement is always under the action of a lateral force and deviates from the set trajectory due to lateral guidance. Well-known methods and ways of studying the curvilinear motion of a wheeled machine, especially in unsteady modes, at high speeds and with small turning radii, provide reliable information only for limited conditions of machine operation on a solid support base. A methodology for calculating the lateral deviation of a wheeled machine when driving on a deformable base from a theoretical curvilinear trajectory as the difference between the actual minimum and theoretical minimum turning radii is proposed. This methodology presents it as a single object, rather than describing the rolling of an individual wheel due to its complexity. This eliminates the time-consuming and materially expensive process of determining empirical coefficients and dependencies. The analytical studies of the trajectory curves used experimental data and the description of these trajectories by the method of nonlinear approximation of the piecewise-smooth function. The actual analytical trajectory is obtained by shifting the theoretical trajectory and the minimum theoretical radius by the amount of lateral deviation. The proposed method of analytical description of the actual trajectory of the curvilinear motion of a wheeled machine on a

deformable support base using experimental data and nonlinear approximation of their piecewise smooth function, as well as the method of determining its lateral deviation with the changes in the calculated and experimental trajectories allow to accurately describe various regimes of unsteady motion along the actual trajectory and solve the problems necessary to rationally use wheeled machines to optimize their design properties and performance.

Keywords: lateral deviation, wheeled vehicle, trajectory, turn, approximation

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INTRODUCTION

A wheeled machine during curvilinear motion is always under the action of lateral force and deviates from the specified trajectory of motion due to side slip. In this case, the angles of the side slip are often commensurate even with the steering wheel angles, which negatively affects some of its kinematic and dynamic characteristics, as well as worsens many of its operational properties [1].

Many theories describing this phenomenon of side slip of an elastic tire have been developed since the discovery in 1925 by the French mechanic J. Brulier [2, 3]. Most of these theories are based on the process of rolling of the wheel on a particular support base without slippage. However, it is known that in loose soil, the cause of additional side slip can be sliding of the wheel tire contact in the transverse direction, lateral deformation and soil shear. Even insignificant in size lateral forces for the specific conditions of operation of the object, as experimental studies show, cause wheel slippage, which together with the elastic deformation of the pneumatic tire, shift in the transverse direction its rim relative to the supporting pad. In this case, the contact pad itself moves sideways relative to the support base due to its deformation [4-7]. Also, the effective application of most theories of lateral movement, especially for curvilinear movement, is hindered by assumptions about the steady-state mode of the wheels motion, about the equivalence of their rolling conditions, about the homogeneity of the ground and the constancy of its physical and mechanical properties.

Due to these reasons, the known methods and the methods of research of wheeled machine movement along a curvilinear trajectory, especially in unsteady modes, at operating speeds and with small turning radii, despite some consistency of analytical and experimental data [8], have a number of drawbacks, for example:

– it is difficult to determine experimentally under different driving conditions the empirical coefficients included in the calculation formulas;

– the obtained analytical dependencies, as a rule, are cumbersome, do not provide complete and reliable information when analyzing the process under study, do not allow to describe the real nature of the contact of the pneumatic wheel with the soil;

– practical calculation accuracy is achieved mainly for limited machine operating conditions, including small wheel angles and low travel speeds;

– the influence of changes in the maneuver time and the steering wheel angle on the appearance and shape of the trajectory of various points of the machine has not been investigated;

– the side slip of the machine wheels is not taken into account.

The need for further experimental studies and theoretical description of the process of curvilinear motion on a deformable base is related to the fact that side slip violates the relationship between the direction of the wheeled machine and the trajectory of its points, which is the cause of deterioration of motion stability and controllability in quite complex operating conditions [9-11].

Hence, it follows that it is necessary to develop a methodology for calculating the lateral deviation from the actual trajectory when turning on a deformable base, which describes the wheeled machine as a single object, rather than the rolling of each wheel due to the ambiguity of the processes that occur during this process. It is also necessary to minimize or completely exclude empirical coefficients and dependencies due to high labor intensity and high material costs in their determination, because this requires experimental research of lateral movement of all employed tire sizes used in machine operation, during their rolling in various soil conditions.

The purpose of the study is to substantiate and develop a methodology for determining the lateral deviation from the required (theoretical) trajectory during the curvilinear movement of a wheeled machine on a deformable base.

The research objectives are:

– experimental determination of the coordinates of the actual trajectory of the tractor on the deformable base;

– development of a methodology for its analytical presentation;

– establishment of patterns of change in the theoretical and actual curves of the turn trajectories on its various parts.

MATERIAL AND METHODS

The relevance of the set tasks is most obvious for universal tractors, in which, when performing agricultural operations, a significant part of the work cycle time falls on the turn, especially on the multi-contour fields of small and medium size. In this case, as a rule, the tractor passes the following stages of the turn [12]: entering the turn, steady turn, exit from the turn. Obviously, to understand the features of curvilinear motion of a wheeled tractor, it is necessary to study its behavior at all these stages of turning.

The most significant side slip of a wheeled machine occurs when entering a corner, where the traction of the wheel with the soil decreases sharply, especially with an increase in speed. Due to the destruction of the soil layer in contact by the wheel, a more intense slip is observed simultaneously with rolling, including in the direction of the tractor axle, i.e. there occurs the so-called bulldozer effect [1, 12]. In this part of the turn, both the translational velocity of the machine and the steering angle of its steering wheels are variable. However, it is here that the type and character of trajectory changes at the steady-state turn section, where these kinematic characteristics are stabilized, are formed. There have been no studies of elastic wheel motion on a deformable base when entering a turn. Theoretically the results obtained without taking into account the side slip and sliding of the wheels [13, 14] give only an opportunity to evaluate and compare different types of wheeled vehicles with changes in design and operating parameters at the design stage and have a rather large discrepancy with the experimental ones [1, 3, 8]. Analysis of the graphs of changes in the time of wheel speeds and torques on the tractor wheels in the experimental study of curvilinear motion showed: the nature of their course indicates a tightening of dynamic processes, which significantly worsens controllability and stability, causes the side slip of the machine, contributes to the disruption of the soil layer[1]. This also confirms the conclusion that a single mechanical-mathematical apparatus for describing the rolling process of each wheel in this case is incorrect to apply.

Elements of a circular loop-free turn are present in any mode of a wheeled vehicle movement. In this regard, it is the subject of the present research when performed by the driver under real operating conditions, in contrast to the test methods when driving on a specified path and with the steering fixed. [15].

Experimental studies of the curvilinear movement of the universal tractor class 2 LTZ-155 with all steerable and drive wheels and the mounted machine-tractor unit based on it were conducted on the experimental fields of the Educational Scientific and Technological Center "Agrotechnology" of the Voronezh SAU to determine the coordinates of the points of the actual trajectory curve. Preliminary soil preparation for the tests consisted in selecting an even, without clearly expressed microrelief horizontal plot using a leveler, which was processed in order to obtain surface properties corresponding to the "field prepared for sowing" background. The soil type was leached chernozem; its initial physical and mechanical characteristics were determined by control measurements on the main plot of the field and on the headlands (see the table).

The essence of the proposed methodology is as follows. A tractor or a mounted unit based on it was installed in a selected area of the field. Separate turns-runs were performed after acceleration in a straight line followed by uniform rotation of the steering wheel to the stop of the guide wheels (to the right or to the left) - the section "coming into corner". Then, on the section of the established turn, movement along the arc of a circle of constant curvature took place so that the longitudinal axis of the tractor turned an angle of 180 degrees from the initial position on the section of acceleration and rotation of the steering wheel in the opposite direction (coming out of corners) in order to access straight-line motion.

Turning both to the left and to the right provides the most reliable results, since it takes into account the kinematic difference between the right and left turns of the tractor, as well as the longitudinal and transverse slope of the field. Progressive speed of tractor and angular speed of the steering wheels were varied. Tests were conducted for a single tractor and a mounted MTA of different configuration.

During the tests, the following parameters were recorded on the oscilloscope tape: time of the experiment, rotation frequency of the track measuring wheel, wheel rotation angles, course angle, path, travelling speed of movement.

The instantaneous radius of the kinematic center trajectory curvature of the tractor was determined by the expression

$$R_i = \frac{l_{tpi}}{\beta_i},$$

where l_{tpi} – the path for the time of turning the tractor frame by the course angle βi, м.

According to the current values ltpi, Ri, βi the calculation determined the abscissa xi and ordinates yi of the trajectory of the kinematic center of the tractor.

Показатели влажности, твердости и плотности почвы опытного участка
Indicators of moisture, hardness and density of the soil

Indicator	On the headland	On the main massif
Soil moisture (W, %) in the layers, cm		
0–10	15,5	18,4
10–20	19,9	22,3
20–30	20,5	22,4
Soil density (ρ, g/cm³) in the layers, cm		
0–10	1,103	0,961
10–20	1,241	1,052
20–30	1,485	1,328
0–30	1,276	1,114
Soil hardness (T, MPa) at the depth, cm		
5	0,64	0,60
10	0,79	0,82
15	0,92	0,86
20	1,14	1,10
25	1,54	1,33
0–25	1,006	0,942

[1]Belyaev A.N. Increasing the efficiency of machine-tractor units on the basis of integral universal row crop wheeled tractors: Doctor of Technical Sciences doctoral thesis, Michurinsk-naukograd, 2019. 440 p.

The transducer PF-6 was used as the amplifying equipment, and the oscilloscope K-12-22 was used as the transducer for registration of the signals. Determination of the path traveled by the unit during the experiment was carried out with a track-measuring wheel equipped with an inductive sensor. Tracking angle of tractor longitudinal axis was measured with the help of the equipment, which consisted of a gyro half-compass GPK-52 with a voltage supply converter PAG-125 and a control panel PU-25. Angles of rotation of the guide wheels were estimated by rheochord sensors installed on the hubs of the front and rear tractor wheels. Duration of the experiments was controlled by the marks left on the oscilloscope tape by electric clocks ECH-62.

RESULTS AND DISCUSSION

One of the variants of experimentally received abscissa (x) and ordinates (y) of the circular loopless turn at the travelling speed v = 1,67 m/s, angular speed of the front driven wheels ω1 = 0,28 1/s, track B = 1,8 m, longitudinal base L = 2,6 m for the single tractor are resulted on fig. 1, where the points mark the actual experimental values of x and y of the turn curve trajectory, and the number 1 denotes the curve, which is the result of nonlinear approximation by explicit function of the specified experimental data [2,3] with an error of 2 · 10-3 m [12, 16]

$$y(x) = 4{,}75x^{0.27} - 0{,}06x^2 + 0{,}3x. \qquad (1)$$

It should be noted that the experimental points are given for the section of the coming into corner and part of the section of the steady turn, although the experimental studies to determine the trajectory were performed at all stages of the turn, but in Fig. 1 the points mark the results before the turn of the car frame by 90 degrees from the original rectilinear trajectory of motion, since for the remaining right sections we consider the trajectory curve of the turn identical to the corresponding left sections.

The radius of curvature of any curve having the form (see footnote 3)

$$\rho(x) = [1 + y'(x)^2]^{1,5} / y''(x), \qquad (2)$$

for the trajectory function (1) is calculated according to the expression (see footnote 2)

$$\rho(x) = [1 + (1{,}282/x^{0{,}73} - 0{,}12x + 0{,}3)^2]^{1,5} / (-0{,}936/x^{1{,}73} - 0{,}12), \qquad (3)$$

the graph of which is shown in Fig. 2.

The mean radius of curvature of the function according to (2) is calculated by the formula (see footnote 3)

$$\rho\_sr = \frac{1}{l}\int_0^l \rho(x)dx, \qquad (4)$$

where l – averaging section length.

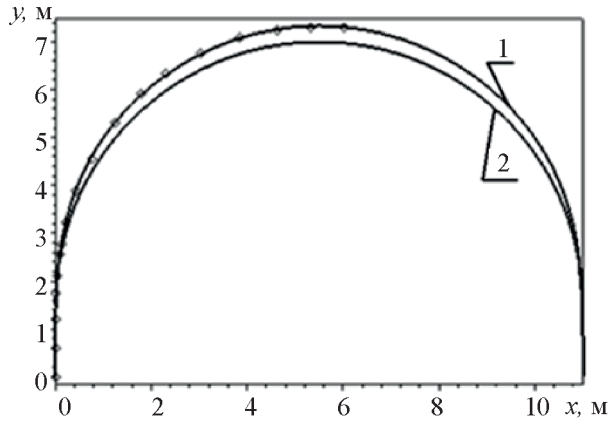

Рис. 1. Траектории поворота трактора:
◊ – экспериментальные точки траектории поворота;
1 – график аппроксимирующей функции экспериментальных точек траектории поворота;
2 – график теоретической функции траектории поворота

Fig. 1. Tractor turning trajectories:
◊ – experimental points of the turning trajectory;
1 – graph of the approximating function of the experimental points of the turning trajectory;
2 – graph of the theoretical function of the turning trajectory

[2]Dyakonov V.P. Maple 10/11/12/13/14 in Mathematical Calculations. Moscow: DMK-Press, 2011. 800 p.
[3]Dyakonov V.P. Encyclopedia of computer algebra. Moscow: DMK-Press, 2009. 1264 p.

When analyzing the function (1), taking into account (3) and (4), its average radius of curvature ρ = 5.48 m was obtained (see Fig. 2).

To describe the theoretical trajectory curve corresponding to the experimental conditions identical to the initial parameters, we use a piecewise smooth function y = f (x) of the form (see footnote 2)

$$f(x)=\begin{cases} p(v)x^{q}, \quad x \le x_Q, \\ \sqrt{R_T^2-\left(x-x_Q-\dfrac{R_T p(v) q \cdot x_Q^{q-1}}{\sqrt{1+\left(p(v) q \cdot x_Q^{q-1}\right)^2}}\right)^2}+ \\ +p(v)\cdot x_Q^{q}-\dfrac{R_T}{\sqrt{1+\left(p(v) q \cdot x_Q^{q-1}\right)^2}}, x > x_Q, \end{cases} \quad (5)$$

Where p and q – quite definite constants, 0 < q < 1; v – travelling speed of the machine, m/s; RT – theoretical minimum turning radius, m; x – the current abscissa of the turn trajectory curve, m; xQ – abscissa of the turn trajectory curve, corresponding to the end of the turn entry section, m.

Due to the side slip and sliding of the tractor, the theoretical curve (4) is located below the experimental points and their functions.

The theoretical function (see Fig. 1, curve 2) is subject to correction, which consists in shifting the ordinates of its points in the turn entry section by a certain positive value, and the theoretical minimum radius of the steady-state turn section is increased by the same value.

Since the specified displacement for the case in question is 0.4 m, the function (5) will take the following form (see footnote 2)

$$y(x)=\begin{cases} 4{,}45\cdot x^{0{,}333}+0{,}4, x > 0{,}25 \\ \sqrt{29{,}8-(x-5{,}25)^2}+1{,}9, x > 0{,}25 \end{cases}. \quad (6)$$

It was found that the shift value is practically equal to the difference between the experimental minimum turn radius - 5.48 m (see Fig. 2) and the theoretical minimum turn radius - 5.061 m. The graph of the function (6) practically coincided with curve 1 in Fig. 1 due to the fact that the actual theoretical and experimental turning radii differ by ~~0.019 m, or 0.~~35%.

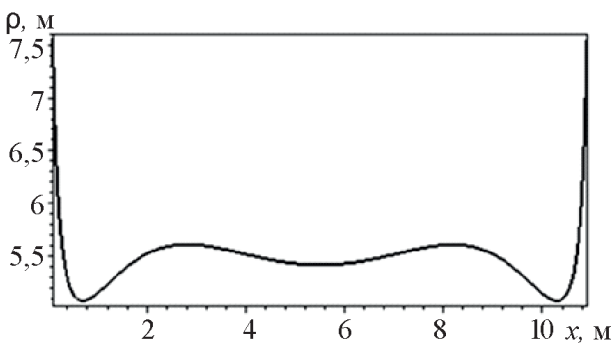

Рис. 2. График радиуса кривизны аппроксимирующей функции экспериментальных точек траектории поворота

Fig. 2. Graph of the radius of curvature of the approximating function of the experimental points of the rotation trajectory

CONCLUSION

Having a theoretical trajectory and the value of side slip (shear) with a very high degree of accuracy we obtain the actual trajectory, close to the actual trajectory, by determining experimentally only the value of the actual minimum radius of the turn. To obtain the actual analytical trajectory and to test the proposed method of determining the lateral deviation of a wheeled machine, it is necessary to calculate the value of the side slip, which is the difference between the actual minimum and theoretical minimum radii of rotation. Since this reveals some regularities in the dependence of the side slip values on the speed, it is likely to be obtained analytically, which is the subject of separate studies.

With an analytical actual trajectory, it is possible to study the motion of a wheeled machine along a given trajectory using direct calculation formulas, which is a simpler and less time-consuming operation compared to mathematical modeling of a complex and ambiguous process [2, 6, 7]. As a result of mathematical modeling, it is also necessary to make many simplifications and assumptions, which reduces the accuracy of the results and often leads to adequate solutions only in particular cases.

Since the motion stability of the majority of wheeled machines determines the quality of technological operations performed, it is necessary to determine the ranges of their motion speeds in order to ensure optimal criteria for the flow of the process. The conducted research also makes it possible to develop a calculation method that contributes to improving the quality of the technological process both by improving the design of machines and by selecting the optimal operating characteristics. As a result of the study of motion along the known trajectory, it is possible to set limits for different conditions and different wheeled machines on the values of possible external disturbances and changes in the internal properties of the system.

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РАЗРАБОТКА КОМБИНИРОВАННОЙ ВАКЦИНЫ ПРОТИВ РИНОПНЕВМОНИИ И МЫТА ЛОШАДЕЙ*

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Представлена разработка инактивированной комбинированной вакцины против ринопневмонии и мыта лошадей. Изучены острая токсичность, пирогенность и иммуногенность вакцины на лабораторных животных. Доклинические испытания вакцины проведены на беспородных аутбредных мышах и кроликах. Испытание вакцинного препарата на кроликах-самцах показало его апирогенность. Иммуногенность вирусного компонента вакцины проверена на аутбредных мышах 10–14-дневного возраста массой тела 6–7 г. Вакцину мышам 1-й группы ($n = 8$) вводили подкожно по 0,3 мл двукратно с интервалом 14 дней. Мыши 2-й группы ($n = 6$) использованы для отрицательного и положительного контроля. Через 14 дней после второй иммунизации проведено контрольное интрацеребральное заражение адаптированным штаммом вируса ринопневмонии лошадей в дозе 0,02 × 6,0 $lgTCD_{50}$/мл. Иммуногенную активность мытного состава вакцины определяли на беспородных белых мышах. Вакцину в дозе 0,5 мл вводили подкожно 10 белым мышам. После вакцинации через 10 дней проведено заражение летальной дозой мытного стрептококка опытной и контрольной групп лабораторных мышей LD_{50}, которая составила 200 тыс. микробных тел в 1 мл. У мышей опытной группы за время наблюдения масса тела увеличилась на 1,5 г, контрольной – на 0,9 г. По результатам патоморфологических и гистологических исследований, изменений во внутренних органах, вызванных введением внутрижелудочно препаратов, не обнаружено. Доклиническое испытание показало отсутствие острой токсичности, аллергизирующих, пирогенных свойств и иммуногенность комбинированной вакцины против ринопневмонии и мыта лошадей. Комбинированная вакцина предохраняет от экспериментального заражения вирусом ринопневмонии на 75%, возбудителем мыта на 80%.

Ключевые слова: комбинированная вакцина, острая токсичность, пирогенность, иммуногенность, мыт, ринопневмония, иммуномодулятор

DEVELOPMENT OF A COMBINED VACCINE AGAINST RHINOPNEUMONIA AND STRANGLES OF HORSES

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The development of an inactivated combined vaccine against rhinopneumonia and horse strangles is presented. Acute toxicity, pyrogenicity and immunogenicity of the vaccine in laboratory animals have been studied. Preclinical trials of the vaccine were conducted on mongrel outbred mice and rabbits. Testing of the vaccine preparation on male rabbits showed its apyrogenicity. The

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immunogenicity of the viral component of the vaccine was tested on 10-14-day-old outbred mice with a body weight of 6-7 g. The vaccine was administered subcutaneously to the 1st group of mice (n = 8) 0.3 ml twice with an interval of 14 days. Mice of the 2nd group (n = 6) were used for negative and positive control. 14 days after the second immunization, a control intracerebral infection with an adapted strain of equine rhinopneumonia virus was carried out at a dose of 0.02 × 6.0 $lgTSD_{50}$/ml. The immunogenic activity of the strangles composition of the vaccine was tested on mongrel white mice. The vaccine in a dose of 0.5 ml was administered subcutaneously to 10 white mice. After vaccination, 10 days later, infection with a lethal dose of strangles streptococcus was carried out in experimental and control groups of laboratory mice LD_{50}, which amounted to 200 thousand microbial bodies in 1 ml. In the mice of the experimental group, body weight increased by 1.5 g during observation, in the control group – by 0.9 g. According to the results of pathomorphological and histological studies, no changes in the internal organs caused by the administration of intragastric drugs were detected. Preclinical testing showed the absence of acute toxicity, allergenic, pyrogenic properties and immunogenicity of the combined vaccine against rhinopneumonia and horse strangles. The combined vaccine protects against experimental infection with the rhinopneumonia virus by 75%, with the causative agent of horse strangles by 80%.

Keywords: combined vaccine, acute toxicity, pyrogenicity, immunogenicity, strangles, rhinopneumonia, immunomodulator

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Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Viral and bacterial diseases of young horses are a complex problem for the global horse industry. Of these, rhinopneumonia and strangles of horses are considered to be the most common diseases [1, 2].

There are different types of rhinopneumonia vaccines around the world: inactivated, attenuated, and live vaccines, as well as different therapies [3, 4]. However, the technologies of using these vaccines provide for two- or threefold immunization. In Russia, dry live virus vaccine from CB/69 strain is used to prevent rhinopneumonia [5, 6].

In the Republic of Sakha (Yakutia), employees of the Yakutsk Research Institute of Agriculture and VIEV (The All-Russian Research Institute of Experimental Veterinary Medicine, Moscow) developed an inactivated vaccine from the SV/69 strain against horse rhinopneumonia with an immunomodulator from a fugate of the *Bacillus subtilus* TNP-3 bacteria strain [7]. In 2018, a strain of Cape streptococcus, *Streptococcus equi* H-5/1, was deposited in the VGNKI - the Russian State Center for Animal Feed and Drug Standardization and Quality (registration number VKSM-B-141P). The strain is used to manufacture a vaccine against horse strangles (invention patent No. 2703485 dated 15.08.2018) [8].

Due to the fact that rhinopneumonia can occur simultaneously with the horse strangles, the development of a combined single-administered vaccine remains relevant. In the available literature, there are no data on analogues of bivalent vaccine for the prevention of rhinopneumonia and horse strangles.

The purpose of the work is to present the development of an inactivated combined vaccine against rhinopneumonia and horse strangles.

The objectives of the study are to study the acute toxicity, pyrogenicity and immunogenicity of a combined vaccine against rhinopneumonia and horse strangles on laboratory animals.

MATERIAL AND METHODS

The combined vaccine was made of inactivated strains of rhinopneumonia virus CB/69, *Streptococcus equi* bacterium "H-5/1" and immunomodulator from the bacterial strain *Bacillus subtilis* TNP-3. Laboratory tests of the experimental series of the vaccine and determination of immunogenicity of the horse strangles were conducted on mongrel laboratory white mice of both sexes aged 5-8 weeks, weighing 18-20 g and healthy male rabbits weighing 1.5-1.6 kg. Harmlessness and pyrogenicity were determined in accordance with GOST 31926-2013 "Drugs for veterinary use. Methods for determination of harmlessness". Determination of immunogenicity of the vaccine viral component was performed in the laboratory of virology of VIEV (Moscow) on outbred mice 10-14 days old with body weight of 6-7 g. The results were mathematically processed using the Student's method.

RESULTS AND DISCUSSION

Injection of the vaccine preparation intragastrically in a dose of 1 cm^3 and physiological solution in the same dose to the mice of the control group had no effect on the general condition of the animals. The mice consumed food completely, were agile, and actively reacted to their surroundings. Analysis of the body weight dynamics of the white mice revealed its positive increase in both the control and experimental groups (see Table 1).

In the experimental group receiving the vaccine preparation the weight gain was 9.2%, in the control group - 5.05%. According to the results of the histological studies, no focal dystrophic changes in the internal organs were found.

To determine pyrogenicity, two groups of 3 healthy male rabbits weighing 1.5-1.6 kg were formed. The combined vaccine was injected into the ear vein of the rabbits in a dose of 0.1 ml (group 2). As a control (Group 1), 0.9% physiological solution was injected. After injection, the body temperature was measured at the intervals of not more than 30 min for 3 h (see Table 2).

During observation before the experiment, the average temperature of the experimental rabbits in group 1 was 38.6 ºC, in group 2 - 38 ºC. On day 4, before the injection, it was 38.5 ºC in group 1 and 38.6 ºC in group 2. After vaccination the temperature of the rabbits increased by 0.2ºC in group 1, and by 0.4ºC in group 2. Thus, the combined vaccine is apirogenic and did not cause changes in animal body temperature.

Immunization efficiency was determined by the number of mice resistant after infection. Immunogenicity of the viral component in the 1st group of mice was 75%, in the control group all mice died. For the control infection with strangles streptococcus, the lethal dose was determined, which amounted to 200 thousand microbial bodies in 1 cm^3. Out of ten immunized mice, two mice fell ill and died. In the control group, all 10 mice fell ill and died. Immunogenicity of the strangles composition of the vaccine was 80%.

The high efficiency of the immunogenic activity of the associated vaccine is due to the antigenically active strains of rhinopneumonia virus, Mycobacterium streptococcus and an im-

Табл. 1. Учет массы тела белых лабораторных мышей, г
Table 1. Body weight count of white laboratory mice, g

Group	Body weight on the day of observation								
	Before the experiment (during 2 days)	On the day of the experiment (after the injection)	1-st	2-nd	3-rd	4-th	5-th	6-th	7-th
1	16,3 ± 9,05	17,2 ± 9,68	17,7 ± 9,82	17,9 ± 9,89	17,2 ± 9,61	18,2 ± 10,11	17,8 ± 10,39	17,9 ± 10,11	17,8 ± 10,25
2	17,0 ± 0,84	17,4 ± 0,91	18,2 ± 0,84	18,2 ± 0,84	18,4 ± 1,06	18,5 ± 1,2	18,2 ± 0,98	18,6 ± 0,63	18,7 ± 0,63

Табл. 2. Результаты измерения температуры тела подопытных кроликов до и после инъекций (n = 3)

Table 2. Results of body temperature measurements of experimental rabbits before and after injections (n = 3)

Day of the experiment	1-st group	2-nd group
Before the injection of the preparation		
1-st	38,7 ± 0,42	38,0 ± 0,21
2-nd	38,3 ± 0,35	37,9 ± 0,21
3-rd	38,8 ± 0,21	38,2 ± 0,28
4-th	38,5 ± 0,21	38,6 ± 0,56
In 30 min	38,5 ± 0,14	38,6 ± 0,49
After the injection of the preparation at the 4-th day of the experiment		
In 30 min	38,6 ± 0,21	37,6 ± 0,70
In 1 h	38,4 ± 0,42	37,9 ± 0,35
In 1,5 h	38,5 ± 0,14	38,4 ± 0,28
In 2 h	38,5 ± 0,07	38,8 ± 0,14
In 2,5 h	38,7 ± 0,35	38,7 ± 0,21
In 3 h	38,7 ± 0,07	39,0 ± 0,21

munomodulator from the *Bac. subtilus* strain TNP-3, which has enzymatic, interferon-inducing, antimicrobial and immunostimulatory properties [9]. The results obtained are consistent with the works of the researchers who found that viral and bacterial antigens in combined vaccines lead to significant stimulation of the phagocytic activity of peritoneal macrophages, which contributes to the development of adaptive immunity [10]. Shiliang A. Liu et al. [11] experimentally proved on laboratory mice that intramuscular injection of live vector vaccine against GVL-1 stimulates formation of humoral and immune response. Seong K. Kim et al. [12] also note that immunization of laboratory mice with weakened herpes virus type 1 strain stimulates the production of innate immune responses in their bodies, which protects them during control infection with a lethal dose of the virus.

CONCLUSIONS

1. It was found that the combined vaccine in the studied doses does not adversely affect the general state of animals, has no allergizing properties, does not cause convulsive reactions, does not impair coordination of movements and has no toxicity in relation to laboratory animals.

2. The immunogenicity of the viral composition of the vaccine was 75% and that of the strangles composition was 80%.

3. Development and implementation of a combined vaccine will increase the effectiveness of preventive measures for respiratory diseases of young horses.

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БОРИС ИВАНОВИЧ ГЕРАСЕНКОВ
(к 100-летию со дня рождения)

В 2022 г. крупному сибирскому ученому-аграрнику, селекционеру и организатору селекционного центра при Сибирском научно-исследовательском институте сельского хозяйства, доктору сельскохозяйственных наук Борису Ивановичу Герасенкову исполнилось 100 лет со дня рождения и 50 лет со времени смерти.

За столь короткий жизненный путь Борис Иванович успел принять активное участие в боевых действиях по защите Родины в Великой Отечественной войне, окончить агрономический факультет Московской сельскохозяйственной академии им. К.А. Тимирязева, специализироваться в селекции и агротехнике кормовых культур и вывести оригинальные сорта и гибриды многолетних трав и кукурузы. На протяжении 10 лет бессменно руководил лабораторией кукурузы и одновременно был заместителем директора СибНИИСХоза по научной работе. В последние 2 года жизни он создал Западносибирский селекционный центр при институте и руководил им. С 1936 г. был в рядах Ленинского комсомола, в 1946 г. вступил в члены КПСС.

Борис Иванович родился 22 июля 1922 г. в г. Борисоглебске Воронежской области в семье рабочих. С 1930 г. учился в средней школе, по окончании которой был призван в ряды Советской армии. Прошел курс артиллерийской подготовки и с начала войны по 10 апреля 1942 г. активно участвовал в боях на Западном и Калининском фронтах. Воевал в качестве командира батареи ПТО в составе 226-го особого отдельного ударного батальона 3-й морской бригады 2-й ударной армии. В 1942 г. был тяжело ранен, потерял правую руку и в течение года лечился в госпиталях. В 1945 г. был награжден «Медалью за победу над Германией в Великой Отечественной войне».

После длительного лечения в госпиталях и демобилизации по ранению и инвалидности Борис Иванович поступил в Московскую сельскохозяйственную академию им. К.А. Тими-

рязева. После ее окончания в марте 1948 г. Б.И. Герасенков был направлен на работу в качестве научного сотрудника на Ставропольскую государственную селекционную станцию. Через год в марте 1949 г. распоряжением заместителя министра МСХ по кадрам переведен в сибирские края – на Нарымскую госселекционную станцию на должность старшего научного сотрудника отдела селекции, семеноводства и агротехники.

На Нарымской опытной станции Б.И. Герасенков работал в составе селекционной группы кормовых культур совместно с опытными селекционерами В.К. Немлиенко и В.Б. Овсянниковым. При его активном участии созданы и переданы на испытание в госсортсеть сорта клевера красного и тимофеевки луговой. В последующем оба нарымских сорта были районированы и отличались высокой урожайностью по сену (40–60 ц/га) и семенам (3–4 ц/га), устойчивостью к экстремальным сибирским условиям, болезням и вредителям, а также к полеганию и затоплению. Они нашли широкое распространение в Западной и Восточной Сибири, а также в Магаданской области.

В декабре 1951 г. Борис Иванович поступил в очную аспирантуру на кафедру растениеводства ТСХА. Научные опыты по орошению пшеницы аспирант Б.И. Герасенков проводил в Ростовской области на черноземах. На основании этих исследований в 1954 г. им успешно защищена кандидатская диссертация. После этого он был направлен на работу в Омск в старейшее научное заведение региона – в Сибирский НИИ сельского хозяйства.

В СибНИИСХозе, где Борис Иванович проработал около 20 лет, в полной мере проявился его талант исследователя. Он стал заниматься крупнейшей агрономической проблемой того времени: изучением адаптационных возможностей кукурузы, новой для Сибири культуры в то время. Эта перспективная зерновая и кормовая культура в 60-е годы прошлого столетия была возведена в стране в ранг «партийной» и повсеместно внедрялась, часто неудачно, в сельскохозяйственное производство страны. Недостаток научных исследований по технологии возделывания культуры, отсутствие адаптированных к сибирским условиям сортов и гибридов сдерживали ее широкое освоение в колхозах и совхозах.

По инициативе Б.И. Герасенкова в институте с 1955 г. были активно развернуты исследования по биологии кукурузы, агротехнике ее возделывания, методам селекции и семеноводству. В 1963 г. Борисом Ивановичем создана первая в Сибири лаборатория кукурузы. За 10-летний период под его руководством удалось решить агротехнические и селекционные проблемы адаптации кукурузы к непростым сибирским почвенно-климатическим условиям и разработать зональные технологические приемы стабильного получения урожаев зеленой массы и зерна. Особо важная и наиболее трудоемкая исследовательская работа под руководством Б.И. Герасенкова проведена группой сотрудников (Г.П. Высокос, В.П. Рогозина, Л.П. Гончарова, Н.В. Соболева, Т.С. Исайченкова и др.) по селекции культуры: в лаборатории созданы сибирские скороспелые сорта и гибриды кукурузы Омская 2, Омская 5, Омская 8, гибрид Омский 22. Вскоре они нашли широкое распространение в растениеводстве региона и послужили в последующем исходным материалом для создания новых селекционных форм. В дальнейшем эти направления были продолжены и нашли широкое развитие.

По современным меркам, публикационное наследство Б.И. Герасенкова небольшое (немногим более 100 статьей, в журналах, сборниках и рекомендациях), но все его работы направлены на теоретическое обоснование методологических подходов к селекции и технологии возделывания кормовых культур в суровых сибирских условиях. В то время эти проблемы были крайне актуальными.

Обобщение материалов исследований по кукурузе позволило Б.И. Герасенкову подготовить диссертацию «Биология и особенности культуры сибирского экотипа кукурузы» на соискание ученой степени доктора сельскохозяйственных наук, которая успешно была защищена в 1964 г. Свой исследовательский опыт Борис Иванович передавал молодежи и подготовил пять аспирантов, защитивших кандидатские диссертации.

Наряду со своей активной научной деятельностью Б.И. Герасенков выполнял также обязанности руководителя всей исследовательской работой в СибНИИСХозе, поскольку бессменно на протяжении последних 10 лет работал заместителем директора по науке. Следует отметить, что в 60-х годах прошлого столетия в институте весьма активно вели исследования по всем направлениях аграрной науки: земледелию, агрохимии, селекции, животноводству, механизации. Опытный кадровый состав старшего поколения и активная молодежь (обучались до 30 аспирантов одновременно) проводили интенсивные научные поиски в лабораториях и на опытных полях и фермах института, в ОПХ, колхозах и совхозах. Следует признать, что Борису Ивановичу удавалось тактично решать все проблемы как с корифеями науки, так и с молодым поколением.

Большой вклад Б.И. Герасенков в качестве руководителя внес в создание в 1972, 1973 гг. при СибНИИСХозе Селекционного центра. Он успел определить основные направления его будущей исследовательской работы, составить перспективные планы комплексных селекционных направлений по полевым культурам, наметить комплексность теоретических и прикладных исследований. Менее чем за год Борис Иванович смог создать группу новых лабораторий, теоретическое сопровождение селекционных процессов растений и подобрать для них молодых и хорошо подготовленных руководителей, кандидатов наук: генетики – Р.А. Цильке, физиологии и биохимии – О.И. Гамзикова, иммунитета – Б.Г. Рейтера, малогабаритной техники – В.А. Домрачева. Как показало время, они успешно справились с перспективными проблемами. Запланированные новое здание Селекционного центра и тепличный комплекс Селекцентра были построены по его планам позже.

Практически все задумки Бориса Ивановича по созданию Селекционного центра при СибНИИСХозе выполнены его приемником членом-корреспондентом РАСХН К.Г. Азиевым и коллективом селекцентра.

Военные раны и рабочие перегрузки дали о себе знать. В начале 1973 г. Борис Иванович Герасенков скоропостижно ушел из жизни.

Время неминуемо стирает память о солдатах и командирах научного фронта, но вклад каждого воина исследовательского полка остается в сортах, агроприемах, теоретических постулатах и в конечном итоге в полученном хлебе насущном и памяти поколений.

СПИСОК НЕКОТОРЫХ ПУБЛИКАЦИЙ ДОКТОРА СЕЛЬСКОХОЗЯЙСТВЕННЫХ НАУК Б.И. ГЕРАСЕНКОВА

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ПРАВИЛА ДЛЯ АВТОРОВ

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

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

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

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

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

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

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

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

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

Публикации для авторов **бесплатны**.

При направлении статьи в редакцию журнала «Сибирский вестник сельскохозяйственной науки» рекомендуем руководствоваться следующими правилами.

РЕКОМЕНДАЦИИ АВТОРУ ДО ПОДАЧИ СТАТЬИ

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

- статья ранее не была опубликована в другом журнале;
- статья не находится на рассмотрении в другом журнале;
- все соавторы согласны с публикацией текущей версии статьи.

Перед отправкой статьи на рассмотрение необходимо убедиться, что в файле (файлах) содержится вся необходимая информация на русском и английском языках, указаны источники информации, размещенной на рисунках и в таблицах, все ссылки оформлены корректно.

ПОРЯДОК НАПРАВЛЕНИЯ РУКОПИСЕЙ СТАТЕЙ

1. Отправка статьи осуществляется через электронную редакцию на сайте журнала **https://sibvest.elpub.ru/jour/index.** После предварительной регистрации автора, в правом верхнем углу страницы выбрать опцию «Отправить рукопись». Затем загрузить рукопись статьи (в формате *.doc или *.docx) и сопроводительные документы к ней. После завершения загрузки материалов обязательно выбрать опцию «Отправить письмо», в этом случае редакция автоматически будет уведомлена о получении новой рукописи.

Сопроводительные документы к рукописи статьи:

- скан-копия письма от организации с подтверждением авторства и разрешением на публикацию (образец на **http://sibvest.elpub.ru/**);
- скан-копия авторской справки по представленной форме (образец на **http://sibvest.elpub.ru/**), в которой должно быть выражено согласие на открытое опубликование статьи в печатном варианте журнала и его электронной копии в сети Интернет;
- скан-копия рукописи с подписями авторов. Автор, подписывая рукопись и направляя ее в редакцию, тем самым передает авторские права на издание этой статьи СФНЦА РАН;
- анкеты авторов на русском и английском языках (образец на **http://sibvest.elpub.ru/**);
- скан-копия справки из аспирантуры (для очных аспирантов).

2. Все поступающие в редакцию рукописи статей регистрируются через систему электронной редакции. В личном кабинете автора отражается текущий статус рукописи.

3. Нерецензируемые материалы (материалы научной хроники, рецензии, книжные обозрения, материалы по истории сельскохозяйственной науки и деятельности учреждений и ученых) направляются на e-mail: **sibvestnik@sfsca.ru** и регистрируются ответственным секретарем.

ПОРЯДОК ОФОРМЛЕНИЯ СТАТЬИ

Текст рукописи оформляется шрифтом Times New Roman, кеглем 14 с интервалом 1,5, все поля 2,0 см, нумерация страниц внизу. Объем статьи не более 15 страниц (включая таблицы, иллюстрации и библиографию); статей, размещаемых в рубриках «Из диссертационных работ» и «Краткие сообщения», – не более 7 страниц.

Структура оформления статьи:

1. **УДК**
2. **Заголовок статьи на русском и английском языках (не более 70 знаков).**
3. **Фамилии и инициалы авторов, полное официальное название научного учреждения, в котором проведены исследования на русском и английском языках.**

Если в подготовке статьи принимали участие авторы из разных учреждений, необходимо указать принадлежность каждого автора к конкретному учреждению с помощью надстрочного индекса.

4. **Реферат на русском и английском языках.** Объем реферата не менее 200–250 слов. Реферат является кратким и последовательным изложением материала статьи по основным разделам и должен отражать основное содержание, следовать логике изложения материала и описания результатов в статье с приведением конкретных данных. Не следует включать впервые введенные термины, аббревиатуры (за исключением общеизвестных), ссылки на литературу. В реферате не следует подчеркивать новизну, актуальность и личный вклад автора; место исследования необходимо указывать до области (края), не упоминать конкретные организации.
5. **Ключевые слова на русском и английском языках.** 5–7 слов по теме статьи. Желательно, чтобы ключевые слова дополняли реферат и название статьи.
6. **Информация о конфликте интересов либо его отсутствии.** Автор обязан уведомить редактора о реальном или потенциальном конфликте интересов, включив информацию о конфликте интересов в соответствующий раздел статьи. Если конфликта интересов нет, автор должен также сообщить об этом.

Пример формулировки: «Автор заявляет об отсутствии конфликта интересов».

7. **Благодарности на русском и английском языках.** В этом разделе указываются все источники финансирования исследования, а также благодарности людям, которые участвовали в работе над статьей, но не являются ее авторами.
8. **Основной текст статьи.** При изложении оригинальных экспериментальных данных рекомендуется использовать подзаголовки:

ВВЕДЕНИЕ (постановка проблемы, цели, задачи исследования)

МАТЕРИАЛ И МЕТОДЫ (условия, методы (методика) исследований, описание объекта, место и время проведения)

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

ЗАКЛЮЧЕНИЕ или **ВЫВОДЫ**

СПИСОК ЛИТЕРАТУРЫ. Количество источников не менее 15. В список литературы включаются только рецензируемые источники: статьи из научных журналов и монографии. Самоцитирование не более 10% от общего количества. Библиографический список должен быть оформлен в виде общего списка в порядке упоминания в тексте, желательны ссылки на источники 2–3-летнего срока давности. Правила оформления списка литературы – в соответствии с ГОСТ Р 7.05–2008 (требования и правила составления библиографической ссылки). В тексте ссылка на источник отмечается порядковой цифрой в квадратных скобках, например [1]. Литература в списке дается на тех языках, на которых она издана. В библиографическое описание публикации необходимо вносить всех авторов, не сокращая их одним, тремя и т.п. Недопустимо сокращение названий статей, журналов, издательств.

Если необходимо сослаться на авторефераты, диссертации, сборники статей, учебники, рекомендации, учебные пособия, ГОСТы, информацию с сайтов, статистические отчеты, статьи в общественно-политических газетах и прочее, то такую информацию следует оформить в *сноску* в конце страницы. Сноски нумеруются арабскими цифрами, размещаются постранично сквозной нумерацией.

Внимание! Теоретические, обзорные и проблемные статьи могут иметь произвольную структуру, но обязательно должны содержать реферат, ключевые слова, список литературы.

ПРИМЕРЫ ОФОРМЛЕНИЯ СПИСКА ЛИТЕРАТУРЫ, REFERENCES И СНОСОК

СПИСОК ЛИТЕРАТУРЫ:

Монография

Климова Э.В. Полевые культуры Забайкалья: монография. Чита: Поиск, 2001. 392 с.

Часть книги

Холмов В.Г. Минимальная обработка кулисного пара под яровую пшеницу при интенсификации земледелия в южной лесостепи Западной Сибири // Ресурсосберегающие системы обработки почвы. М.: Агропромиздат, 1990. С. 230–235.

Периодическое издание

Пакуль А.Л., Лапшинов Н.А., Божанова Г.В., Пакуль В.Н. Технологические качества зерна мягкой яровой пшеницы в зависимости от системы обработки почвы // Сибирский вестник сельскохозяйственной науки. 2018. Т. 48. № 4. С. 27–35. DOI: 10.26898/0370-8799-2018-4-4.

REFERENCES:

Составляется в том же порядке, что и русскоязычный вариант, по следующим правилам:

Фамилии И.О. авторов в устоявшемся способе транслитерации, англоязычное название статьи, *транслитерация названия русскоязычного источника (например через сайт: https://antropophob.ru/translit-bsi) = англоязычное название источника.* Далее оформление для монографии: город, англоязычное название издательства, год, количество страниц; для журнала: год, номер, страницы). (In Russian).

Пример: Avtor A.A., Avtor B.B., Avtor C.C. Title of article.

Транслитерация авторов. Англоязычное название статьи

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

Транслитерация источника = Англоязычное название источника

Монография

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

Часть книги

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

Периодическое издание

Pakul A.L., Lapshinov N.A., Bozhanova G.V., Pakul V.N. Technological grain qualities of spring common wheat depending on the system of soil tillage. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2018, vol. 48, no. 4, pp. 27–35. (In Russian). DOI: 10.26898/0370-8799-2018-4-4.

СНОСКИ:

Цитируемый текст[1].

[1]*Климова Э.В., Андреева О.Т., Темникова Г.П.* Пути стабилизации кормопроизводства Забайкалья // Проблемы и перспективы совершенствования зональных систем земледелия в современных условиях: материалы науч.-практ. конф. (Чита, 16–17 октября 2008 г.). Чита, 2009. С. 36–39.

Цифровой идентификатор Digital Object Identifier – DOI (когда он есть у цитируемого материала) необходимо указывать в конце библиографической ссылки.

Пример:

Chu T., Starek M.J., Brewer M.J., Murray S.C., Pruter L.S. Assessing lodging severity over an experimental maize (Zea mays L.) field using UAS images // Remote Sensing. 2017. Vol. 9. P. 923. DOI: 10.3390/rs9090923.

Наличие DOI статьи следует проверять на сайте http://search.crossref.org/ или https://www.citethisforme.com. Для этого нужно ввести в поисковую строку название статьи на английском языке.

РИСУНКИ, ТАБЛИЦЫ, СКРИНШОТЫ И ФОТОГРАФИИ

Рисунки должны быть хорошего качества, пригодные для печати. Все рисунки должны иметь подрисуночные подписи. Подрисуночную подпись необходимо перевести на английский язык. Рисунки нумеруются арабскими цифрами по порядку следования в тексте. Если рисунок в тексте один, то он не нумеруется. Отсылки на рисунки оформляются следующим образом: «На рис. 3 указано, что …» или «Указано, что … (см. рис. 3)». Подрисуночная

подпись включает порядковый номер рисунка и его название. «Рис. 2. Описание жизненно важных процессов». Перевод подрисуночной подписи следует располагать после подрисуночной подписи на русском языке.

Таблицы должны быть хорошего качества, пригодные для печати. Предпочтительны таблицы, пригодные для редактирования, а не отсканированные или в виде рисунков. Все таблицы должны иметь заголовки. Название таблицы должно быть переведено на английский язык. Таблицы нумеруются арабскими цифрами по порядку следования в тексте. Если таблица в тексте одна, то она не нумеруется. Отсылки на таблицы оформляются следующим образом: «В табл. 3 указано, что …» или «Указано, что … (см. табл. 3)». Заголовок таблицы включает порядковый номер таблицы и ее название: «Табл. 2. Описание жизненно важных процессов». Перевод заголовка таблицы следует располагать после заголовка таблицы на русском языке.

Фотографии, скриншоты и другие нерисованные иллюстрации необходимо загружать отдельно в виде файлов формата *.jpeg (*.doc и *.docx – в случае, если на изображение нанесены дополнительные пометки). Разрешение изображения должно быть >300 dpi. Файлам изображений необходимо присвоить название, соответствующее номеру рисунка в тексте. В описании файла следует отдельно привести подрисуночную подпись, которая должна соответствовать названию фотографии, помещаемой в текст.

Следует обратить внимание на написание формул в статье. Во избежание путаницы необходимо греческие (α, β, π и др.), русские (А, а, Б, б и др.) буквы и цифры писать прямым шрифтом, латинские – курсивным (*W*, *Z*, *m*, *n* и др.). Математические знаки и символы нужно писать также прямым шрифтом. Необходимо четко указывать верхние и нижние надстрочные символы (W^1, F_1 и др.).

ВЗАИМОДЕЙСТВИЕ МЕЖДУ ЖУРНАЛОМ И АВТОРОМ

Редакция просит авторов при подготовке статей руководствоваться изложенными выше правилами.

Все поступающие в журнал «Сибирский вестник сельскохозяйственной науки» статьи проходят предварительную проверку на соответствие формальным требованиям. На этом этапе редакция оставляет за собой право:

- принять статью к рассмотрению;
- вернуть статью автору (авторам) на доработку с просьбой устранить ошибки или добавить недостающие данные;
- вернуть статью автору (авторам) без рассмотрения, оформленную не по требованиям журнала;
- отклонить статью из-за несоответствия ее целям журнала, отсутствия оригинальности, малой научной ценности.

Переписка с авторами рукописи ведется через контактное лицо, указанное в рукописи.

Все научные статьи, поступившие в редакцию журнала «Сибирский вестник сельскохозяйственной науки», проходят обязательное двухстороннее «слепое» рецензирование (double-blind – автор и рецензент не знают друг о друге). Рукописи направляются по профилю научного исследования на рецензию членам редакционной коллегии.

В спорных случаях редактор может привлечь к процессу рецензирования нескольких специалистов, а также главного редактора. При положительном заключении рецензента статья передается редактору для подготовки к печати.

При принятии решения о доработке статьи замечания и комментарии рецензента передаются автору. Автору дается 2 месяца на устранения замечаний. Если в течение этого срока автор не уведомил редакцию о планируемых действиях, статья снимается с очереди публикации.

При принятии решения об отказе в публикации статьи автору отправляется соответствующее решение редакции.

Ответственному (контактному) автору принятой к публикации статьи направляется финальная версия верстки, которую он обязан проверить.

ПОРЯДОК ПЕРЕСМОТРА РЕШЕНИЙ РЕДАКТОРА/РЕЦЕНЗЕНТА

Если автор не согласен с заключением рецензента и/или редактора или отдельными замечаниями, он может оспорить принятое решение. Для этого автору необходимо:

- исправить рукопись статьи согласно обоснованным комментариям рецензентов и редакторов;
- ясно изложить свою позицию по рассматриваемому вопросу.

Редакторы содействуют повторной подаче рукописей, которые потенциально могли бы быть приняты, однако были отклонены из-за необходимости внесения существенных изменений или сбора дополнительных данных, и готовы подробно объяснить, что требуется исправить в рукописи для того, чтобы она была принята к публикации.

ДЕЙСТВИЯ РЕДАКЦИИ В СЛУЧАЕ ОБНАРУЖЕНИЯ ПЛАГИАТА, ФАБРИКАЦИИ ИЛИ ФАЛЬСИФИКАЦИИ ДАННЫХ

Редакция научного журнала «Сибирский вестник сельскохозяйственной науки» в своей работе руководствуется традиционными этическими принципами научной периодики и сводом принципов «Кодекса этики научных публикаций», разработанным и утвержденным Комитетом по этике научных публикаций, требуя соблюдения этих правил от всех участников издательского процесса.

ИСПРАВЛЕНИЕ ОШИБОК И ОТЗЫВ СТАТЬИ

В случае обнаружения в тексте статьи ошибок, влияющих на ее восприятие, но не искажающих изложенные результаты исследования, они могут быть исправлены путем замены pdf-файла статьи. В случае обнаружения в тексте статьи ошибок, искажающих результаты исследования, либо в случае плагиата, обнаружения недобросовестного поведения автора (авторов), связанного с фальсификацией и/или фабрикацией данных, статья может быть отозвана. Инициатором отзыва статьи может быть редакция, автор, организация, частное лицо. Отозванная статья помечается знаком «Статья отозвана», на странице статьи размещается информация о причине отзыва статьи. Информация об отзыве статьи направляется в базы данных, в которых индексируется журнал.

УВАЖАЕМЫЕ ПОДПИСЧИКИ!

Подписку на журнал «Сибирский вестник сельскохозяйственной науки»
(как на годовой комплект, так и на отдельные номера)
можно оформить одним из следующих способов:

– на сайте Почта России. Зайти в раздел «Онлайн-сервисы», затем – «Подписаться на газету или журнал». Подписной индекс издания ПМ401;
– в агентстве подписки ГК «Урал-Пресс» по индексу 46808. Ссылка на издание http://ural-press.ru/catalog/97210/8656935/?sphrase_id=319094. В разделе контакты зайти по ссылке http://ural-press.ru/contact/, где можно выбрать филиал по месту жительства;
– в редакции журнала (телефон 7-383-348-37-62; e-mail: sibvestnik@sfsca.ru).

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