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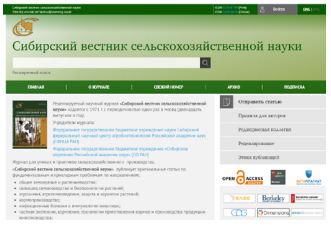

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СИБИРСКИЙ ВЕСТНИК СЕЛЬСКОХОЗЯЙСТВЕННОЙ НАУКИ

SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

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

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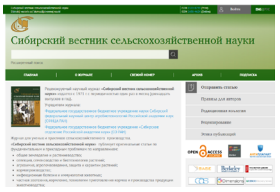

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НАШИ ЮБИЛЯРЫ

OUR JUBILJARS

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Фотосинтетическая активность листьев и продуктивность раннеспелого гибрида кукурузы Дорка в условиях Северного Нечерноземья

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Работа посвящена изучению фотосинтетической активности и последействия низкой положительной температуры на CO_2-газообмен листьев в связи с продуктивностью раннеспелого гибрида кукурузы Дорка в центральном агроклиматическом районе Республики Коми (61°40′ с. ш. 50°49′ в. д.). Опыты проводили в типичный по погодным условиям сезон вегетации на участке со среднеокультуренной подзолистой почвой. Семена высевали в середине июня ручным способом в гряды. К уборке (I декада сентября) сырая масса надземной части растений составляла около 690 г. Основная часть биомассы (около 80%) была представлена стеблями с влагалищами листьев, початки отсутствовали. Средняя за три года урожайность зеленой массы составила 355 ц/га. Установлено, что независимо от возраста растений фотосинтетическая активность листьев возрастает с увеличением освещенности. При интенсивности фотосинтетически активной радиации, близкой к полной солнечной, и температуре 20 °С скорость нетто-фотосинтеза листьев верхнего яруса молодых растений кукурузы составляла около 14 мкмоль CO_2/м^{2}с, у зрелых растений этот показатель не превышал 8 мкмоль CO_2/м^{2}с. Выдерживание молодых растений (фаза 4–5 листьев) в холодной камере при 6 ºС в течение 7 ч слабо влияло на фотосинтез, но снижало дыхание листьев. Увеличение экспозиции до 12 ч привело к развитию признаков окислительного стресса и подавлению ассимиляции на 40%. Полученные данные дополняют эколого-биологическую характеристику изучаемого гибрида кукурузы. Результаты исследований показывают, что сравнительно низкая ассимиляционная активность и чувствительность CO_2-газообмена к снижению температуры ограничивают реализацию фотосинтетического потенциала продуктивности гибрида кукурузы Дорка в холодном климате.

Ключевые слова: CO_2-газообмен, температура, окислительный стресс, продуктивность, кукуруза, холодный климат

Photosynthetic activity of the leaves and productivity of the early-maturing corn hybrid Dorka in the conditions of the northern Non-Chernozem Zone

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The paper is devoted to the study of photosynthetic activity and aftereffect of low positive temperature on CO_2-gas exchange of the leaves in connection with the productivity of early maturing corn hybrid Dorka in the central agroclimatic region of the Komi Republic (61°40′N, 50°49′E). The experiments were conducted in a typical growing season in a plot with a medium-cultivated podzolic soil. The seeds were sown in mid-June by hand in the ridges. By harvesting (I ten-day period of Sep-

tember), the raw weight of the above-ground part of the plants was about 690 g. The main part of the biomass (about 80%) was represented by stems with leaf sheaths, the cobs were absent. The three-year average yield of the green mass amounted to 355 c/ha. It was found that regardless of the age of the plants photosynthetic activity of the leaves increases with increasing illumination. At the intensity of photosynthetically active radiation close to full solar radiation and temperature 20 °C, the net photosynthesis rate of the upper tier leaves of young corn plants was about 14 μmol CO_2/m^{2}s, in mature plants this index did not exceed 8 μmol CO_2/m^{2}s. Keeping young plants (phase of 4–5 leaves) in a cold chamber at 6 ºC for 7 h had little effect on photosynthesis, but reduced leaf respiration. Increasing the exposure to 12 h resulted in the development of the signs of oxidative stress and suppression of assimilation by 40%. The obtained data complete the ecological and biological characterization of the studied corn hybrid. The results of the research show that relatively low assimilatory activity and sensitivity of CO_2 gas exchange to temperature decrease restrain the realization of photosynthetic productivity potential of corn hybrid Dorka in cold climate.

Keywords: CO_2-gas exchange, temperature, oxidative stress, productivity, corn, cold climate

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INTRODUCTION

Corn is a valuable fodder and grain crop of subtropical origin. As it belongs to the group of heat-loving plants, the optimum temperature for its growth and development is 25–30 °C. Corn is characterized by C4-type carbon metabolism and two photosynthetic cycles with carboxylating enzymes localized in different leaf cells. The presence of the so-called CO_2 concentrating mechanism, suppression of ribulosebiphosphate carboxylase oxygenase activity and, consequently, photorespiration, shift of the temperature optimum of photosynthesis to the zone of higher temperatures ensure efficient water use by plants and realization of the productivity potential of this crop in regions with warm and arid climate. According to researchers, the value of net photosynthesis of corn leaves was 40 μmol CO_2/m^{2}s in northern Italy[1], in semi-arid conditions in China it was from 22 to 26 μmol CO_2/m^{2}s [1], and was 1.5–2.0 times higher when irrigated [2].

The noticeable warming of climate in the Northern Hemisphere observed in recent decades, the emergence of early maturing and cold-resistant varieties and hybrids, the use of modern cultivation technologies (seed encapsulation and dredging, planting in beds, etc.)

[1] *Vitale L., Tommasi P.D., Arena C., Fierro A., Virzo De Santo A., Magliulo V.* Effects of water stress on gas exchange of field grown *Zea mays* L. in Southern Italy: an analysis at canopy and leaf level // Acta Physiologiae Plantarum, 2007, vol. 29, N 4, pp. 317–326.

create conditions for growing corn for green mass in Siberia[2] [3] and the northern part of the Non-Chernozem region [4, 5].

Three-year data on biomass accumulation of early-maturing relatively cold- and drought-resistant three-line hybrid corn Dorka (included in the State Register for the East Siberian region for silage cultivation) indicate the variation of yield of this crop depending on the weather conditions of the growing season when grown in the central agroclimatic region of the Komi Republic [5].

In 2018, with the sum of daily average active temperatures above 10 °C ($DAAT_{10}$) of about 1500 °C for May-August and hydrothermal coefficient (HTC) equal 2, the green matter yield of hybrid Dorka was about 570 kg/ha. A decrease in $DAAT_{10}$ by almost 30% and moderate rainfall (HTC = 2.3) in 2020 resulted in a proportional decrease in green matter yield. In 2019, the daily average temperatures of the vegetation period were 2–3 °C below the mean annual value, and precipitation was 1.5–2.0 times higher than usual. This resulted in a 6-fold decrease in green biomass accumulation compared to 2018. As a result, in 2018–2020, the yield of green mass amounted to 565, 87 and 415 c/ha, respectively [5]. The average yield for the three years was 355 c/ha, which is comparable to the average yields for the Russian Federation[3]. Corn biomass is characterized by a relatively high nutritive value, contains carotenoids, sugars, amino acids, mineral elements, not inferior to these indicators of single- and perennial cereal grasses cultivated in the Komi Republic [5, 6].

Photosynthesis is the basis of the production process, but systematic studies of photosynthetic activity of corn in the north of the Non-Chernozem region have not been practically conducted. Their relevance is due to the need to study the physiological basis of corn yield under cold climate conditions, to assess the stability of the varieties and hybrids, their suitability for use in northern crop production.

In this connection, the purpose of our work was to study photosynthetic activity and the aftereffect of reduced temperature on CO_2-gas exchange of the leaves of corn hybrid Dorka under cultivation in the conditions of the central agroclimatic region of the Komi Republic.

MATERIAL AND METHODS

The experiments were conducted in 2020 in the vicinity of Syktyvkar (middle taiga zone). The soil of the experimental plot was podzolic, medium degree of cultivation, humus content of 4.5%, pH_{water} = 6.8. The seeds were sown in the middle of June on a plot of 100 m2 by hand in the ridges. The distance between the rows was 0.7 m, seeding rate 6–7 seeds/rm. The sprouts appeared 2 weeks after the sowing. Appearance of panicles was noted 45–50 days after full sprouting, cobs were absent. The plants were harvested in the first ten days of September, 70 days after sprouting.

The growing season 2020 was moderately warm and humid, weather conditions did not differ much from the mean annual value. July was the warmest and sunniest, in June and August the air temperature was significantly lower (see Table 1). It should be noted that the research region is characterized by significant daily temperature variations. During the period of active vegetation, average night temperatures are usually 5–10 °C lower than day temperatures.

To assess biomass accumulation during the harvesting period, 15 typical plants were selected, each of which was separated by organs and weighed. Water content in the biomass was determined by drying a part of the samples at 105 ºC. Photosynthetic activity of the leaves was studied in the phases of 4–5 and 9–10 leaves, as well as after panicle emergence. The rate of CO_2-gas exchange was measured on the middle part of the completed growth of the upper tier leaves in 5–6-fold biological repetition in an open system using an infrared gas analyzer

[2] *Avetisyan A.T., Danilov V.P., Mudrova V.E.* Productivity of maize and basic cultivation techniques under conditions of Krasnoyarsk forest-steppe // Siberian Herald of Agricultural Science, 2017, vol. 47, N 6, pp. 57–65.

[3] Yield of corn for fodder - total (weight of green mass) in 2016, c/ha (according to Rosstat data) // AgroVestnik: Internet portal. URL: https://agrovesti.net/lib/industries/forage/urozhajnost-kukuruzy-na-korm-vsego-ves-zelenoj-massy-v- 2016-godu-ts-ga.html (date of reference: 28.12.2024).

Табл. 1. Погодные условия вегетационного сезона 2020 г.

Table 1. Weather conditions of the growing season 2020

Month	Long-run annual average		2020	
	Air temperature, °C	Precipitation, mm	Air temperature, °C	Precipitation, mm
June	14,8	74	13,8	41
July	17,5	73	20,0	59
August	13,7	75	13,7	71
September	8,1	57	10,0	96

Note. Compiled on the basis of the data from the Syktyvkar hydrometeorological station (synoptic index 23804), presented on the site "Weather Schedule" (https://rp5.ru).

(LI-7000, USA) at a temperature of 20 ºC and photosynthetically active radiation (PAR) flux density from 0 to 1600 μmol quanta/m^2s. A system of red (maximum at 634 nm) and blue (maximum at 447 nm) LEDs (in a ratio of 11 : 1) was used as a light source. The leaves were detached from the plant and immediately placed in a leaf chamber to measure CO_2 uptake in the light and CO_2 release in the dark. Biological repetition was 6–7-fold, and a freshly harvested leaf was used for each repetition.

To reveal the effect of temperature reduction during night hours, whole plants in the phase of 4–5 leaves were kept in a dark chamber at 6 ºC for 7 and 12 h. Immediately after exposure, the rate of CO_2-gas exchange was measured at 0, 700 and 1600 μmol quanta/m^2s and at a temperature of 20 ºC. The level of plant stress after cold exposure was assessed by changes in the content of lipid peroxidation products reacting with thiobarbituric acid, accumulation of hydrogen peroxide and activity of superoxide dismutase (SOD), which is a key enzyme of antioxidant defense[4].

Statistical processing of the data was performed using Statistica 10 program (StatSoft Inc., USA). All calculations were performed at a given significance level of $p \leq 0.05$. The tables and figures show arithmetic mean values and their standard errors.

RESULTS AND DISCUSSION

By harvesting the height of the plants averaged 160 cm, the raw weight per plant reached 800 g (see Table 2). The main part of the biomass was represented by stems with leaf sheaths. The contribution of leaf laminae to the total biomass of the plant was 4 times less than that of stems, and of roots accounted for slightly more than 10%. Cobs were absent. Water content in plant organs varied within 81–89% of raw biomass. The highest water content was characterized by stems with leaf sheaths, which accounted for almost 80% of the aboveground mass.

Determination of CO_2-gas exchange showed that regardless of plant age, photosynthetic activity of leaves increased with increasing illumination (see fig. 1). The highest rate of visible CO_2 absorption was registered at PAR intensity of 1600 μmol quanta/m^2s. The value of this indicator in young plants (phase of 4–5 leaves) was about 14 μmol CO_2/m^2s, in mature, formed plants it was 40% less. Decrease in the ability of the upper tier leaves to use high-intensity light, apparently, is caused not only by the age of plants, but also by adaptation of photosynthetic apparatus to cenosis thickening. The rate of dark

Табл. 2. Сырая биомасса и содержание воды в растениях в период уборки урожая

Table 2. Raw biomass and water content of the plants during the harvesting period

Plant organs and parts	Raw biomass, g/plant	Water content, % of wet weight
Laminas	129 ± 8	81
Stalk + leaf sheaths	547 ± 68	89
Panicle	16 ± 2	81
Roots	105 ± 11	82
The whole plant	796 ± 83	86

[4]*Radyukina N.L., Ivanov Yu.V., Shevyakova N.I.* Methods for assessing the content of reactive oxygen species, low-molecular-weight antioxidants and the activity of major antioxidant enzymes // Molecular-genetic and biochemical methods in modern plant biology, Moscow, 2012, pp. 347–364.

CO_2 release reached about 1.5 μmol/m^{2}s, which is on average 10% of the maximum rate of visible photosynthesis.

The results of model experiments with exposure of young plants (phase of 4–5 leaves) at 6 ºC showed that cooling had a stronger effect on CO_2 release in the dark than on the rate of CO_2 uptake in the light (see fig. 2). Already after 7 hours of exposure, the respiration rate measured at 20 ºC was 2.5 times lower than the control (parameters of control plants: respiration rate – 1.5 μmol CO_2/m^2; photosynthesis rate – 8 and 14 μmol CO_2/m^2 at 700 and 1600 μmol quanta/m2s illumination, respectively). As it is known, inhibition of respiration at decreasing temperature leads to a reduction in the formation of energy and metabolites necessary for plant growth. Changes in photosynthetic rate after 7-h chilling were weakly pronounced, whereas 12-h exposure suppressed assimilation almost 2-fold compared to the control.

After 12-hour cold exposure of plants, the amount of lipoperoxidation products (TBA-RP) in the leaves increased by 15%, the concentration of hydrogen peroxide almost doubled (see Table 3). The lowered temperature led to a 1.6-fold increase in the SOD activity level.

Corn genotypes differ in cold tolerance and ability to acclimatize to suboptimal temperatures[5, 6] [7–11]. According to J. Leipner

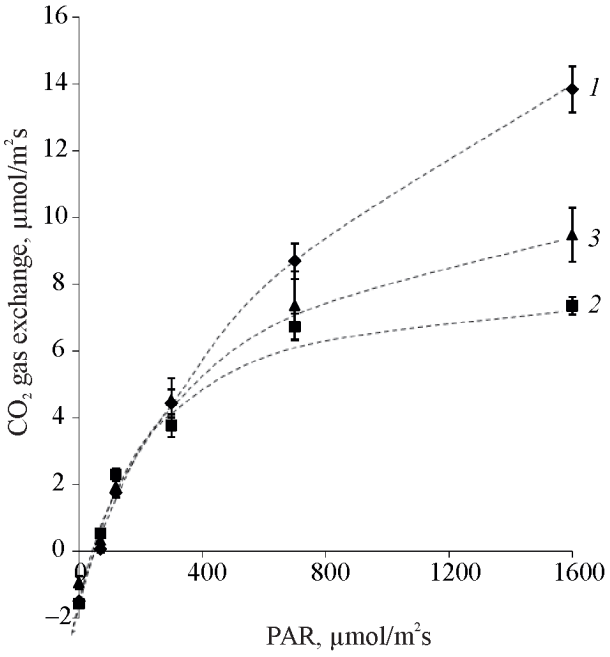

Рис. 1. Зависимость CO_2-газообмена листьев верхнего яруса от интенсивности ФАР:
1 – фаза 4–5 листьев; *2* – фаза 9–10 листьев; *3* – появление метелки

Fig. 1. Dependence of CO_2-gas exchange of the upper tier leaves on PAR intensity:
1 – the phase of 4–5 leaves; *2* – the phase of 9–10 leaves; *3* – the phase of panicle appearance

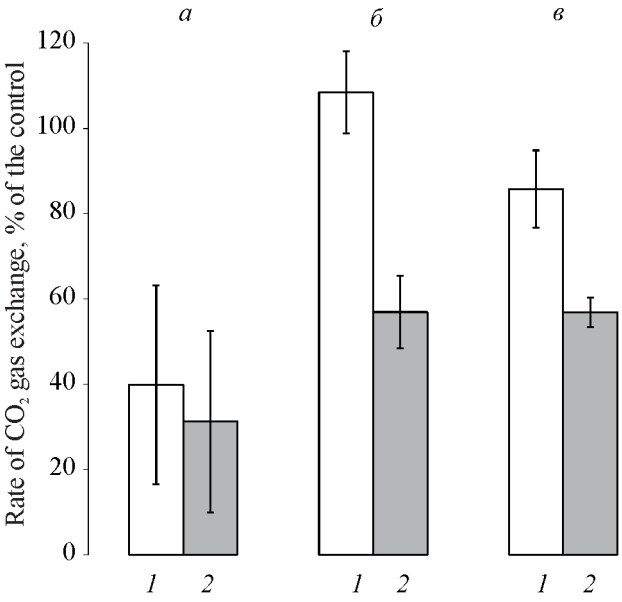

Рис. 2. Последействие охлаждения растений кукурузы на CO_2-газообмен листьев:
1, 2 – экспозиция 7 и 12 ч соответственно; *а* – скорость выделения CO_2 в темноте; *б*, *в* – скорость видимого поглощения CO_2 при интенсивности ФАР 700
и 1600 мкмоль квантов/м^{2}с соответственно

Fig. 2. Effects of corn plant chilling on the CO_2-gas exchange of the leaves:
1, 2 – the exposure for 7 and 12 h accordingly; *a* – the rate of CO_2 release in the dark; *б*, *в* – visible CO_2 absorption rate at PAR intensities of 700 and 1600 μmol quanta/m^{2}s, respectively

[5]*Koscielniak J., Janowiak F., Kurczyeh Z.* Increase in photosynthesis of maize hybrids (*Zea mays* L.) at suboptimal temperature (15 ºC) by selection of parental lines on the basis of chlorophyll a fluorescence measurements // Photosynthetica, 2005, vol. 43, pp. 125–134.

[6]*Sobkowiak A., Jonczyk M., Adamczyk J., Szczepanik J., Solecka D., Kuciara I., Hetmanczyk K., Trzcinska-Danielewicz J., Grzybowski M., Skoneczny M., Fronk J., Sowiński P.* Molecular foundations of chilling-tolerance of modern maize // BMC Genomics, 2016, vol. 17, Art. 125.

et al.[7], corn plants grown at suboptimal temperature (15 °C) reacted less to low-temperature effects than those cultivated at 25 °C, which indicates the ability of corn to acclimatize.

Corn cold resistance is a complex trait provided by many physiological and molecular mechanisms [8–15]. The data available in the literature indicate the negative effect of low temperature on the growth and development of heat-loving plants, including corn. Cold stress increases the generation of reactive oxygen species, leads to activation of membrane lipid peroxidation processes, disruption of cellular homeostasis, and suppression of photosynthesis.

In our experiments, a significant decrease in assimilatory activity of the leaves of corn hybrid Dorka was observed after 12-h exposure at 6°C, whereas respiration was suppressed after 7 h of cold exposure. The content of hydrogen peroxide in the leaves of experimental plants increased by 45%, while the amount of lipoperoxidation products increased to a lesser extent – only by 15%. Apparently, this was promoted by the activation of SOD, an antioxidant defense enzyme that performs the dismutation reaction of the aggressive superoxide radical ($O_2^{\bullet-}$) to O_2 and the more stable form of activated oxygen (H_2O_2). Judging from the response of CO_2 gas exchange and pro-/antioxidant metabolism of the leaves, it can be assumed that young plants of the corn hybrid Dorka are sensitive to a temporary decrease in temperature under natural conditions, especially during night hours. The obtained data complete the ecological and biological characterization of the studied hybrid.

Табл. 3. Последействие 12-часового охлаждения растений кукурузы на про-/антиоксидантный метаболизм листьев

Table 3. Effects of 12-h chilling of corn plants on pro-/antioxidant metabolism of the leaves

Option	TBA-RP, nM/g dry weight	H_2O_2, μM/g dry weight	SOD, units/mg of protein
Control	220,0 ± 6,1[a]	54,0 ± 3,3[a]	9,7 ± 0,2[a]
Experiment (6 °C, 12 h)	261,2 ± 5,2[b]	98,5 ± 0,9[b]	15,7 ± 0,6[b]

Note. Different letters indicate significant differences.

Current trends of agricultural production expansion to the northern regions are based on the consideration of the factors caused by global climate warming [16]. Climate warming observed in recent decades in the central and southern regions of the Komi Republic has led to an increase in the sum of active temperatures above 10 °C from 1400 to 1560 °C and an increase in the duration of the growing season with average daily temperatures above 10 °C from 88 to 95 days [4]. Warming and increase in the duration of the growing season create conditions for expanding the base of northern fodder production by growing cold-resistant early maturing varieties of corn for green mass.

CONCLUSIONS

1. The rate of net absorption of CO_2 in the leaves of young plants of the corn hybrid Dorka in the conditions of the central agroclimatic region of the Komi Republic was about 14 μmol/m^{2}s, in mature plants it did not exceed 8 μmol/m^{2}s, which is 2–3 times lower than the values typical for corn in more southern regions.

2. The effect of 12-hour exposure of the plants in the phase of 4–5 leaves at 6 °C was manifested in the development of oxidative stress and suppression of CO_2 gas exchange.

3. Despite the temperature limitation of photosynthetic potential, cold-resistant early maturing corn hybrid Dorka under cold climate conditions is able to accumulate green biomass comparable to average yields in the Russian Federation.

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Влияние препаратов биологического происхождения на урожайность семян льна масличного в условиях Кировской области

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Представлены результаты изучения производства экологически чистых масел из семян и плодов сельскохозяйственных культур по технологиям, рационально сочетающим химические и биологические направления защиты растений. Лен масличный является ценным источником полиненасыщенных жиров, содержит значительное количество белка, пищевых волокон, относится к продуктам функциональной направленности. В условиях Кировской области проведены исследования влияния препаратов биологического происхождения на урожайность семян льна масличного. В полевом опыте изучено применение препаратов гумат +7 «Здоровый урожай» и псевдобактерин-2Ж. Исследования проводили на льне масличном сорта Северный, обрабатывая его семена, вегетирующие растения в фазу «елочка», а также сочетая эти два способа обработки. Применяли препараты в чистом виде и использовали их комплексное сочетание. Установлено, что препараты биологического происхождения достоверно повышают полевую всхожесть на 2,4% в среднем по вариантам опытов. Максимальное превышение контроля отмечено в вариантах с обработкой семян гуматом +7 «Здоровый урожай» (85,6%), а также с комплексом препаратов биологического происхождения (гумат +7 «Здоровый урожай» + псевдобактерин-2Ж) (86,3%), двукратное использование комплекса приводит к увеличению сохранности на 7,4%. Наибольший эффект применения на урожайность семян отмечен при проведении изучаемыми препаратами предпосевной обработки и использовании их двукратно. Максимальный уровень урожайности отмечен при двукратном использовании комплекса препаратов биологического происхождения (1,43 т/га). Установлено достоверное положительное влияние двукратного применения комплекса препаратов биологического происхождения на число коробочек на одном растении (12,3 шт.). Число полноценных семян в коробочке увеличивает обработка семян гуматом +7 «Здоровый урожай», а также двукратное применение изучаемых препаратов и их комплекса (в среднем на 16%). Не установлено достоверного влияния препаратов биологического происхождения на массу 1000 семян. Для выращивания масличного льна по технологии, предусматривающей увеличение степени биологизации, можно рекомендовать использование комплекса гумат +7 «Здоровый урожай» + псевдобактерин-2Ж для предпосевной обработки семян и последующей обработки растений в фазу «елочка».

Ключевые слова: лен масличный, биологизация, продуктивность, растительные жиры, пестицидная нагрузка

The effect of preparations of biological origin on the yield of oil flax seeds in the conditions of the Kirov region

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The results of studying the production of ecologically pure oils from seeds and fruits of agricultural crops using the technologies rationally combining chemical and biological directions of plant protection are presented. Oil flax is a valuable source of polyunsaturated fats, contains a significant amount of protein, dietary fiber, belongs to the products of functional orientation. The research on the effect of preparations of biological origin on the yield of oil flax seeds was carried out in the Kirov region. The application of the preparations humate +7 “Healthy Harvest” and pseudobacterin-2L was studied in the field experiment. The studies were conducted on oil flax of the Severny variety, treating its seeds, vegetative plants in the “herringbone” phase, as well as combining these two methods of treatment.

The preparations were applied in pure form and their complex combination was used. It was found that preparations of biological origin significantly increase field germination by 2.4% on average in the variants of the experiment. Maximum excess of control was observed in the variants with seed treatment with humate +7 "Healthy Harvest" (85.6%), as well as with a complex of preparations of biological origin (humate +7 "Healthy Harvest" + pseudobacterin-2L) (86.3%), double use of the complex leads to an increase in viability by 7.4%. The greatest effect of application on seed yield was observed when the studied preparations were used for pre-sowing treatment and applied twice. The maximum level of yield was observed with twofold use of a complex of preparations of biological origin (1.43 t/ha). A reliable positive effect of double application of the complex of preparations of biological origin on the number of bolls on one plant (12.3 pcs.) was established. Treatment of seeds with humate +7 "Healthy Harvest" as well as double application of the studied preparations and their complex (on average by 16%) increases the number of full-grown seeds in a boll. No reliable effect of biological origin preparations on 1000 seed weight was found. The use of complex humate +7 "Healthy Harvest" + pseudobacterin-2L for pre-sowing seed treatment and subsequent treatment of plants in the "herringbone" phase can be recommended to grow oil flax according to the technology that provides for an increase in the degree of biologization,

Keywords: oil flax, biologization, productivity, vegetable fats, pesticide load

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INTRODUCTION

Due to the increasing number of people living on the planet, the needs of the population and the processing industry to intensify and expand the range of work of the industry involved in the production of oils and fats are increasing [1]. Vegetable fats are of great importance both directly in human nutrition and for the production of various products (food or technical).

Our country is characterized by very diverse soil and climatic conditions. In this regard, the list of oilseed crops capable of producing sustainable yields of seeds of a given quality differs by regions of the Russian Federation [2]. According to the Federal State Statistics Service, 18,728.0 thousand hectares of crops that are a source of vegetable oil were sown in our country in 2022, of which a significant share (6133.8 thousand hectares) accounts for the Volga Federal District[1].

Among oilseed crops in our country the most widespread are soybean, sunflower, rape (spring and winter) [3], as well as oilseed flax. In the Kirov Oblast, significant areas are allocated to spring rape. However, there is a tendency to increase the area of oil flax. In 2022 it was sown on the area of 2.9 thousand hectares, which is 73% more than in 2021.

The main part of the crops for 2023 in the Kirov region is occupied by the varieties VNIIMK 620, Severny (9.1–9.6% each) and Lirina (13.0%), as well as a high share of unsorted flax (more than 60%). In 2024, the crops increased to almost 7.0 thousand hectares, and the share of unsorted flax decreased to 37%, while the crops of the Severny variety increased to 14.4% and Lirina to 37.4% (with an average yield level of 10–16 c/ha depending on the conditions of the year).

[1]URL: https://rosstat.gov.ru/

Oil flax seeds are a source of fat and protein. Flax oil belongs to the category of drying oils. Due to its ability to form a thin strong film in the air, it is widely used in various industries: pharmaceutical, aviation, printing, etc. [4]. [4]. Fatty acidic composition of flax oil allows us to refer it to the food products of functional orientation. The lack of essential fatty acids affects the cardiovascular system, functioning of biological membranes, fat metabolism processes, etc.[2]

High content of unsaturated fatty acids in the oil, when used for food purposes, helps to reduce the risk of alimentary-dependent diseases.

Flax seed protein is characterized by a significant list of essential amino acids, its composition is close to soy protein. Its introduction into the diet will help to achieve a balanced diet by filling the deficiency of amino acids [5–8].

The document "On the Strategy of Scientific and Technological Development of the Russian Federation"[3] identifies as a priority the need "... to ensure food security...", which can be realized by obtaining environmentally friendly products.

Currently, the level of pesticide load in agriculture remains quite high [9, 10]. Nevertheless, the trend of increasing the degree of biologization of the industry remains significant [11, 12]. An actual direction of research is the search for a balance between the use of chemical plant protection products and the use of biopesticides [13, 14].

The search for analogs of chemical preparations that have a protective effect on plants from abiotic and biotic stressors corresponds to the priority directions of agricultural research. The study of the effectiveness of the integrated plant protection components that increase the degree of its biologization is an important aspect of the introduction of new format farming elements into the practice of agricultural production.

The purpose of research was to study the effectiveness of the effect of preparations of biological origin on the yield of oil flax seeds and their quality.

Objectives of the research were as follows: analyzing the influence of the use of preparations of biological origin on the formation of the density of oil flax crops; studying the level of yield formed under the influence of the preparations of biological origin; determining their influence on the elements of the productivity structure.

MATERIAL AND METHODS

The object of research were oil flax plants and seeds of the Severny variety, a reproduction of sown elite seeds. It is bred in the Federal Scientific Center "V.S. Pustovoit All-Russian Research Institute of Oil crops". Pedigree: created by repeated individual selection from a hybrid population from crossing a line from the VIR collection sample (Morocco K-1994) to breeding line No. 157. The variety was included in the State Register in 1994 and allowed for cultivation in the Volga-Vyatka region. Plants of this variety are characterized by uniform flowering and maturation, and the growing season in the Kirov region is characterized by an average duration of 91–95 days. Depending on the meteorological conditions, the height of the Severny flax can vary between 50–70 cm. Its flattened stalks are suitable for mechanized harvesting.

The effectiveness of two preparations of biological origin was studied on oil flax: humate +7 "Healthy Harvest" and pseudobacterin-2L (both produced in the Kirov branch of the Rosselkhozcenter). In the conditions of the Kirov region (north-east of the Non-Chernozem zone), which is part of the fourth agroecological (Volgo- Vyatka) region, these products were studied on cereals, leguminous crops and perennial grasses. No studies have been conducted on oil flax. Both products are approved for use in our country.

The basis for production of humate +7 "Healthy Harvest" is natural raw materials of organic origin (peat or coal), from which humic substances are extracted. The product is additionally enriched with trace elements in chelate form and can be used both for pre-sowing

[2]*Zaporozhskaya L.I., Gammel I.V.* Characterization and biological role of essential polyunsaturated fatty acids // Medical Council, 2012, N 12, pp. 134–137.

[3]Strategy of Scientific and Technological Development of the Russian Federation: approved by the Decree of the President of the Russian Federation of February 28, 2024, N 145, 2024 // URL: http://publication.pravo.gov.ru/document/0001202402280003?index=2 (date of reference 29.02.2024).

treatment of seed material and for application to vegetative plants. Pseudobacterin-2L is a product of biological synthesis based on the bacterium *Pseudomonas aureofaciens BS* 1393, which has a positive effect on the phytosanitary condition of plants by suppressing the development of pathogenic microorganisms. In addition, the preparation stimulates the growth of the root system of plants.

Field experiments to study the effect of the preparations of biological origin were laid in 2022–2023 on the extrafield of Agrotechnopark of the Vyatka State Agrotechnological University, sod-podzolic soils of which were characterized as light- and medium-loamy in granulometric composition. The content of mobile forms of phosphorus (P_2O_5) was very high (288 mg/kg according to Kirsanov), exchangeable potassium (K_2O) was high (178 mg/kg). The content of organic matter was low at 1.34%, the soils were very acidic with pH 4.1[4].

According to the results of the agrochemical survey, acidic soils occupy 3/4 of arable land in the Kirov region. In general, soil conditions meet the requirements of oil flax, the limiting factor in obtaining high yields is the soil acidity (optimally pH 5–6 is required).

The forecrop in both years was spring barley. Tillage in the spring period is aimed at weed control and creation of granular and finely compacted layer. It consisted of harrowing at physical ripeness of the soil (harrow cart SG-15), two-fold complete cultivation (cultivator KBM-4,2) and final combined cultivation (cultivator KOMBI 3). The rate of the applied fertilizer was $N_{30}P_{30}K_{30}$ kg a.i./ha with the spreader RMU 950 "Farmer". Sowing was carried out by a row method (row spacing of 15 cm) with a seed drill SSFK-7M in the middle of the second ten-day period of May with a seeding rate of 8 million germinated seeds/ha to a depth of 3–4 cm. Placement was randomized, fourfold repetition, the accounting area of plots was 4.5 m^2. Harvesting of the plots was carried out by combine harvester Terrion SR 2010. Laying of the experiment, observations, research and evaluation of the results were carried out according to standard and generally accepted methods (see Table 1)[5, 6].

When treating the seeds, the preparations dosage of 1 l/t was used, when treating vegetative plants – 1 l/ha (pseudobacterin-2L) and 0.5 l/ha (humate +7 "Healthy Harvest").

RESULTS AND DISCUSSION

Unfavorable conditions during the sprouting period can have a significant impact on crop yields. In the conditions of the Kirov region optimal (for sowing and sprouting) soil and air temperatures are observed at the end of I and beginning of II ten-day period of May. In 2022, the beginning of the II ten-day period was characterized by an average air temperature of 14.5 °C. In 2023 at the same time there was cooler weather (11.5 °C), but it fully corresponded to the needs of oil flax to the temperature factor at the initial stage of development. Usually at this time there is a sufficient degree of soil moistening. The amount of precipitation practically did not differ from the usually observed norms, and it also did not become a limiting factor for seed germination. The Selyaninov Hydrothermal Coefficient of humidification (HTC) for the growing season 2022 was 2.3 (due to high precipitation in June–July – 117–130 mm), which characterizes it as overwatered, in 2023 it was quite humid – HTC 1.9 (high precipitation was observed in July – 177 mm). Field germination of oil flax seeds of the Severny variety in all the variants was, as a rule, more than 80% (see fig. 1).

In the control, the field germination of the seeds averaged 82.2% over the years of research.

[4]The data are presented according to the results of analyses of the accredited laboratory of soil and agrochemicals analyses of FSBI SCAS "Kirovsky".

[5]*Dospekhov B.A.* Methods of field experiment: with the basics of statistical processing of research results. 5th edition, suppl. and revised. Moscow: Agropromizdat, 1985, 351 p.

[6]Methods of field experiments with oil crops / edited by V.M. Lukomets. Krasnodar, 2010, 327 p.

Табл. 1. Схема опыта
Table 1. Experiment scheme

Full name	Short name
1. Control – without treatment	1. C
2. Seed treatment with humate +7 “Healthy Harvest”	2. Hum (S)
3. Seed treatment with pseudobacterin-2L	3. Ps-2L (S)
4. Seed treatment with humate +7 “Healthy Harvest” + pseudobacterin-2L	4. Hum (S) + Ps-2L (S)
5. Treatment of plants in the “herringbone” phase with humate +7 “Healthy Harvest”	5. Hum (P)
6. Treatment of plants in the “herringbone” phase with pseudobacterin-2L	6. Ps-2L (P)
7. Treatment of plants in the “herringbone” phase with humate +7 “Healthy Harvest” + pseudobacterin-2L	7. Hum (P) + Ps-2L (P)
8. Double treatment (seeds and plants in the “herringbone” phase) with humate +7 “Healthy Harvest”	8. Hum (S) + Hum (P)
9. Double treatment (seeds and plants in the “herringbone” phase) with pseudobacterin-2L	9. Ps-2L (S) + Ps-2L (P)
10. Double treatment (seeds and plants in the “herringbone” phase) with humate +7 “Healthy Harvest” + pseudobacterin-2L	10. Hum + Ps-2L (S) + Ps-2L (P)

The lower value compared to the control was observed in the variants with no seed pre-sowing treatment (variants 4–6) and ranged from 77.4 to 80.8%. The coefficient of variation by years of the indicator characterizing the presence of favorable conditions for the development of plants from the seed and for the emergence of seedlings in field conditions ranged from 11.2 to 14.3 depending on the variants of the experiment. No significant deviations in the coefficient of variation between varieties were observed.

The meteorological conditions of the growing season affect not only the amount of yield, but also the safety of plants for harvesting (plant survival rate). During the period from the emergence of sprouts to the onset of the “herringbone” phase, meteorological conditions 2023 slightly differed from the average annual values. The observed air temperatures during this period ranged from 16 to 20°C on average for 1 day, and the amount of precipitation was small, but not affecting the period of sprouting - “herringbone”. In 2022, during the similar period of development of young flax plants, air temperatures were 30–70% lower than the mean annual data. Night temperatures during this period ranged from 0 to 7°C, while daytime temperatures ranged from 5 to 13°C. Low temperatures were accompanied by precipitation in the form of rain. The development of flax plants in 2022 was slower compared to the following year.

The period of rapid growth, observed in flax from the end of the “herringbone” phase to budding, occupied 30–33 days during the study period. Temperature characteristics of June 2022 and 2023 were close to the mean annual. A distinctive feature of this period was the amount of precipitation, which in 2022 exceeded the norm by 48%, and July 2023 could be characterized as dry. Plant development was slower at this time, but rainfall at the end of the period of rapid growth had a favorable effect on plant growth.

The transition from budding to flowering averaged 8 days in 2022 and 7 days in 2023. Precipitation was absent during most of the period, and air temperatures were at or slightly below the long-term average (18–20°C) in 2023 (14–16°C) in 2022.

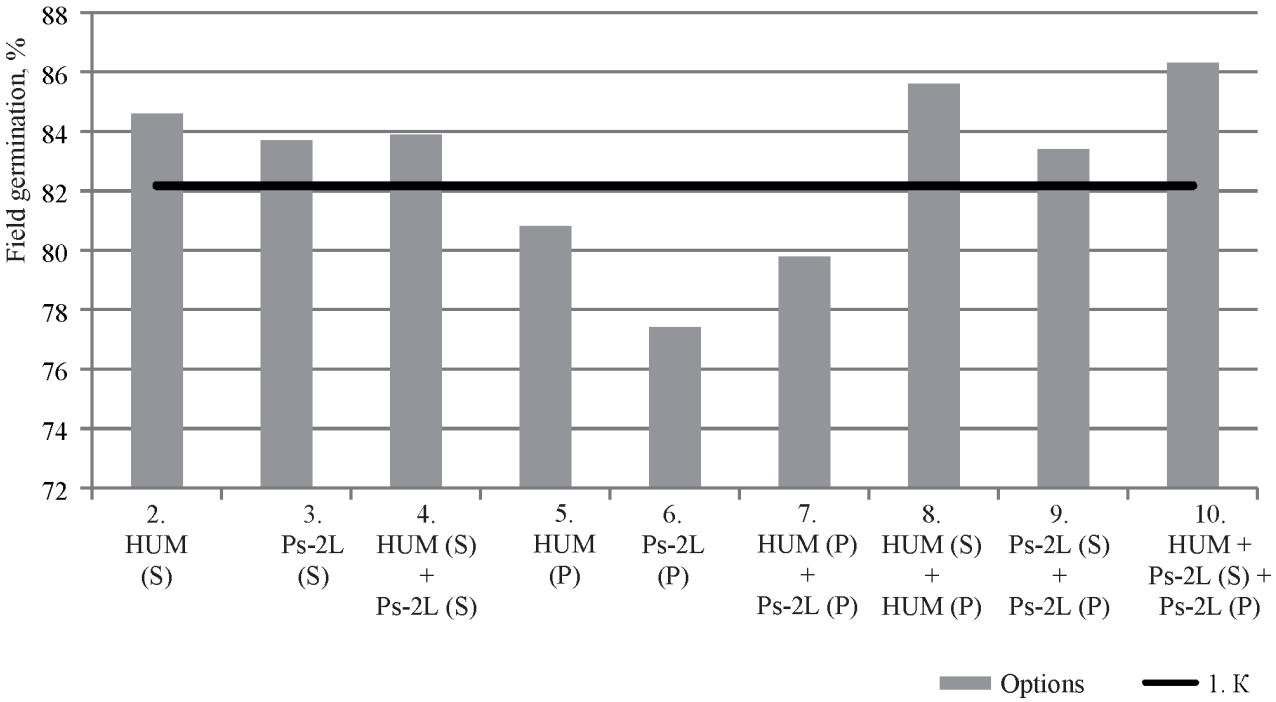

Рис. 1. Полевая всхожесть семян масличного льна (в среднем за 2022–2023 гг.)
Fig. 1. Field germination of oil flax seeds (average for 2022–2023)

During the period from flowering to ripening, the weather was warm enough for the north-east of the Non-Chernozem zone in both years. In the second half of July and most of August 2022, the average temperature per day was about 19–20 °C, which is 2–3 °C higher than the usually observed values. This period 2023 was characterized by an increase in average temperatures by 2.5–4.5 ° C compared to the mean annual data. The amount of precipitation in August was significantly below the norm both in 2022 and 2023. Seed formation and maturation were under favorable conditions in the Kirov region. The duration of the ripening period in flax did not differ significantly by year and amounted to 52–54 days.

In general, during the vegetation periods of the studied years the conditions were quite favorable for flax development and the final safety of plants was quite high and ranged from 84.0 to 88.7% (see fig. 2).

In the control, which was not subjected to any treatment with preparations of biological origin, the safety of plants for harvesting amounted to 81.3% on average across the repetitions. In the variants, the excess of the proportion of surviving plants was from 3.3 to 9.1 p.p., which indicates the influence of the use of preparations on this parameter in the prevailing meteorological conditions. The survival rate was higher in the variants with double application. Treatment of the seeds and vegetative plants with humate +7 “Healthy Harvest” and pseudobacterin-2L increases survival rate by 6.3 and 6.8%, respectively. Joint treatment with the complex of preparations according to the same scheme increases the proportion of surviving plants by 7.4%.

The use of biological origin preparations contributed to the growth of seed yield in most of the studied variants (1.37 t/ha on average for the variants) (see Table 2).

During the period under consideration, there was no reliable decrease in any case. As a rule, seed treatment or application of the preparations twice had a greater effect on the yield. On average for 2022–2023, the yield significantly higher than the control was recorded in such variants and reached 1.37–1.43 t/ha. More significant germination was recorded in the variant with double treatment with complex preparations and

amounted to 0.14 t/ha with the control yield of 1.29 t/ha.

Sowing density in the described experiment was sufficient due to good field germination and favorable meteorological conditions during growth and development. In this case, branching in the lower part of the stem was absent in most plants and formation of a single stem took place. The number of productive stems was 1.12 per plant.

On average, 11.62 bolls were formed on each flax plant (see Table 3). More bolls than the control were formed in the variants with double treatment with humate +7 "Healthy Harvest" (12.1 bolls) and double treatment with a complex of preparations of biological origin (12.3 bolls).

In the control variant, an average of 6.2 full-grown seeds were formed in a boll. In a number of variants, the increase in the number of seeds amounted to more than 11%. More than seven seeds were formed in variants 2 and 7 (7.1 pieces each), as well as in variants 8 (7.4 pieces) and 9 (7.3 pieces).

The weight of 1000 seeds varied from 7.4 to 7.5 g. This indicator in the studied variants was at the level of control or exceeded it. The proportion of the variants with 1000 seeds weight below the control level was 30%. At the same time, there was no significant effect of application of the preparations of biological origin on this parameter.

CONCLUSION

When analyzing the influence of meteorological factors on the density of oil flax crops, their significant negative and reliable influence on this parameter was not observed. Pre-sowing treatment of oil flax seeds influenced its field germination. On average, it was higher by 2.4% compared to the control. The best field germination was observed in the variants that provided seed treatment with humate +7 "Healthy Harvest" (85.6%), as well as with a complex of preparations of biological origin (humate +7 "Healthy Harvest" + pseudobacterin-2L) (86.3%). Preservation of plants for harvesting in agrometeorological conditions of the experiment was higher when flax was treated with preparations of biological origin. The percentage of safety was higher in case of double treatments (pre-sowing

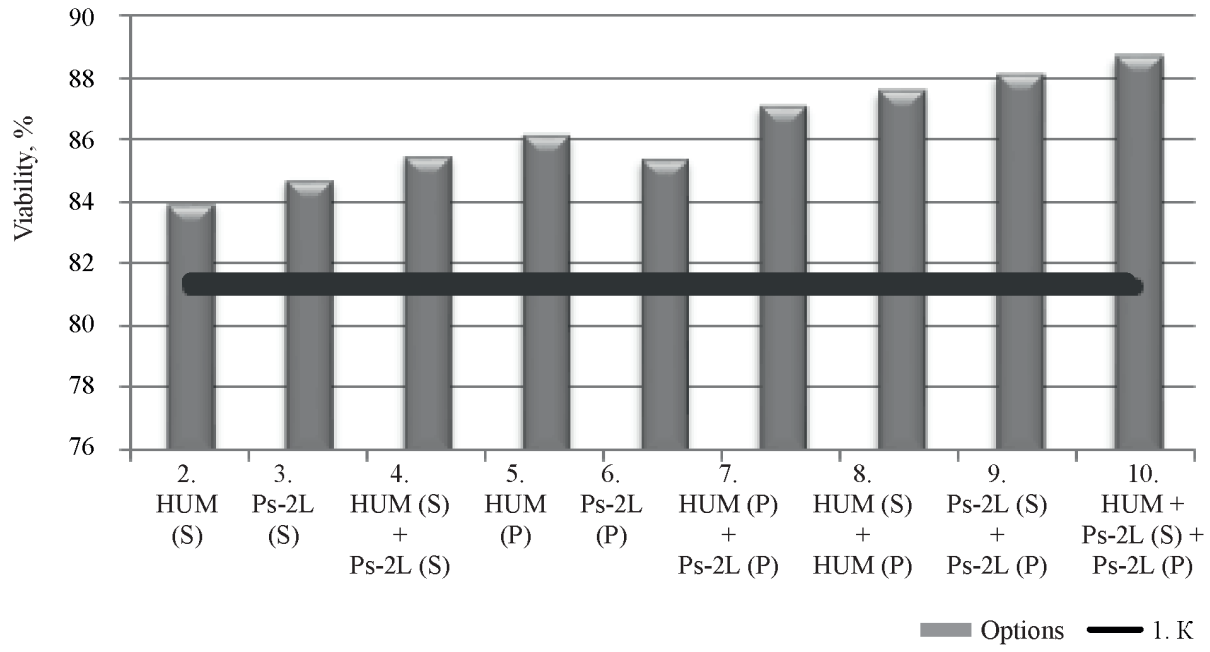

Рис. 2. Сохранность растений масличного льна, %
Fig. 2. Preservation of oil flax plants, %

Табл. 2. Урожайность семян масличного льна, т/га
Table 2. Yield of oil flax seeds, t/ha

Option	2022		2023		Average	
	t/ha	± to 1. C	t/ha	± to 1. C	t/ha	± to 1. C
1. C	1,27	—	1,31	—	1,29	—
2. Hum (S)	1,34	0,07	1,41	0,10	1,38	0,09
3. Ps-2L (S)	1,37	0,10	1,44	0,13	1,41	0,12
4. Hum (S) + Ps-2L (S)	1,31	0,04	1,43	0,12	1,37	0,08
5. Hum (P)	1,31	0,04	1,34	0,03	1,33	0,04
6. Ps-2L (P)	1,33	0,06	1,31	0,00	1,32	0,03
7. Hum (P) + Ps-2L (P)	1,28	0,01	1,34	0,03	1,31	0,02
8. Hum (S) + Hum (P)	1,35	0,08	1,47	0,16	1,41	0,12
9. Ps-2L (S) + Ps-2L (P)	1,37	0,10	1,39	0,08	1,38	0,09
10. Hum + Ps-2L (S) + Ps-2L (P)	1,39	0,12	1,46	0,15	1,43	0,14
LSD_{05}		0,06		0,08		0,07

treatment of seeds and vegetative plants). Application of the same-name preparations gives an increase in safety by 6.3–6.8%. Twofold use of complex humate +7 "Healthy Harvest" + pseudobacterin-2L increases plant density by 7.4%.

The use of preparations of biological origin contributed to the growth of seed yield in most of the studied variants. The greatest effect of application was observed in case of influence on the seeds by pre-sowing treatment and use of preparations twice. On average for two years, the maximum yield level, characterized by a reliable excess, was observed when using the complex of preparations of biological origin twice (1.43 t/ha).

A significant positive effect of double application of the complex of preparations of biological origin on the number of bolls per plant (6%

Табл. 3. Элементы структуры продуктивности льна масличного (в среднем за 2022–2023 гг.)
Table 3. Elements of the structure of oil flax productivity (on average for 2022–2023)

Option	Bolls on one plant, pcs.	Seeds in one boll, pcs.	Weight of 1000 seeds, g
1. C	11,6 ± 0,2	6,2 ± 0,3	7,5 ± 0,1
2. Hum (S)	11,8 ± 0,3	7,1 ± 0,2*	7,4 ± 0,1
3. Ps-2L (S)	11,2 ± 0,3	6,1 ± 0,3	7,6 ± 0,2
4. Hum (S) + Ps-2L (S)	10,8 ± 0,4	6,8 ± 0,2	7,6 ± 0,2
5. Hum (P)	11,2 ± 0,3	6,5 ± 0,2	7,4 ± 0,2
6. Ps-2L (P)	11,4 ± 0,3	6,2 ± 0,3	7,5 ± 0,2
7. Hum (P) + Ps-2L (P)	11,9 ± 0,3	6,8 ± 0,2	7,4 ± 0,1
8. Hum (S) + Hum (P)	12,1 ± 0,2	7,1 ± 0,3*	7,5 ± 0,1
9. Ps-2L (S) + Ps-2L (P)	11,9 ± 0,3	7,4 ± 0,2**	7,5 ± 0,1
10. Hum + Ps-2L (S) + Ps-2L (P)	12,3 ± 0,3*	7,3 ± 0,2**	7,5 ± 0,2

Note. The differences are significant at the probability level:*P>0,95; **P>0,99.

more than the control) was found. The formation of full-grown seeds in one boll was significantly influenced by seed treatment with humate +7 "Healthy Harvest", as well as by double application of the studied preparations and their complex (by 16% on average). No significant effect of humate +7 "Healthy Harvest", pseudobacterin-2L and their complex on the weight of 1000 seeds was recorded.

Thus, it is possible to recommend the double application (treatment of seeds and vegetative plants) of the complex of preparations of biological origin humate +7 "Healthy Harvest" + pseudobacterin-2L for oil flax in order to increase seed yield in the system of biological farming in the agrometeorological conditions of the north-east of the Non-Chernozem zone.

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Разработка способов выращивания оздоровленных микрорастений картофеля сорта Солнечный

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Изучено влияние различных условий выращивания, включающих разные составы питательной среды и различные источники освещения, на развитие микрорастений картофеля сорта Солнечный в лабораторных условиях *in vitro*. При использовании полноспектральных светодиодных ламп и модифицированной питательной среды Мурасиге-Скуга с пониженным содержанием агар-агара у растений отмечено увеличение высоты на 25% и снижение площади поверхности листовых пластин на 19%. Микрорастения, выращиваемые с использованием полноспектральных светодиодных ламп и модифицированной питательной среды Мурасиге-Скуга с пониженным содержанием агар-агара и добавлением индолилуксусной кислоты в концентрации 0,1 мг/л отличались от контрольных уменьшенными высотой (на 23%), числом междоузлий (на 24%) и числом листьев (на 26%). При использовании полноспектральных светодиодных ламп и модифицированной питательной среды Мурасиге-Скуга с пониженным содержанием агар-агара (4 г/л) и добавлением индолилуксусной кислоты в концентрации 0,5 мг/л отмечено уменьшение числа междоузлий на 24%, листьев – на 14, площади поверхности листовых пластин – на 39%, ускорение ризогенеза и увеличение массы корневой системы – на 117%. Микрорастения, выращиваемые с использованием линейных светодиодных ламп и модифицированной питательной среды Мурасиге-Скуга с добавлением индолилуксусной кислоты в концентрации 0,1 мг/л, были выше контрольных на 70%, имели сниженную на 48% массу листьев, уменьшенную на 53% площадь поверхности листовых пластин, а также увеличенную на 36% массу стебля. У микрорастений, выращиваемых с использованием линейных светодиодных ламп и модифицированной питательной среды Мурасиге-Скуга, отмечено увеличение высоты стебля на 73%, числа междоузлий на 20%, или 1 шт., длины корневой системы на 17%, ускорение ризогенеза и снижение площади листовой поверхности на 39%. Разработаны способы культивирования оздоровленных микрорастений картофеля сорта Солнечный, направленные на ускоренное получение большого количества растений и подготовку микрорастений к пересаживанию на аэрогидропонные установки.

Ключевые слова: картофель, меристемная технология оздоровления, состав питательной среды, источники освещения, способ выращивания растений

Development of the methods for growing healthy potato microplants of the Solnechny variety

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The effect of different growing conditions, including different compositions of nutrient medium and different sources of illumination, on the development of potato microplants of the Solnechny variety under *in vitro* laboratory conditions was studied. Using full-spectrum LED lamps and modified Murashige-Skoog nutrient medium with reduced agar-agar content, plants showed a 25% increase in height and a 19% decrease in lamina surface area. The microplants grown using full-spectrum LED lamps and modified Murashige-Skoog nutrient medium with reduced agar-agar content and addition of indolylacetic acid at a concentration of 0.1 mg/ l differed from the control ones by reduced height (by 23%), the number of internodes (by 24%) and the number of leaves (by 26%). Using full-spectrum LED lamps and modified Murashige-Skoog nutrient medium with reduced agar-agar content (4 g/l) and addition of indolylacetic acid at a concentration of 0.5 mg/l, a decrease in the number of internodes

by 24%, leaves by 14, lamina surface area by 39%, acceleration of rhizogenesis and increase in root system weight by 117% were observed. Microplants grown using linear LED lamps and modified Murashige-Skoog nutrient medium supplemented with indolylacetic acid at a concentration of 0.1 mg/l were 70% taller than controls, had 48% reduced leaf mass, 53% reduced lamina surface area, and 36% increased stem mass. Microplants grown using linear LED lamps and modified Murashige-Skoog nutrient medium showed a 73% increase in stem height, a 20% or 1 unit increase in the number of internodes, a 17% increase in root system length, an acceleration of rhizogenesis, and a 39% decrease in leaf area. Methods of cultivation of healthy potato microplants of the Solnechny variety have been developed, aimed at accelerated generation of a large number of plants and preparation of microplants for transplanting to aerohydroponic plants.

Keywords: potato, meristem health recovery technology, nutrient medium composition, illumination sources, plant cultivation method

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INTRODUCTION

Potato as the most important food crop, which is one of the first places in the world crop production, has a serious disadvantage: it is infected by a wide range of various diseases and pests. In this regard, at the present stage of agricultural science development, biotechnological methods of seed material health improvement are more and more widely introduced into the practice of seed production[1, 2] [1, 2]. Modern methods of agricultural biotechnology allow placing the production of agricultural crops on a new technological level, which makes it possible to expand the range of the products manufactured, improve its quality and significantly reduce the production process of cultivation of cultural plants [3]. The most promising direction for solving this problem is the use of clonal micropropagation methods[3, 4] [4].

Biotechnological methods most effectively allow mass and accelerated multiplication of healthy potato clones directly in an *in vitro* culture, which reduces the time of obtaining seed tubers. This is due to the high multiplication rate of meristem plants microcuttings in the *in vitro* culture[5, 6]. One of the ways to improve the efficiency of biotechnological methods in potato seed production is the search for optimal conditions for cultivation of the obtained potato microclones, which makes it possible, on the one hand, to achieve the desired results (a large num-

[1]*Uskov A.I.* Production of improved source material for potato seed production: strategy substantiation // Achievements of Science and Technology of AIC, 2009, N 6, pp. 30–33.

[2]*Fedorova Yu.N., Fedorova L.N., Lebedeva N.V.* Study of potato miniplants of the Belarusian selection in the conditions of the Pskov region // Bulletin of KrasSAU, 2013, N 9, pp. 103–105.

[3]*Anisimov B.V., Smolegovets D.V., Shatilova O.N.* Recommendations on the technology of *in vitro* cultivation of microtubers and their use in the process of original seed production: recommendations; RASKhN VNIIKh. Moscow, 2009, 21 p.

[4]*Zamalieva F.F., Gareev R.G.* State and prospects for the development of potato seed production on the improved basis in the Republic of Tatarstan // Potato seed production in modern market conditions: interregional scientific and practical seminar. Kazan, 2004, pp. 7–10.

[5]*Anisimov B.V., Tulcheev V.V.* Variety resources of seed potatoes on the Russian market // Potato seed production in modern market conditions: interregional scientific and practical seminar. Kazan, 2004, pp. 1–6.

[6]*Zamalieva F.F., Gareev R.G.* State and prospects for the development of potato seed production on the improved basis in the Republic of Tatarstan. // Potato seed production in modern market conditions: interregional scientific and practical seminar. Kazan, 2004, pp. 7–10.

ber of plants, a certain quality of plants, etc.), on the other hand, to reduce the costs of production.

The following growing conditions are of great importance in the cultivation of potato microplants: composition of the nutrient medium, spectral composition and intensity of illumination [2, 5], photoperiod [6, 7], and temperature [8, 9]. When developing cultivation methods, all these factors are taken into account or they work on individual elements. Studies by many authors have proved the variety-specific response of potato to growing conditions, in particular, the spectral composition of light[7] [10–13], and the composition of the nutrient medium [13–15]. In this regard, it is necessary to develop methods of potato cultivation separately for each variety.

Authors of this work for several years studied the reaction of potato microplants of the Solnechny variety to different compositions of the nutrient medium, the presence or absence of phytohormones in the nutrient medium, the use of different sources of illumination in laboratory conditions *in vitro*. Based on the results of these studies, the best variants with a favorable effect on plant development were selected and combinations of them were made to study their effect on plant development and further development of the cultivation methods.

The purpose of the research is to develop methods of growing healthy potato microplants of the Solnechny variety under *in vitro* laboratory conditions.

MATERIAL AND METHODS

The work was carried out at the Siberian Research Institute of Agriculture and Peat – branch of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences. The object of the experiments was healthy maternal microclones of potato *Solanum tuberosum* L. of the Solnechny variety.

The Solnechny variety is medium-maturing, suitable for processing into potato products. The commercial yield of the variety is 178–290 c/ha. The tuber is rounded with eyes of medium depth. The skin is smooth, yellow. The flesh is yellow. The weight of a marketable tuber is 139–290 g. The starch content is 14.4–16.0%. The taste is good. The marketability is 85–98%, storability 94%. It is resistant to potato cancer pathogen, and is slightly affected by the golden potato cyst-forming nematode. It is included in the State Register of the Russian Federation for the West Siberian (10) region[8].

Healthy plants were selected in the field, and the harvest was stored for storage. After the end of the dormancy period, the tubers were given thermotherapy for 40 days at 37°C, after which the tubers were germinated until sprouts of 2–3 cm in size were obtained. Apex meristem was isolated from the sprouts and then full-grown microplants were grown from it, which were subsequently used in the experiments. Before the experiment, all microplants were diagnosed by real-time PCR to confirm the absence of pathogens in them. The plants were grown in a light rack, isolated sections of which were equipped with different light sources. The number of lamps used was calculated taking into account equal illumination of each section, which was 4000 lux. During the experiment, microplants were cultivated at 20–22 °C with a photoperiod of 16/8 h (light/dark) in test tubes for 28 days.

35 plants of each variety were grown on each variant in threefold repetition. During the experiment on the 3rd, 7th, 14th, 21st, 28th days, the parameters characterizing plant development were measured: plant length, root presence, number of leaves and internodes per plant. On the 28th day, the weight of the root system, shoot, leaves, stem and leaf area were measured.

[7] *Burdysheva O.V., Sholgin E.S., Remennikova M.V., Maximov A.Y., Lisina T.N., Tsema L.G., Latypova A.L., Yakhina A.I.* Effect of illumination of different spectrum on morphometric indices, protein and proline content in potato leaves (in vitro) varieties Nevsky, Gornyak, Udacha, Kamensky // Development of modern systems of farming and animal husbandry, providing ecological safety of the environment: Proceedings of the All-Russian Scientific Conference (Perm, July 5–7, 2023), Perm, 2023, pp. 194–201.

[8] https://gossortrf.ru/registry/gosudarstvennyy-reestr-selektsionnykh-dostizheniy-dopushchennykh-k-ispolzovaniyu-tom-1-sorta-rasteni/solnechnyy-kartofel/

The purpose of the work was to develop two methods of growing healthy potato microplants of the Solnechny variety:

– for rapid production of large numbers of potato microplants;

– for preparation of the Solnechny potato microplants for transplanting to aerohydroponic plants.

For the development of the methods, the selection of plant cultivation conditions was carried out to achieve the goals with the lowest costs. The considered variants of the cultivation conditions were selected based on the results of preliminary studies and are presented in Table 1.

The compositions of the nutrient medium used are given in Table 2.

The composition of the nutrient medium used as a control is selected based on the literature sources[9, 10]. For several years, it has been successfully used by the authors of this work to grow healthy potato microplants by microcuttings.

Statistica 10.0 software package for Windows was used for statistical processing of the results. The nonparametric Mann-Whitney test was used to compare the numerical values of the indicators.

RESULTS AND DISCUSSION

The results of studying the effect of different growing conditions on the healthy potato microplants of the Solnechny variety at different cultivation periods are presented in Tables 3 and 4.

Plants of variant 2 differed from the control plants by increased height (on the 28th day of cultivation the difference amounted to 25%), slightly reduced number of the leaves (by 7% on

Табл. 1. Схема экспериментов по изучению влияния различных условий выращивания на оздоровленные микрорастения картофеля сорта Солнечный

Table 1. Scheme of the experiments to study the influence of various growing conditions on healthy microplants of the Solnechny potato variety

Experiment option	Illumination source	Nutrient medium
1. Control	OSRAM fluorescent lamps, cool daylight, 36 W power	Murashige-Skoog medium modified for microcutting (MS)
2. To prepare for transplanting plants to aeroponic systems	Full spectrum LED lamps, power 42 W	MS with reduced agar-agar content (4 g/l)
3. To prepare for transplanting plants to aeroponic systems	Full spectrum LED lamps, power 42 W	MS with reduced agar-agar content (4 g/l) and addition of indoleacetic acid (IAA) at a concentration of 0.1 mg/l
4. To prepare for transplanting plants to aeroponic systems	Full spectrum LED lamps, power 42 W	MS with reduced agar-agar content (4 g/l) and addition of IAA at a concentration of 0.5 mg/l
5. For rapid increase in the number of plants	OSRAM-3000 K linear LED lamps, warm white light, 18 W power	MS with the addition of IAA at a concentration of 0.1 mg/l
6. For rapid increase in the number of plants	OSRAM-3000 K linear LED lamps, warm white light, 18 W power	MS

[9] *Trofimets L.N., Boyko V.V., Anisimov B.V. et al.* Virus-free potato seed production: recommendations. Moscow: Agropromizdat, 1990.

[10] *Lebedeva N.V.* Influence of nutrient medium composition on the formation of potato microplants under *in vitro* conditions: extended abstract of candidate's thesis in agriculture, Moscow, 2015.

Табл. 2. Составы питательной среды для выращивания оздоровленных растений картофеля, мг/л
Table 2. Compositions of the nutrient medium for growing healthy potato plants, mg/l

Composition of the medium	MS	MS with reduced agar-agar content	MS with reduced agar content and the addition of IAA at a concentration of 0.1 mg/l	MS with reduced agar content (4 g/l) and the addition of IAA at a concentration of 0.5 mg/l	MS with the addition of IAA at a concentration of 0.1mg/l
Macro salts					
NH_4NO_3	825	825	825	825	825
KNO_3	950	950	950	950	950
$CaCl_2 \cdot 2H_2O$	220	220	220	220	220
$MgSO_4 \cdot 4H_2O$	185	185	185	185	185
KH_2PO_4	85	85	85	85	85
H_3BO_3	3,1	3,1	3,1	3,1	3,1
$MnSO_4 \cdot 4H_2O$	11,15	11,15	11,15	11,15	11,15
$CoCl_2 \cdot 6H_2O$	0,0125	0,0125	0,0125	0,0125	0,0125
$ZnSO_4 \cdot 7H_2O$	4,3	4,3	4,3	4,3	4,3
$CuSO_4 \cdot 5H_2O$	0,0125	0,0125	0,0125	0,0125	0,0125
$Na_2MoO_4 \cdot 2H_2O$	0,125	0,125	0,125	0,125	0,125
KI	0,415	0,415	0,415	0,415	0,415
Iron chelate					
$Fe_2SO_4\,7H_2O$	13,9	13,9	13,9	13,9	13,9
Na_2- EDTA $\cdot 2H_2O$	18,65	18,65	18,65	18,65	18,65
Thiamine	2,5	2,5	2,5	2,5	2,5
Pyridoxine	5	5	5	5	5
АС-К	2,5	2,5	2,5	2,5	2,5
Growth regulators					
Saccharose	30000	30000	30000	30000	30000
Agar-agar	7000	4000	4000	4000	7000
IAA	–	–	0,1	0,5	0,1

the 28th day) and reduced total surface area of the leaf plates (by 19% on the 28th day). There was a tendency to increase stem weight on the 28th day of cultivation.

In plants of variant 3 on the 28th day of cultivation, the height was 23% lower than in the control, the number of internodes was 24% lower (1.3 pieces), and the number of leaves was 26% lower. There was also a tendency to decrease leaf and shoot weight, as well as to increase the weight of the root system.

Starting from the 7th day of cultivation, the number of internodes and leaves was reduced in the plants of variant 4 compared to the control. On the 28th day of cultivation, the difference in the number of internodes was 24% (1.3 pieces), in the number of leaves – 14%. Rhizogenesis was accelerated in the plants of this variant, and on the 28th day of cultivation the weight of the root system was 117% higher than in the control. At the same time, the total surface area of laminas was reduced by 39%.

There was an increase in plant height of variant 5 compared to the control, on the 28th day of cultivation the difference amounted to 70%. The leaf mass of plants of this variant was reduced

Табл. 3. Влияние различных условий выращивания на показатели развития микрорастений картофеля сорта Солнечный

Table 3. The influence of various growing conditions on the development indicators of potato microplants of the Solnechny variety

Experiment option	24 hours				
	3rd	7th	14th	21st	28th
Height, cm					
1 (control)	0,16 ± 0,02	0,41 ± 0,05	2,65 ± 0,22	4,18 ± 0,32	6,06 ± 0,41
2	0,10 ± 0,02	0,30 ± 0,03	2,89 ± 0,30	5,59 ± 0,49*	7,57 ± 0,54*
3	0,16 ± 0,02	0,48 ± 0,07	2,03 ± 0,23*	3,30 ± 0,37*	4,69 ± 0,41*
4	0,11 ± 0,02	0,30 ± 0,04	2,55 ± 0,30	4,13 ± 0,43	5,78 ± 0,39
5	0,21 ± 0,04	1,07 ± 0,14***	4,70 ± 0,44	7,39 ± 0,57***	10,27 ± 0,65***
6	0,16 ± 0,03	0,76 ± 0,11**	4,72 ± 0,39***	7,61 ± 0,57***	10,49 ± 0,56***
Number of nodes					
1 (control)	0,02 ± 0,02	0,55 ± 0,09	2,39 ± 0,15	3,13 ± 0,21	5,22 ± 0,30
2	0 ± 0	0,51 ± 0,09***	2,17 ± 0,16*	3,41 ± 0,24***	5,11 ± 0,26
3	0,02 ± 0,02	0,67 ± 0,12***	1,69 ± 0,16***	2,71 ± 0,26***	3,94 ± 0,30***
4	0,04 ± 0,03	0,34 ± 0,08***	1,72 ± 0,19**	2,85 ± 0,25***	3,94 ± 0,24***
5	0,02 ± 0,02	0,81 ± 0,11**	2,83 ± 0,19	3,91 ± 0,26***	5,30 ± 0,28
6	0,04 ± 0,04	0,89 ± 0,12**	3,28 ± 0,16*	4,37 ± 0,22***	6,13 ± 0,25*
Number of leaves					
1 (control)	0,09 ± 0,05	0,80 ± 0,13	3,52 ± 0,21	4,44 ± 0,27	6,20 ± 0,33
2	0 ± 0	0,89 ± 0,14***	3,15 ± 0,23**	4,75 ± 0,30***	5,80 ± 0,27*
3	0,05 ± 0,04	0,96 ± 0,17***	2,42 ± 0,25***	3,47 ± 0,32***	4,60 ± 0,34***
4	0,04 ± 0,03	0,60 ± 0,14***	2,73 ± 0,27**	4,17 ± 0,30***	5,32 ± 0,24***
5	0,04 ± 0,02	1,22 ± 0,19**	3,54 ± 0,24	4,82 ± 0,29***	6,18 ± 0,31
6	0,05 ± 0,05	1,24 ± 0,17**	4,09 ± 0,19	5,13 ± 0,25***	6,65 ± 0,27
Number of plants with emerging roots					
1 (control)	6	45	73	75	75
2	15	45	74	75	75
3	13	46	73	75	75
4	21	50	75	75	75
5	10	49	74	75	75
6	17	73	75	75	75

Note. Differences are statistically significant compared to the control group:
*$p < 0,05$,
**$p < 0,01$,
***$p < 0,001$.

Табл. 4. Влияние различных условий выращивания на морфологические показатели оздоровленных микрорастений сорта Солнечный на 28-е сутки культивирования

Table 4. The influence of various growing conditions on the morphological parameters of healthy microplants of the Solnechny variety on the 28th day of cultivation

Experiment option	Leaf mass, g	Stem weight, g	Weight of the shoot, g	Root system weight, g	Root system length, cm	Total area of laminar surface, cm^2
1 (control)	0,48 ± 0,08	0,44 ± 0,06	0,91 ± 0,13	0,41 ± 0,07	5,92 ± 0,33	4,31 ± 0,28
2	0,46 ± 0,07	0,57 ± 0,08	1,04 ± 0,14	0,39 ± 0,05	5,83 ± 0,39	3,51 ± 0,20**
3	0,24 ± 0,04	0,38 ± 0,06	0,62 ± 0,10	0,81 ± 0,19	5,36 ± 0,40	4,09 ± 0,50
4	0,37 ± 0,07	0,39 ± 0,06	0,77 ± 0,12	0,89 ± 0,14**	6,23 ± 0,29	2,64 ± 0,26***
5	0,25 ± 0,04*	0,60 ± 0,09*	0,85 ± 0,12	0,89 ± 0,16	7,02 ± 0,48*	2,03 ± 0,20***
6	0,26 ± 0,04	0,52 ± 0,07	0,78 ± 0,11	0,71 ± 0,12	6,92 ± 0,31*	2,67 ± 0,24***

Note. Differences are statistically significant compared to the control group.:
*$p < 0,05$,
**$p < 0,01$,
*** $p < 0,001$.

by 48%, stem mass was increased by 36%, the total lamina surface area was reduced by 53%.

Plants of variant 6 differed from the control by increased height (73% difference on the 28th day) and the number of internodes (by 20%, or 1 piece), accelerated rhizogenesis, increased root system length (by 17% on the 28th day of cultivation), and decreased total leaf area (by 39% on the 28th day of cultivation).

When calculating the economic efficiency of the application of different conditions for growing potato microplants, only the cost of nutrient medium of different composition, purchase and operation of different lighting sources were taken into account, since all other costs were the same.

When calculating the cost of using different lighting sources, the following characteristics were taken into account: cost per lamp, recommended lifetime, luminous flux and power consumption. When calculating the cost of one month of operation, the different number of lamps of different types required to illuminate one section of the experimental rack in accordance with the requirements of the methodology of growing potato plants *in vitro* was taken into account. The cost of nutrient medium of different composition and the cost of using different light sources in accordance with the studied variants are presented in Table 5. The period of operation of lighting sources (one month) was chosen due to the fact that the preparation of nutrient medium for repeated microclonal propagation occurs once a month. 250 tubes with microplants are placed on one section of the light rack. Growing 250 microplants for one month requires 2.5 liters of nutrient medium.

The studied variants differed significantly in the costs of nutrient medium and light sources. The cheapest were variants 5 and 6, the most expensive was variant 1 (control).

CONCLUSION

Based on the conducted studies, two methods of growing healthy potato microplants of the Solnechny variety under in vitro laboratory conditions were developed. The cultivation variant including the use of full-spectrum LED lamps and Murashige- Skoog nutrient medium modified for microcuttings with a reduced content of agar-agar (4 g/l) and addition of IAA at a concentration of 0.5 mg/l is recommended to be used to prepare the Solnechny variety potato microplants for transplanting to aerohydroponic plants. In order to quickly obtain a large number of potato microplants of the Solnechny pota-

Табл. 5. Стоимость питательной среды и одного месяца эксплуатации источников освещения по вариантам в соответствии со схемой эксперимента в расчете на одну секцию светового стеллажа, р.

Table 5. The cost of the nutrient medium and 1 month of operation of the lighting sources according to the options in accordance with the experimental design per one section of the light rack, rubles

Experiment option	Cost of the nutrient medium	Costs for one month of lamp operation	Total costs on the nutrient medium and lighting
1 (control)	140,50	740,40	880,90
2	95,50	621,00	716,50
3	95,53	621,00	716,53
4	95,55	621,00	716,55
5	140,53	266,00	406,53
6	140,50	266,00	406,50

to variety, it is recommended to use cultivation variant 6, in which linear LED lamps and the Murashige- Skoog nutrient medium modified for microcuttings are used.

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Физиолого-биохимическая оценка морозостойкости винограда в Краснодарском крае

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Представлены результаты физиолого-биохимической оценки морозостойкости шести сортов винограда различного эколого-географического происхождения в условиях Краснодарского края: Достойный, Красностоп АЗОС, Восторг (Россия), Кристалл (Венгрия), Алиготе (Франция), Зариф (Таджикистан). В ходе исследования оводненность побегов определяли весовым методом после высушивания навесок в термостате при 105 °С до постоянной массы. Содержание углеводов (крахмала и растворимых сахаров) определяли фотоколориметрическим антроновым методом, концентрацию пролина – методом капиллярного электрофореза. Установлено, что оводненность побегов и содержание крахмала снижались в течение осенне-зимнего периода и зависели от сорта. У сортов Кристалл, Красностоп АЗОС, Восторг обнаружено наибольшее снижение оводненности тканей побегов (на 13,54–15,11%), тогда как у Алиготе и Зарифа данный показатель снизился на 6,50 и 7,83% соответственно. У всех изучаемых сортов выявлена положительная корреляционная зависимость между оводненностью побегов и содержанием крахмала (r = 0,91). В результате гидролиза запасного крахмала у сортов Кристалл, Красностоп АЗОС, Восторг содержание сахаров увеличилось в 1,90–1,98 раза, у Алиготе и Зарифа – в 1,22 и 1,41 раза. Отрицательная корреляция зафиксирована между содержанием крахмала и растворимых сахаров (r = –0,88). Повышенная концентрация пролина к началу периода покоя отмечена у сортов Кристалл, Красностоп АЗОС, Восторг (20,01–25,34 мкг/г сырой массы), у Алиготе и Зарифа величина данного показателя составила 15,16–18,04 мкг/г сырой массы. Выявлены корреляционные зависимости между рассматриваемыми физиолого-биохимическими параметрами. Более высокую корреляцию наблюдали между оводненностью и содержанием крахмала (r = 0,91), чем между оводненностью и содержанием пролина (r = –0,47). Согласно результатам исследования, сорта Кристалл, Красностоп АЗОС, Восторг, выделившиеся по физиолого-биохимическим показателям как высокоустойчивые к низким отрицательным температурам, могут быть использованы в селекции для выведения морозостойких сортов.

Ключевые слова: виноград, морозостойкость, оводненность, крахмал, растворимые сахара, пролин

Physiological and biochemical assessment of frost resistance of grapes in the Krasnodar Territory

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The article presents the results of physiological and biochemical assessment of frost resistance of six grape varieties of different ecological and geographical origin in the conditions of the Krasnodar Territory: Dostoyny, Krasnostop AZOS, Vostorg (Russia), Crystal (Hungary), Aligote (France), Zarif (Tajikistan). Shoot water content was determined by the gravimetric method after drying the samples in a thermostat at 105 °C to constant weight. The content of carbohydrates (starch and soluble sugars) was determined by photocolorimetric anthrone method, the concentration of proline was determined by capillary electrophoresis. It was found that shoot water content and starch content decreased during the autumn-winter period and depended on the variety. The Crystal, Krasnostop AZOS, Vostorg varieties showed the greatest decrease in shoot tissue water content (by 13.54–15.11%) compared to the Aligote and Zarif varieties, for which this indicator decreased by 6.50 and 7.83%. All the studied varieties demonstrated a positive correlation between shoot hydration and starch content (r = 0,91). As a result of reserve starch hydrolysis, the sugar content increased by 1.90–1.98 times in Crystal,

Krasnostop AZOS, Vostorg, compared to Aligote and Zarif, where it increased by 1.22 and 1.41 times. A negative correlation was observed between starch and soluble sugar content (r = –0,88). Increased concentration of proline by the beginning of the dormancy period was observed in the varieties Crystal, Krasnostop AZOS, Vostorg (20.01–25.34 μg/g crude weight), in Aligote and Zarif the value of this indicator amounted to 15.16–18.04 μg/g crude weight. Correlation dependencies between the studied physiological and biochemical parameters were revealed. A higher correlation was observed between water content and starch content (r = 0.91) than between water content and proline content (r = –0.47). The varieties Crystal, Krasnostop AZOS, Vostorg, distinguished by physiological and biochemical indicators as highly resistant to low negative temperatures, can be used in selection for developing frost-resistant varieties.

Keywords: grapes, frost resistance, water content, starch, soluble sugars, proline

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The authors declare no conflict of interest.

INTRODUCTION

In most countries grapes are considered an economically important agricultural crop. Currently, about 12 thousand grape varieties are known, the area of its cultivation in the world is over 6.7 million hectares [1]. In the Krasnodar region vineyards occupy 24.8 thousand hectares, i.e. 28.3% of the total area of vineyards in Russia [2]. In recent years, not only the area of cultivation, but also the gross harvest and yield of this crop have increased in the Krasnodar Territory [3]. At the same time, there is a decrease in the adaptability of some varieties [4]. This problem is associated with the change of weather and climatic conditions in the region, in particular, with the decrease in recent years of minimum winter air temperatures by 2.2 °C. If in 1977–1996 temperatures below -18 °C were observed 1 time, in 1997–2017 extremely low temperatures were recorded 5 times. In other countries of the world, changes in the growth and development of grapevine affecting its adaptability have also been observed [5, 6].

Low winter temperatures are the main abiotic stressor affecting the growth and productivity of grapes. In this regard, winter hardiness and frost resistance are important components of the adaptive potential of grape varieties in the breeding programs. Physiological and biochemical parameters serve as reliable diagnostic criteria of plant resistance to abiotic stresses and are often used to identify winter-hardy and low negative temperature tolerant varieties of various agricultural crops. It has been shown that carbohydrates (starch and sugars) play an important role in ensuring winter hardiness of nut, grain and fruit crops, as well as grapes [7–13]. An extensive list of metabolites (phenolic compounds, ascorbic and abscisic acids, proline, antioxidant enzymes) ensures the ability of plants to survive in unfavorable conditions [8–10, 14].

Objectives of the study:

1) assessment of the degree of frost resistance of grape varieties of different ecological and geographical origin by a number of physiological and biochemical parameters;

2) selection of the most frost-resistant varieties for subsequent cultivation in the Krasnodar region and use in the breeding process.

MATERIAL AND METHODS

The study was conducted in the autumn-winter period 2022/23. The objects of research were interspecific grape hybrids of different ecological and geographical origin: Dostoiny, Krasnostop AZOS, Vostorg (Russia), Crystal (Hungary),

Aligote (France), Zarif (Tajikistan). Variety samples were provided by the Center for Collective Use "Anapa ampelographic collection" of the Anapa Zonal Experimental Station – a branch of the Federal State Budgetary Institution "North Caucasian Federal Scientific Centre of Horticulture, Viticulture, and Winemaking".

The plants were of 1995, scion – Kober 5BB. Formation – bilateral high-stemmed spiral cordon AZOS. The planting scheme was 3.0 × 2.5 m, soil – southern carbonate chernozem.

Water content of the shoots was determined by the weight method after drying the samples in the thermostat at 105 °C to constant weight expressed as a percentage of the raw weight [12]. The content of starch and sugars was determined by photocolorimetric anthrone method[1], proline concentration was determined by capillary electrophoresis on a Kapel 104P device according to the methodology based on obtaining an electrophoregram by direct detection of absorbing components of the sample[2].

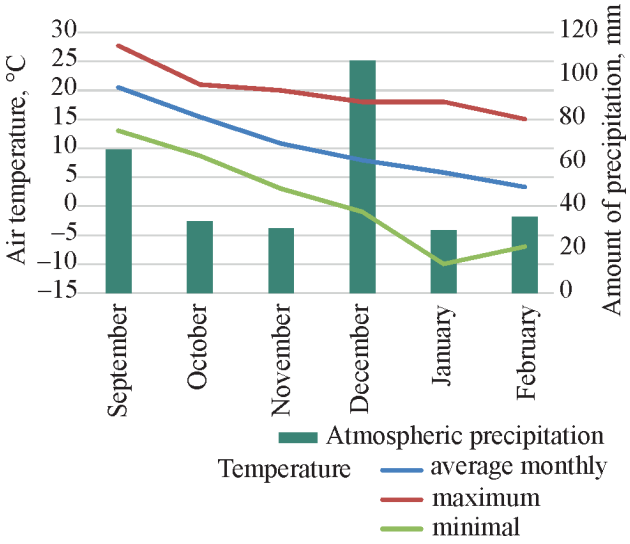
The instrumentation of the Center of collective use of high-tech equipment of the North Caucasian Federal Scientific Centre of Horticulture, Viticulture, and Winemaking was used. The measurements were carried out in threefold analytical repetition on ten annual shoots of each variety[3]. The calculations were performed using the program package Microsoft Excel 2010.

According to the data of Anapa weather station, the average annual air temperature in the research area is 12.5...13.5 °C, during the period of active vegetation of grapes (May – September) it reaches 20.5 °C, during the period of forced dormancy of plants (January – February) it is up to 2.7 °C. The minimum temperature during the wintering period of grapes can fall to –26 °C. The annual sum of atmospheric precipitation is 550–600 mm [15].

In the autumn-winter period 2022/23, average monthly air temperatures gradually decreased from 20.5 °C in September to 3.3 °C in February. The minimum air temperature (–10 °C) was recorded in January 2023, and the maximum (27.7 °C) in September 2022. The average monthly precipitation amounted to 29–107 mm (see fig. 1).

RESULTS AND DISCUSSION

The period of preparation for winter dormancy, which begins in September, plays an important role in the formation of winter hardiness of vines. The strongest influence on the completion of tissue maturation processes and the passage of hardening phases is exerted by the temperatures of autumn months. During hardening, complex physiological and biochemical changes occur such as accumulation of reserve nutrients, os-



Puc. 1. Метеоусловия на участке исследований

Fig. 1. Meteorological conditions at the research site

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moprotectants, outflow of water from cells with subsequent reduction of water content [10, 12].

According to some researchers, the water content of non-woody shoots of grapevine is 65–80%, by the end of the growing season it decreases to 45–55%, in winter it can reach 50%. In frost-resistant varieties water content of shoots and buds decreases to a greater extent [10–12].

In our study, water content of shoots decreased during the autumn-winter period and depended on the variety. In September, the maximum water content was observed in Zarif variety (65.35%), and the minimum was recorded in the Aligote variety (55.04%) (see the Table).

By January, when grape plants showed the greatest frost resistance, shoot water content decreased to 42.61–57.23% depending on the variety. It decreased most of all in the varieties Crystal, Krasnostop AZOS, Vostorg by 15.11; 13.54; 13.81%, respectively, which indicates their increased frost resistance. Water content of the Dostoiny variety decreased by 11.99%, Aligote by 6.50, Zarif by 7.83%. In February, shoot water content did not change significantly. Similar dynamics of water content of annual shoots and buds in the autumn-winter period was found in grapes under conditions of Iran and Turkey [10, 12].

Carbohydrates make a significant contribution to the realization of the potential of frost resistance of grapes. By the fall (September – October) the vine contains up to 20% of carbohydrates (starch and sugars) [11]. Starch under the action of low negative temperatures is transformed into sugars that perform osmoprotective function. Not only the high content of carbohydrates, but also the degree of starch conversion into sugars is important for a favorable overwintering. It was found that in more frost-resistant varieties of various horticultural crops (walnut, apple, almond, plum), as well as grapes, starch hydrolysis begins earlier and proceeds more intensively [7, 8, 11, 12].

In our studies, the starch content in the shoots in September amounted to 29.32-35.05 mg/g dry weight (see fig. 2, *а*). Throughout the autumn-winter period, the starch concentration decreased, and in January it amounted to 15.82-25.30 mg/g of dry weight, depending on the variety. A positive correlation between shoot water content and starch content was observed in all the studied varieties; as water content decreased, the amount of starch decreased. The average correlation coefficient *r* between these indicators for September – February was equal to 0.91. It was found that to a greater extent the concentration of starch decreased in the varieties Crystal, Krasnostop AZOS, Vostorg by 1.95; 1.90; 1.99 times, respectively. In the variety Dostoiny it decreased by 1.66 times, Aligote and Zarif by 1.31 and 1.33 times.

As a result of starch hydrolysis, the value of the sum of soluble sugars (glucose, sucrose, fructose) increased. In September, it amounted to 12.01-16.91 mg/g of dry weight, depending on the variety (see fig. 2, *б*). In January, by the

Оводненность побегов в осенне-зимний период 2022/23 г., %
Water content in grape shoots in the autumn-winter period 2022/23, %

Variety	September	October	November	December	January	February
Crystal	65,15 ± 0,23	60,08 ± 0,57	57,25 ± 1,17	55,42 ± 0,47	50,04 ± 0,42	50,26 ± 0,57
Dostoyny	55,16 ± 1,43	51,31 ± 0,19	47,43 ± 1,03	45,49 ± 0,71	43,17 ± 0,73	43,52 ± 0,32
Krasnostop AZOS	57,97 ± 0,19	55,61 ± 0,27	49,51 ± 0,49	47,27 ± 0,73	44,43 ± 0,72	44,08 ± 0,32
Vostorg	56,42 ± 0,68	53,03 ± 0,41	46,41 ± 1,12	45,81 ± 0,64	42,61 ± 1,08	42,20 ± 0,81
Aligote	55,04 ± 0,40	53,41 ± 1,25	50,42 ± 0,73	49,08 ± 0,91	48,54 ± 0,57	48,37 ± 1,01
Zarif	65,35 ± 0,46	62,27 ± 0,71	60,54 ± 0,27	58,29 ± 0,97	57,23 ± 0,28	57,52 ± 0,35

Note. The differences are significant between varieties and months according to the t-test at $p \leq 0,05$.

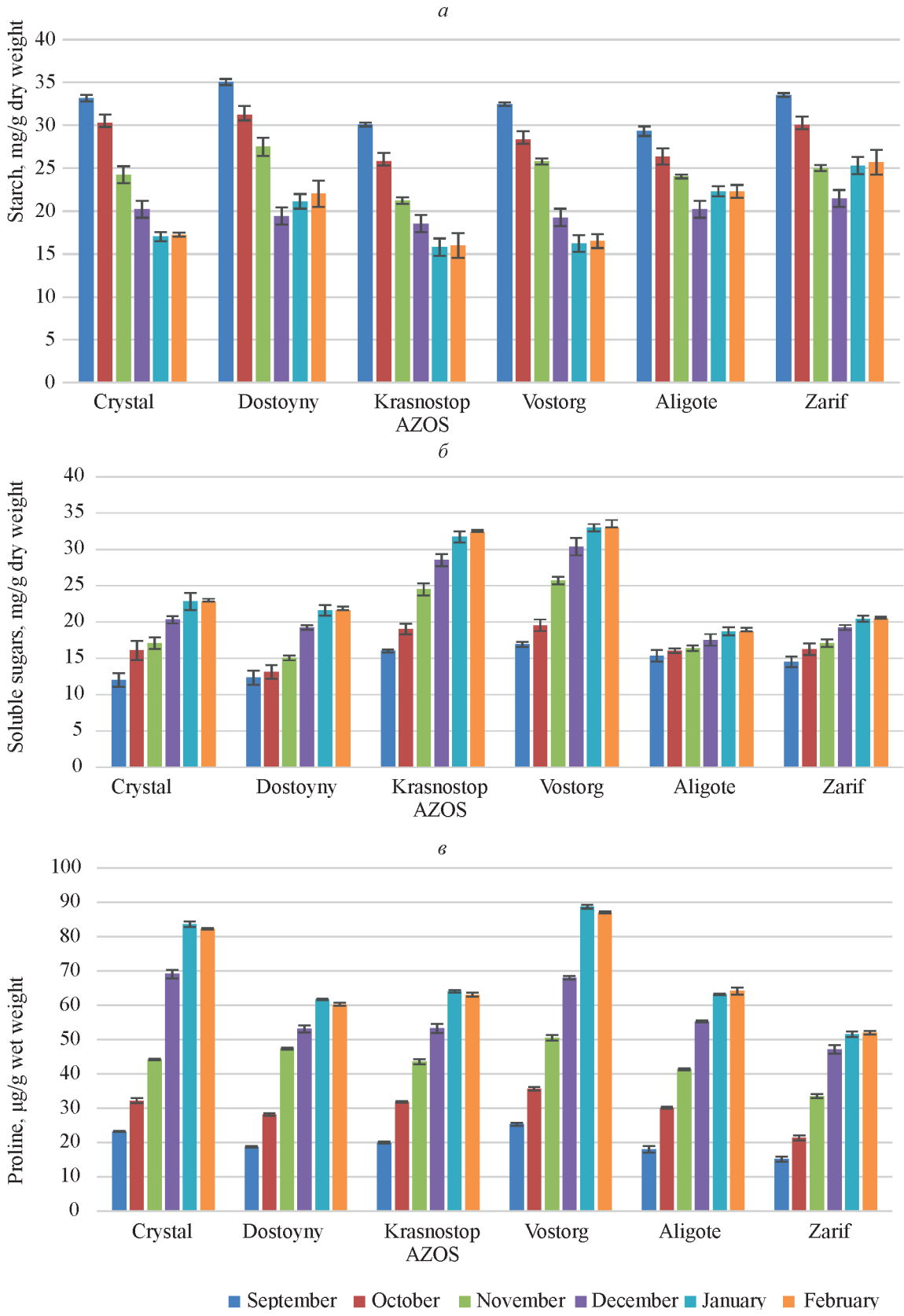

Рис. 2. Содержание крахмала (*а*), растворимых сахаров (*б*) и пролина (*в*) в побегах
Различия существенны между сортами и месяцами по *t*-критерию при $p \leq 0{,}05$.
Fig. 2. Starch (*а*), soluble sugars (*б*) and proline (*в*) content in the shoots
The differences are significant between the varieties and months by *t*-criterion at $p \leq 0.05$.

time of the end of starch hydrolysis, the content of soluble sugars reached 18.71-32.98 mg/g of dry weight. A negative correlation between the content of starch and soluble sugars was revealed (r = –0,88). Thus, in winter, enrichment of the shoots with sugars occurs due to the breakdown of starch. The most intensive process of conversion of starch into sugars was observed in the varieties Crystal, Krasnostop AZOS, Vostorg, as a result of which the content of sugars in these varieties increased by 1.90; 1.98 and 1.95 times, respectively. In comparison with them the concentration of sugars in Aligote and Zarif increased by 1.22 and 1.41 times.

One of the most important metabolites involved in the formation of frost resistance of plants is the amino acid proline. Studies have reported an increase in proline content in response to low temperatures in various berry and grain crops. However, the increase in its content, which is necessary to achieve a certain level of frost resistance, occurs only after exposure to hardening temperatures [8]. Thus, a sharp increase in proline content was observed during the hardening period in industrial table grape varieties [10].

In our studies in September, the increased level of proline was observed in the varieties Crystal, Krasnostop AZOS, and Vostorg at 20.01– 25.34 μg/g of crude weight (see fig. 2, c). Proline content increased until the middle of winter. While in September the value of this index reached 15.16–25.34 μg/g crude weight, in January it varied from 52.05 to 87.06 μg/g crude weight depending on the variety. In all the studied varieties, proline concentration increased by 3.20–3.60 times. A negative correlation between shoot water content and proline content was revealed; as shoot tissue water content decreased, the amount of proline increased. The average correlation coefficient r for September–February was equal to –0,47.

CONCLUSION

As a result of the conducted physiological and biochemical evaluation of six grape varieties of different ecological and geographical origin for frost resistance by indirect indicators of resistance, the highly frost-resistant varieties Vostorg, Crystal and Krasnostop AZOS have been selected.

For these varieties during the autumn-winter period the following features have been revealed:

1) greater reduction in shoot water content (by 13,54–15,11%) as compared to the Aligote and Zarif varieties, which had a decrease of 6,50–7,83%;

2) more complete hydrolysis of starch, as a result of which the content of sugars increased by 1.90–1.98 times, in Aligote and Zarif – by 1.22 and 1.41 times, respectively;

3) increased level of proline content by the beginning of the dormancy period (20.01–25.34 μg/g crude weight), in Aligote and Zarif it was 15.16–18.04 μg/g of crude weight.

Correlations between the studied physiological and biochemical parameters were established. A higher correlation was observed between water content and starch content (r = 0.91). The correlation coefficient between water content and proline content was equal to –0,47.

Thus, the high-frost-resistant varieties Vostorg, Crystal and Krasnostop AZOS can be used in breeding for the development of frost-resistant varieties.

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Эффективность использования аэро- и гидропонных установок при выращивании миниклубней картофеля

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Проведены исследования по выращиванию миниклубней картофеля четырех сортов на аэро- и гидропонных установках в сравнении с традиционным способом получения миниклубней (в поле). Лучший результат получен на аэропонных установках, урожай миниклубней с одного растения составил 54,1 шт., на гидропонных установках и в поле он был меньше в 5,0 и 5,6 раза. Сорта картофеля по-разному реагировали на контролируемые условия аэропоники и гидропоники. Более адаптированными оказались сорта Сокур и Златка с урожаем соответственно 77,8 и 60,0 шт. на аэропонике и 17,5 и 11,2 шт. на гидропонике. Менее адаптированными были сорта Лина и Сафо с урожаем на аэропонике 35,5 и 43,0 шт., на гидропонике – 8,0 и 6,1 шт. соответственно. Искусственные условия выращивания миниклубней картофеля и показания к уборке миниклубней по размеру, которые определяют зрелость клубня, не позволяли реализовать сортовой потенциал сорта по содержанию сухого вещества и крахмала. Недобор по этим показателям составляет в среднем 6,2 и 4,4% по аэропонным установкам и 6,7 и 4,2% – по гидропонике по сравнению с полевыми клубнями. Высокий урожай (число миниклубней с одного растения) – основной показатель при производстве исходного материала для семеноводства картофеля, он дает основание считать аэропонный метод получения миниклубней лучшей альтернативой традиционным способам получения материала в поле и теплицах. Данный метод позволяет значительно увеличить производство миниклубней, сократить процесс производства семенного материала за счет увеличения коэффициента размножения в питомниках.

Ключевые слова: картофель, аэропоника, гидропоника, миниклубни, клубнеобразование

Efficiency of using aeroponic and hydroponic plants in growing potato minitubers

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Studies on growing potato minitubers of four potato varieties on aeroponic and hydroponic plants in comparison with the traditional method of minitubers production (in the field) were carried out. The best result was obtained on aeroponic plants, the yield of minitubers from one plant amounted to 54.1 pieces, on hydroponic plants and in the field, it was less in 5.0 and 5.6 times. Potato varieties responded differently to controlled aeroponics and hydroponics conditions. The varieties Sokur and Zlatka were more adapted with the yields of 77.8 and 60.0 pieces, respectively, on aeroponics and 17.5 and 11.2 pieces on hydroponics. Lina and Safo varieties were less adapted with the yields of 35.5 and 43.0 pieces on aeroponics and 8.0 and 6.1 pieces on hydroponics, respectively. Artificial conditions for growing potato minitubers and indications for harvesting minitubers by size, which determines tuber maturity, did not allow to realize the varietal potential of the variety in terms of dry matter and starch content. Underperformance on these parameters averaged 6.2 and 4.4% for aeroponic plants and 6.7 and 4.2% for hydroponics compared to field tubers. High yield (number of minitubers from one plant) is the main indicator in the production of source material for potato seed production, it gives reason to consider the aeroponic method of minitubers production as the best alternative to traditional methods of material production in the field and greenhouses. This method allows to significantly increase the

production of minitubers, reduce the process of seed production by increasing the multiplication rate in nurseries.

Keywords: potato, aeroponics, hydroponics, minitubers, tuber formation

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Conflict of interest
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INTRODUCTION

At present, innovative technologies of potato minitubers production are coming to the forefront, which allow maximizing the acceleration of the process of potato seeds production on a healthy basis. The most promising methods are hydro- and aeroponic methods of plant cultivation, each of which has its pros and cons [1].

The use of modern technologies for obtaining potato minitubers with a high multiplication rate and preserving the effect of health improvement is an extremely urgent task, it is these technologies that will determine the prospects and efficiency of potato seed production [2, 3].

Aeroponics is a high-tech process of growing plants in an airy environment without the use of soil, in which nutrients are delivered to the plant roots in a form of a spray of aerosols [4, 5].

The main advantages of this technology are that this pathogen-free method of obtaining healthy plants (with a shortened vegetation period of plants) has a continuous process of growing minitubers without depending on weather and climatic conditions of the environment. The proposed method allows growing larger quantities of plants on limited planting areas than in the open ground or in a greenhouse. In addition, the absence of soil in this method eliminates sterilization of the substrate, control of relevant diseases and simplifies plant care. It significantly increases the multiplication rate, eliminates contamination of plants by vectors or other means [6].

The duration of vegetation of plants under aeroponics conditions, according to literature data, can be from four to eight months. During this period, 45 minitubers can be obtained from one plant. In traditional cultivation methods, one plant produces 4 to 8 minitubers within three to four months and they are harvested in one go. The new technology allows increasing the number of minitubers per plant to almost 100 pcs. According to some authors, the natural potential of plants can reach 250...300 minitubers per one plant[1] [7].

Not all tubers are harvested in one go, they are harvested over a longer period of time, which allows for a specific tuber size and stimulates the plant to form new tubers. All of this makes

[1]*Sadbekov D.Zh., Akhmetov S.G., Otto A.S., Demchuk E.V.* Aero-hydroponics. The role of research work of students in the development of agro-industrial complex: Collection of articles of the Russian scientific research conference. Omsk: Omsk SAU named after P.A. Stolypin, 2020, pp. 265–268. URL:www.elibrary.ru/item.asp?id=42620748&pff=1

it possible to get a higher yield for the same production costs.

15 years have passed since the introduction of hydroponic technologies, but these technologies have not become widespread in our country. The reasons are not straightforward: high cost of equipment, insufficient tuber formation, need for continuous energy supply, spread of infections through nutrient solutions. However, these technologies are very promising for potato multiplication compared to the traditional method of obtaining minitubers from microplants in the ground. Foreign colleagues compared the efficiency of minitubers production at an aeroponic facility in comparison with the traditional method of growing microplants in the ground. According to the study it was found that the yield on the aeroponic facility is 7 times higher [8].

The advantage of growing plants in an aeroponic facility compared to greenhouse conditions is the creation of optimal regulated temperature conditions and the frequency of tuber harvesting. Similar results were achieved in the experiments on hydroponic facilities [7]. Field tests of tubers obtained using aeroponics show that their quality and viability are not lower than those grown in the traditional way [9]. However, the production of minitubers on aeroponic facilities and ensuring the specified productivity are largely determined by the variety [10-12]. Moreover, the detected varietal characteristics do not always coincide with the characteristics of the variety in terms of the growing season duration, growth and development, and productivity of the variety when grown in an open ground. In order to increase the efficiency of new technologies, further study of variety behavior under new conditions is required.

The purpose of the research is to determine the efficiency of using aero- and hydroponic facilities in the production of potato minitubers.

MATERIAL AND METHODS

The study was conducted in 2017–2019. A single-tier aeroponic module and two-tier hydroponic plants were used. The traditional technology of growing minitubers in the field was used as a control.

The study included varieties of different maturity dates: medium-early – Lina and Safo, medium-maturing – Sokur and Zlatka. Each variety was planted on at least one plant or 16 plants. *In vitro* material obtained in the laboratory was used for growing minitubers. All plants were tested for virus content by a PCR method. The leaf area was determined by the die-cut method.

The cycle of operations on the plants began with the planting of test tube plants. Before planting, the plants were washed from the agarized medium. During vegetation, plants underwent three phases of ontogenesis: adaptation, active growth, and tuberization. The beginning of tuber formation and its end were marked.

For each phase, a regulation including duration of the photoperiod, temperature, nutrient solution composition, nutrient solution feeding mode, nutrient solution pH, salt content, and phase duration is presented. As the nutrient solution was consumed, it was replenished with the necessary amount of water. The nutrient solutions presented by the developers were used in the experiment.

GOST established a range of minitubers size from 9 to 60 mm for the category of minitubers, which was an indicator for harvesting. In the experiment, when determining plant productivity (the number of minitubers from one plant), harvesting was carried out every 3–5 days depending on the variety when minitubers reached the size of 15–20 mm. Mathematical processing of the yield data was carried out according to B.A. Dospekhov, for other indicators it was not carried out. The plot area in the open ground was 3.9 m2, there were five repetitions, one for analysis (dynamics of leaf area), single harvesting. Cultivation of experimental plants was carried out according to the technology adopted in seed production.

RESULTS AND DISCUSSION

Growth and development of plants on aeroponic and hydroponic plants were carried out under similar conditions as in the field. On average (for comparison of technologies) the

beginning of tuber formation was observed in field conditions in 48 days, in plants on aeroponic and hydroponic plants in 62 and 53 days, respectively. The vegetation period averaged 86 days in field conditions, 143 and 133 days in aeroponic and hydroponic conditions, respectively. The feature "early maturity" in growing potato minitubers on the installations lost its significance. Thus, the middle-early variety Safo on aeroponic facilities started tuberization later than all others, only on the 72nd day from planting, while the medium-maturing variety Zlatka began tuberization on the 65th day. On hydroponic facilities, the middle-early variety Lina started tuberization on the 60th day, as well as the medium-maturing variety Sokur (see Table 1).

One of the indicators that determine the productivity of plants is the leaf area. In this study, on average (to compare technologies) leaf area in all varieties regardless of maturity group had approximately the same value, 10 days after planting it amounted to 12.7-11.6 cm^2 on the plants, in the field it was 11.8 cm^2. The leaf area of the Zlatka variety during the period of intensive tuber formation was the largest and amounted to 0.8 m^2 on aeroponic plants, 0.3 m^2 on hydroponic plants and 0.9 m^2 in the field (see Table 2). With age, hydroponic plants were inferior in the value of leaf area to aeroponic and field plants.

The highest yield of minitubers was obtained on aeroponic plants, on average (for comparison of technologies) 54.1 tubers were harvested from one plant. Much less was obtained on hydroponic plants and in field conditions – 10.7 and 9.7 tubers per plant, respectively (see Table 3).

Among all, two varieties (Lina and Safo) marked as low-yielding varieties when grown under controlled conditions, on aeroponic and hydroponic facilities, they formed respectively 35.5–43.0 units on the first and 8.0–6.1

Табл. 1. Продолжительность основных периодов формирования урожая миниклубней (среднее за 2017–2019 гг.), сут

Table 1. Duration of the main periods of minitubers harvest formation (average for 2017–2019), days

Variety	Aeroponic facilities			Hydroponic facilities			Field conditions		
	The period from planting to		The period of tuberization	The period from planting to		The period of tuberization	The period from planting to		The period of tuberization
	the start of tuberization	the last harvest		the start of tuberization	the last harvest		the start of tuberization	the last harvest	
Sokur	63	143	80	60	127	67	55	86	36
Lina	50	124	74	60	128	68	50	86	36
Safo	72	157	85	41	140	99	38	86	48
Zlatka	65	150	85	50	137	87	50	86	36

Табл. 2. Динамика площади листьев растений картофеля в период выращивания (среднее за 2017–2019 гг.)

Table. 2. Dynamics of leaf area of potato plants during the growing period (average for 2017–2019)

Variety	Aeroponic facilities		Hydroponic facilities		Field conditions	
	10 days from the sowing, cm^2	Intense tuber formation period, m^2	10 days from the sowing, cm^2	Intense tuber formation period, m^2	10 days from the sowing, cm^2	Intense tuber formation period, m^2
Sokur	12,4	0,5	11,8	0,2	11,8	0,8
Lina	10,5	0,6	10,8	0,1	11,0	0,8
Safo	15,0	0,6	13,5	0,2	10,4	0,7
Zlatka	12,8	0,8	10,4	0,3	13,9	0,9

units on the second plants. Sokur and Zlatka varieties were the most productive in almost all cultivation variants, except for the field. Each plant of these varieties formed respectively: 77.8 and 60.0 pieces on aeroponic facilities, 17.5 and 11.2 pieces on hydroponic facilities. The highest number of minitubers per plant was obtained by the variety Sokur (77.8 pcs.), the lowest by the variety Lina (35.5 pcs.). The most productive varieties by the number of minitubers per plant in field conditions were Lina (10.4 pcs.) and Zlatka (11.2 pcs.). Aeroponic facilities with appropriate technology were much more efficient than hydroponic facilities and the field. Aeroponic technology produced an average of 54.1 pieces per plant, while hydroponic and field technology produced 5.0 and 5.6 times less, respectively.

Biochemical parameters of minitubers obtained on aero- and hydroponic plants had equal values for dry matter, starch and vitamin C, but significantly differed from field minitubers (see Table 4). The dry matter content of aerial and hydroponic minitubers was 14.9 and 14.4%, while that of field minitubers was 21.1%, or 1.4 and 1.5 times higher than that of minitubers from the facilities. Starch content of minitubers obtained in controlled conditions amounted to 6.6–6.4%, field – 10.8%, or was 1.7 times higher (see Table 4).

The content of vitamin C on average was marked approximately the same for all methods of minitubers production. Minitubers of the Safo, Zlatka and Lina varieties both on aeroponic and hydroponic facilities showed high values for dry matter and starch.

CONCLUSION

Minitubers obtained in the field, on modern facilities and according to modern technologies are the main and most common source material that is used in the establishment of the first field generation nursery.

Табл. 3. Продуктивность сортов картофеля при выращивании миниклубней (среднее за 2017–2019 гг.)
Table 3. Productivity of potato varieties in the cultivation of minitubers (average for 2017–2019)

Variety	Aeroponic facilities		Hydroponic facilities		Field conditions	
	Number of harvests	Number of minitubers from one plant	Number of harvests	Number of minitubers from one plant	Number of harvests	Number of minitubers from one plant
Sokur	13,3	77,8	9,0	17,5	1,0	8,6
Lina	14,0	35,5	13,0	8,0	1,0	10,4
Safo	16,0	43,0	14,0	6,1	1,0	8,6
Zlatka	15,2	60,0	14,0	11,2	1,0	11,2
LSD_{05}		7,3		4,2		4,1

Табл. 4. Биохимический состав сортов картофеля при выращивании миниклубней (среднее за 2017–2019 гг.)
Table 4. Biochemical composition of potato varieties in the cultivation of minitubers (average for 2017–2019)

Variety	Aeroponic facilities			Hydroponic facilities			Field conditions		
	Dry matter, %	Starch, %	Vitamin C, mg/100 g	Dry matter, %	Starch, %	Vitamin C, mg/100 g	Dry matter, %	Starch, %	Vitamin C, mg/100 g
Sokur	11,3	6,5	8,0	10,4	6,0	6,5	18,6	10,0	8,0
Lina	15,2	7,0	8,0	15,0	7,2	7,7	22,8	11,7	8,0
Safo	16,7	6,2	7,7	15,5	6,0	8,0	20,8	10,4	7,5
Zlatka	16,4	6,0	7,9	16,6	7,2	7,0	22,2	11,2	8,0

The best option for obtaining minitubers from the methods of soil-less plant cultivation is the aeroponic method. The efficiency of this method is determined by optimal conditions of tuber formation (the latter came when a sufficient leaf area of 0.6 m^2 was formed), high productivity of all the studied varieties in comparison with hydroponic and traditional (field) methods of minitubers production. On average it is possible to get 54.1 minitubers per plant on aeroponic facilities, while on hydroponics 5.0 times and in the field 5.6 times less. The success of growing minitubers on aeroponics and hydroponics is largely determined by the variety, yield fluctuations by variety can reach 46%, or 42.3 pieces per plant (varieties Sokur and Lina). The most productive varieties were Sokur and Zlatka both on aeroponics and hydroponics, the yield of minitubers per plant for these varieties was 77.8 and 60.0 pcs. on aeroponics and 17.5 and 11.2 pcs. on hydroponics, respectively.

The use of hydroponic facilities for growing minitubers is justified and effective, especially in view of year-round cultivation.

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Оценка коллекционных образцов сои по хозяйственным признакам и структуре листового аппарата

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Приведены результаты изучения хозяйственных признаков и морфологических показателей листьев коллекционных образцов сои, выращенных в условиях Приморского края. Установлено влияние структурных элементов листа на урожайность культуры. Научные исследования выполнялись с 2021 по 2023 г. в лаборатории селекции сои. Стабильные высокие значения урожайности наблюдали у сортов российского происхождения – Приморская 4 (277,1 г/м^2), Бриз (286,4 г/м^2), Приморская 13 (290,7 г/м^2). Крупносемянностью характеризовались 33,3% образцов сои (масса 1000 семян более 190 г). Высокое содержание белка в семенах (более 40%) сформировалось у образцов Киото, Бриз, Приморская 13; масла (более 24%) – Приморская 4, XN 4, Шарм. Крупным размером листовой пластинки характеризовались сорта XN 4 (237,8 см^2) и Бриз (180,7 см^2), мелким – НС Мина (101,3 см^2). Индекс площади листьев (ИПЛ) сортов варьировал от 5,5 до 8,7 м^2/м^2, высокие значения наблюдали у образцов Киото, Шарм, Бриз, XN 4. Максимальное содержание хлорофилла в листьях обнаружено в сортах Хей-хе 4 и Дочь Викинга. Выявлена сильная корреляционная связь продуктивности с индексом площади листа у 58,3% сортов сои. При увеличении площади листовой пластинки сорта снижали продуктивность, корреляция составляла от –0,05 до –0,98. С увеличением количества листьев на растении повышался уровень продуктивности сортов. При увеличении содержания хлорофилла в листьях сои снижалась продуктивность, за исключением двух среднераннеспелых сортов Киото и Хей-хе 4.

Ключевые слова: соя, сорт, коллекция, площадь листа, индекс площади листа, хлорофилл, продуктивность

Evaluation of soybean collection samples on economic traits and leaf apparatus structure

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The results of the study of economic traits and morphological indices of the leaves of collection samples of soybean grown in the conditions of the Primorsky Territory are presented. The influence of leaf structural elements on the crop yield was established. The research was performed from 2021 to 2023 in the Soybean Breeding Laboratory. Stable high yield values were observed in the varieties of Russian origin – Primorskaya 4 (277.1 g/m^2), Briz (286.4 g/m^2), Primorskaya 13 (290.7 g/m^2). 33.3% of soybean samples were characterized by large seeds (1000 seeds weight of more than 190 g). High content of protein in seeds (more than 40%) was formed in the samples Kyoto, Briz, Primorskaya 13; oil (more than 24%) – Primorskaya 4, XN 4, Charm. The large size of the leaf lamina was distinguished in the varieties XN 4 (237.8 cm^2) and Briz (180.7 cm^2), while the small size was observed in NS Mina (101.3 cm^2). Leaf area index (LAI) of the varieties ranged from 5.5 to 8.7 m^2/m^2, with high values observed in the accessions Kyoto, Charm, Briz, and XN 4.

Maximum chlorophyll content in leaves was found in the varieties Hei-he 4 and Doch Vikinga. A strong correlation between productivity and leaf area index was found in 58.3% of soybean varieties. As the leaf lamina area increased, varieties decreased in productivity, the correlation ranged from –0.05 to –0.98. As the number of leaves on the plant increased, the productivity level of the varieties increased. With increasing chlorophyll content in soybean leaves, productivity decreased, except for two medium-early maturing varieties Kyoto and Hei-he 4.

Keywords: soybean, variety, collection, leaf area, leaf area index, chlorophyll, productivity

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INTRODUCTION

Soybean is a common agricultural crop in the Far East. Due to the monsoon climate in the region, the maximum amount of precipitation is observed in the second half of summer, which provides plants with the necessary amount of moisture during critical phases of growth and development (flowering, bean formation and filling, green mass accumulation)[1] [1–3].

Soybean is sensitive to changes in environmental factors, their mismatch with the biological characteristics of the crop reduces its yield level[2] [4, 5].

To increase productivity and improve the quality of soybean yield, it is necessary to have forms and varieties with rational plant morphotypes capable of maintaining the maximum intensity of photosynthesis in different climatic conditions, which determines the yield by 90–95% [6]. The highest and most stable soybean yields can be obtained only in the crops where the formation of optimal leaf area in relation to certain cultivation conditions is observed. It has been established that in many respects the yield depends on the growth rate and duration of active leaf functioning and is closely related to the structure of the leaf apparatus [7, 8]. The leaf area of each variety is formed due to the combination of all its constituent elements, taking into account morphological differences, which is dynamic and constantly changing throughout the growing season [9, 10].

In order to study and identify a number of the issues related to production and physiological processes of soybean, the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K.Chaiki has formed a collection of varieties of various introductions which are subjected to comprehensive evaluation [11–13].

The purpose of the research was to study soybean samples of different origin by economic traits and morphological leaf parameters in the conditions of the Primorsky Territory and to determine the influence of leaf structure elements on the level of crop productivity.

MATERIAL AND METHODS

The research was carried out on the fields of the Soybean Breeding Laboratory of the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K.Chaiki (near Ussuriysk) in 2021–2023.

In 2021 weather conditions were characterized by increased air temperature and lack of

[1] *Mamonova A.G., Semenova E.A., Kamolykh V.O.* Change in the biochemical composition of soybean seeds during cultivation in different environmental conditions of the Far Eastern region // Far East Agrarian Herald, 2015, N 1 (33), pp. 34–39.

[2] *Lopatkina E.F., Ala A.Ya.* Morphophysiological analysis of soybean varieties and hybrids // Specific issues of genetics, biology and physiology of soybean: scientific and technical bulletin. VASKhNIL, Siberian Branch, Novosibirsk, 1977, vol. 7, 8, pp. 66–77.

precipitation. In 2022, the total amount of precipitation exceeded the average annual norms, 2023 differed from the previous year by prolonged periods of excessive moisture and increased temperature background (the average air temperature per month during the growing season of soybean exceeded the average annual values by 1.4–2.3 °C).

Soil of the experimental site was meadow-brown bleached soil with heavy mechanical composition, organic matter content of 2.5% with pH of the soil solution at 5.7.

The objects of research were 12 collection samples of soybeans from the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K.Chaiki of two groups of ripeness of different origin: Chinese (He Nong 62, XN 4, Hei-he 4), Serbian (NS Mina), Canadian (0331), American (Kyoto), Ukrainian (Charm), Russian (Doch Vikinga, Briz, Musson, Primorskaya 4, Primorskaya 13).

The experiments were conducted according to the methodology[3]. Cultivation of the crop was carried out in accordance with the agrotechnics adopted for the Primorsky Territory[4]. The seed sowing rate was 500 thousand seeds/ha, the area of one plot was 1.8 m^2. Sowing and harvesting were carried out manually.

Material description, phenological observations, yield estimation and records on the main economically valuable traits were carried out during the growing season of soybean according to the methodological guidelines[5, 6].

The sample size for analysis of leaf morphological parameters and productivity was 10 plants of soybean. Observations, counts and measurements of the elements of plant and leaf structure were carried out in the first ten-day period of August (from the 5th to the 10th day) during the bean filling phase. Leaf area index (LAI), characterizing the ratio of plant leaf area to soil area, was calculated according to the instructions[7].

The average area of the complex (triple) leaf (S_{tl}) was determined on the basis of field photographs of soybean leaves on millimeter paper with subsequent processing of the material in a specially developed program in the laboratory of cell biology and developmental biology of the Federal Scientific Center of the East Asia Terrestrial Biodiversity. The level of chlorophyll content in the leaf plate of soybean varieties was measured using the atLEAF CHL instrument (USA).

Calculation of mean values of the trait with setting the error of the sample mean and correlation analysis of straight-line dependence were performed according to the method of field experiment (see footnote 3) in the program Microsoft Office Excel for Windows.

RESULTS AND DISCUSSION

Duration of soybean vegetation period is one of the main varietal traits of the crop, which determines the possibility of genotype cultivation in certain climatic conditions. During the experiment, the variation of the indicator values depending on weather conditions was observed – in the mid-early maturing group from 102 to 109 days, in the mid-ripening group from 110 to 114 days (see Table 1). The least variation of this trait was observed in the samples Charm, 0331 and He Nong 62.

Lack of moisture, as well as its excess, can significantly reduce crop yields during critical periods of soybean development. The lowest yielding varieties were Doch Vikinga (160.0 g/m^2) and Hey-he 4 (167.3 g/m^2). The maximum values of yield by years were observed in the varieties of Russian selection – Primorskaya 4, Briz, Primorskaya 13. By the weight of 1000 seeds 33.3% of soybean samples were characterized

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

[4]*Chaika A.K., Tilba V.A., Moiseenko A.A. et al.* Adaptive and progressive technologies of soybean and corn cultivation in the Far East: method. recommendations. Vladivostok: Dalnauka, 2009, 139 p.

[5]Methodology of state variety testing of agricultural crops. Moscow, 1989, vol. 2, 194 p.

[6]*Korsakov N.I., Myakushko Yu.P.* Soybean. Methodical instructions on breeding and seed production. L.: VIR, 1975, 159 p.

[7]*Eshchenko V.E., Trifonova M.F., Kopytko P.G. et al.* Fundamentals of experimental work in crop production. Moscow: KolosS, 2009, 268 p.

Табл. 1. Хозяйственные показатели коллекционных сортов сои (среднее за 2021–2023 гг.), $X \pm Sx$
Table 1. Economic indicators of collection soybean varieties (average for 2021–2023), $X \pm Sx$

Variety	Yield, g/m²	Weight of 1000 seeds, g	Plant height, cm	Period of vegetation, days	Content in the seeds, %	
					oil	protein
Middle-early ripeness group						
Doch Vikinga	160,0 ± 50,9	170,7 ± 8,3	62,9 ± 8,6	102 ± 2,1	23,1 ± 1,3	37,1 ± 1,3
Kyoto	265,3 ± 64,1	198,3 ± 22,5	61,4 ± 19,0	109 ± 6,0	23,8 ± 1,3	41,4 ± 1,3
NS Mina	227,6 ± 87,3	146,3 ± 7,8	70,5 ± 11,8	107 ± 3,0	23,7 ± 1,4	39,0 ± 2,3
Hei-he 4	167,3 ± 55,6	180,0 ± 6,2	46,1 ± 10,4	102 ± 5,3	23,0 ± 1,1	40,1 ± 0,7
Charm	272,2 ± 84,2	166,0 ± 25,2	69,2 ± 14,5	106 ± 1,8	24,4 ± 1,9	37,6 ± 2,6
Middle ripeness group						
Primorskaya 4	277,1 ± 77,0	166,7 ± 11,5	73,8 ± 26,3	110 ± 3,0	24,2 ± 2,1	35,3 ± 0,6
0331	262,3 ± 84,8	175,3 ± 4,6	61,9 ± 18,9	111 ± 1,5	23,7 ± 1,6	38,4 ± 2,6
He Nong 62	227,9 ± 38,0	195,7 ± 14,4	62,3 ± 8,7	110 ± 0,6	23,5 ± 1,7	39,0 ± 2,9
XN 4	181,0 ± 59,3	174,3 ± 9,3	72,0 ± 20,3	114 ± 3,6	24,7 ± 1,7	36,9 ± 3,2
Briz	286,4 ± 68,7	198,3 ± 23,6	63,7 ± 19,0	114 ± 4,0	22,2 ± 1,5	41,0 ± 0,7
Musson	181,3 ± 23,0	162,0 ± 18,4	73,2 ± 26,2	113 ± 2,9	21,9 ± 1,0	40,0 ± 2,0
Primorskaya 13	290,7 ± 75,0	193,3 ± 15,3	74,0 ± 26,3	112 ± 2,1	22,2 ± 1,3	40,8 ± 0,8
$LSD_{0,95}$	52,4	20,7	11,3	4,1	1,1	2,5

by large-seededness, the indicator of which ranged from 193.3 to 198.3, g. The varieties Hei-he 4 and 0331 were stable in this trait.

All varieties in the trial had average plant height, except for the Chinese sample Hei-he 4. Stably high protein content (more than 40%) during three years of study was observed in the samples Kyoto, Briz, Primorskaya 13. Varieties Primorskaya 4, XN 4, Charm were distinguished by oil content (more than 24%).

One of the conditions for the organization of effective breeding is knowledge of the morph-ophysiological type of the initial forms that are planned to be used in hybridization. Soybean lacks mechanisms to restrain leaf lamina growth and is predisposed to the formation of excessive leaf area, which increases the risk of excessive transpiration and a tendency to lodging of plants.

According to the results of observations, the average area of soybean complex leaf in the studied samples varied by years and ranged from 101.3 to 237.8 cm² (see Table 2). Varieties XN 4 (237.8 cm²) and Briz (180.7 cm²) were characterized by the largest leaf lamina size, while NS Mina (101.3 cm²) appeared to be the smallest. Significant variation in the leaf area was present in soybean accessions Charm (± 76.5) and 0331 (± 64.0 cm²).

With the same value of stem density on the plot (40.3 plants/m²), the samples Doch Vikinga and Briz formed a greater number of lateral branches compared to the others, which in this case is their varietal peculiarity. The lower density of XN 4 plants did not contribute to the formation of a greater number of additional branches.

The leaf area index (LAI) of the varieties ranged from 5.5 to 8.7 m²/m². The index above 8.0 m²/m² was observed in soybean samples both in the mid-early ripeness group (Kyoto, Charm) and in the middle (Briz, XN 4). In the

Табл. 2. Морфологические показатели листьев и растений сои (среднее за 2021–2023 гг.), $X \pm Sx$
Table 2. Morphological parameters of soybean leaves and plants (average for 2021–2023), $X \pm Sx$

Variety	LAI, m^2/m^2	Number of leaves, pcs ./plant	$S_{тл}$,cm^2	Density of stem stand, plants/m^2	Number of lateral branches, pcs ./plant	Chlorophyll, units
Middle-early ripeness group						
Doch Vikinga	6,3 ± 2,8	11,3 ± 3,6	133,5 ± 14,8	40,3 ± 7,8	2,7 ± 0,6	46,8 ± 4,5
Kyoto	8,5 ± 3,3	12,8 ± 2,1	156,1 ± 45,3	43,0 ± 7,9	0,7 ± 0,3	43,9 ± 1,0
NS Mina	6,1 ± 1,9	13,1 ± 1,7	101,3 ± 12,8	45,0 ± 7,9	1,7 ± 0,6	42,7 ± 3,2
Hei-he 4	6,1 ± 1,8	10,7 ± 1,9	145,2 ± 58,3	41,3 ± 7,6	0,8 ± 0,3	47,6 ± 2,5
Charm	8,7 ± 5,0	11,0 ± 1,0	174,1 ± 76,5	44,0 ± 5,3	0,7 ± 0,4	45,8 ± 3,3
Middle ripeness group						
Primorskaya 4	7,1 ± 2,1	10,5 ± 1,5	170,8 ± 57,4	40,3 ± 5,5	1,3 ± 0,4	42,4 ± 3,9
0331	6,1 ± 2,7	12,7 ± 3,7	131,4 ± 64,0	39,3 ± 6,1	1,3 ± 0,1	44,6 ± 4,3
He Nong 62	5,5 ± 1,3	10,4 ± 1,9	133,7 ± 15,5	39,7 ± 2,3	0,4 ± 0,4	43,0 ± 1,9
XN 4	8,2 ± 0,4	10,6 ± 0,6	237,8 ± 39,6	33,7 ± 8,1	0,5 ± 0,6	41,6 ± 4,1
Briz	8,7 ± 2,3	11,8 ± 1,4	180,7 ± 22,6	40,3 ± 5,5	2,3 ± 0,6	44,5 ± 2,6
Musson	7,7 ± 1,4	12,9 ± 1,3	138,1 ± 25,8	43,3 ± 2,1	0,6 ± 0,3	40,3 ± 5,1
Primorskaya 13	7,9 ± 2,4	11,2 ± 0,9	163,5 ± 53,4	44,0 ± 5,3	1,5 ± 0,3	40,1 ± 2,0

Note. LAI – leaf area index; $S_{тл}$ – compound leaf average area.

previously conducted studies in the conditions of the Primorsky Territory typical results were obtained on another set of soybean varieties[8], the variation of this trait was 6.0–8.0 m^2/m^2.

The difference in the number of leaves per plant was insignificant and amounted to 10.4–13.1 pieces. Chlorophyll content in the leaves of the middle-early soybean group was higher than that of the medium-ripening group. The maximum value of chlorophyll was formed in the leaves of Hei-he 4 and Doch Vikinga varieties.

A search for relationships between the values (see Table 3) was performed to establish the influence of the plant and leaf structure elements on the formation of productivity of soybean varieties.

Table 3 shows the variation of the correlation index over the test period, the value of which did not significantly change by years. The result of the correlation analysis revealed a strong direct reliable relationship between the productivity and the leaf area index in 58.3% of soybean varieties, negative strong dependence was observed in XN 4. It was found that the productivity of soybean varieties positively depended on the number of leaves, which changed in a greater direction with increasing plant height. The opposite phenomenon was characteristic of the Serbian variety NS Mina. Basically, soybean varieties decreased productivity with increasing leaf lamina area, there was an inverse correlation with different level of relationship (from -0.05 to -0.98), except for the variety 0331, the value of productivity of which increased with the formation of leaf lamina of a larger size. It should be noted that the level of productivity of middle-early ripeness group varieties decreased to a lesser extent.

The formation of productivity level depending on the number of lateral branches occurred individually for each variety, which reacted differently to the increase/decrease in the number

[8] *Vashchenko A.P., Mudrik N.V., Fisenko P.P., Dega L.A., Chaika N.V., Kapustin Y.S.* Soybean in the Far East. Vladivostok: Dalnauka, 2014, 435 p.

Табл. 3. Коэффициенты корреляции (*r*) между продуктивностью и элементами структуры растения и листа сои, 2021–2023 гг., r_{min}–r_{max}

Table 3. Correlation coefficients (*r*) between yield and elements of plant and soybean leaf structure, 2021–2023, r_{min}–r_{max}

Variety	LAI	Number of leaves	$S_{тл}$	Number of lateral branches	Chlorophyll
Middle-early ripeness group					
Doch Vikinga	0,54…0,92	0,37…0,52	0,06…0,10	–0,89…–0,96	–0,19…–0,49
Kyoto	0,97…1,00	0,34…0,60	–0,13…–0,31	–0,77…–0,90	0,40…0,71
NS Mina	0,00…0,07	–0,52…–0,78	–0,05…–0,32	–0,87…–0,98	–0,67…–0,93
Hei-he 4	0,42…0,69	0,92…1,00	–0,25…–0,43	0,00…–0,04	0,98…1,00
Charm	0,94...1,00	0,97…0,99	–0,16…–0,41	0,21…0,46	–0,71…–0,86
Middle ripeness group					
Primorskaya 4	0,97…1,00	0,21…0,46	–0,10…–0,23	0,00…0,04	–0,59…–0,71
0331	0,82…0,96	0,72…0,93	0,53…0,70	–0,50…–0,74	–0,90…–0,98
He Nong 62	0,72…0,91	0,91…0,98	–0,92…–0,98	0,81…0,93	–0,77…–0,95
XN 4	–0,87…–0,98	0,93…0,98	0,07…0,11	0,66…0,92	–0,68…–0,73
Briz	0,93…1,00	0,89…0,96	–0,62…–0,79	–1,00…–1,00	–0,93…–0,99
Musson	0,95…0,99	0,36…0,50	–0,62…–0,85	0,00…–0,07	–0,81…–1,00
Primorskaya 13	0,61…0,89	0,98…1,00	–0,42…–0,53	–0,94…–1,00	–0,96…–0,99

of additional branches. Inverse correlation with a complete connection by years was characteristic of the variety Briz. When the chlorophyll content of soybean leaves increased, productivity decreased, except for two mid-early maturing varieties Kyoto and Hei-he 4.

CONCLUSION

High yield values were observed in soybean varieties of the Russian selection (Primorskaya 4, Briz, Primorskaya 13). Large seeds (1000 seeds weight index of more than 190 g) were distinguished in 33.3% of soybean samples. High content of protein in the seeds (more than 40%) was formed by the varieties Kyoto, Briz, Primorskaya 13; oil (more than 24%) by Primorskaya 4, XN 4, Charm. The average area of complex leaf of soybean samples varied by years from 101.3 to 237.8 cm^2. The largest size of leaf lamina was characteristic of the varieties XN 4 and Briz, small size was typical of NS Mina. Leaf area index above 8.0 m2 / m2 was observed in soybean samples in the medium-early ripeness group (Kyoto, Charm) and medium (Briz, XN 4). The maximum chlorophyll content was formed in the leaves of the varieties Hei-he 4 and Daughter of Viking. A strong direct correlation between productivity and leaf area index was found in 58.3% of soybean varieties. Soybean productivity positively depended on the number of leaves. The varieties decreased productivity with increasing plant leaf area (r r ranged from –0.05 to –0.98) and chlorophyll levels in soybean leaves.

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Сравнительная урожайность сортов озимой ржи на легких почвах дерново-подзолистого типа

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В Нечерноземной зоне Российской Федерации, в частности в условиях Брянского региона, складывается тенденция снижения посевных площадей озимой ржи, но при этом отмечен рост урожайности зерна с 1,74 до 3,10 т/га. Однако практическое использование почвенно-климатических условий региона позволяет получать урожайность зерна озимых зерновых культур до 8,0 т/га. Озимая рожь обладает высоким потенциалом урожайности за счет использования новых перспективных сортов, обладающих хорошими характеристиками качества зерна. В 2024 г. Государственной комиссией по охране селекционных достижений выдан патент на сорт диплоидной озимой ржи Новозыбковская нива. За годы конкурсного испытания (2020–2023) урожайность зерна колебалась от 4,50 до 6,66 т/га с числом падения от 200 до 260 с. Сорт обладает разным типом колоса: четырехрядный (тип 2), шестирядный (тип 3) и ветвистый (тип 2а) в соотношении 40 : 5 : 55%. Высота растений не превышает 150 см, число продуктивных стеблей изменялось от 6 до 20 шт., масса зерна с колоса – 1,5–3,0 г, масса 1000 семян – 33–40 г. Конкурсное сортоиспытание за 2020–2021 гг. с сортами Валдай (стандарт), Московская 12, Пикассо и селекционным номером СН-251-14-150 показало, что он по урожайности зерна превосходил отечественные на 0,73–0,92 т/га (с нормой высева 2 млн всхожих зерен/га), на 0,55–0,70 т/га (4 млн зерен/га), на 0,71–1,01 т/га (6 млн зерен/га) и иностранный – на 0,46–0,45 т/га (2 и 6 млн зерен/га). При аналогичном испытании в 2022 и 2023 гг. с сортами Пикассо, Этерно, Пабо, Валдай и Московская 12 и с нормой высева 4 млн зерен/га (170 кг/га) он оказался более урожайным относительно отечественных – на 0,40–0,52 т/га и зарубежных – на 0,78–1,75 т/га.

Ключевые слова: озимая рожь, селекция, конкурсное сортоиспытание, сортообразец, продуктивность стеблей, урожайность

Comparative yield of winter rye varieties on light soils of sod-podzolic type

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In the Non-Black Earth zone of the Russian Federation, in particular in the conditions of the Bryansk region, there is a tendency of a decrease in sown areas of winter rye, but at the same time the growth of grain yield from 1.74 to 3.10 t/ha has been noted. However, the practical use of the soil and climatic conditions of the region makes it possible to obtain up to 8.0 t/ha of winter grain crops. Winter rye has a high yield potential due to the use of new promising varieties with good grain quality characteristics. In 2024, the State Commission for the Protection of Breeding Achievements granted a patent for a variety of diploid winter rye Novozybkovskaya niva. During the years of competitive testing (2020–2023), grain yields ranged from 4.50 to 6.66 t/ha with a drop rate of 200 to 260 C. The variety has different ear types: four-row (type 2), six-row (type 3) and branched (type 2a) in a ratio of 40:5:55%. The height of the plants does not exceed 150 cm, the number of productive stems varied from 6 to 20 pcs., the weight of grain per ear is 1.5–3.0 g, the mass of 1000 seeds is 33–40 g. Com-

petitive variety trial for 2020–2021 with the varieties Valdai (standard), Moskovskaya 12, Picasso and the selection number CH-251-14-150 showed that it exceeded domestic grain yields by 0.73–0.92 t/ha (with a seeding rate of 2 million grains/ha), by 0.55–0.70 (4 million grains/ha), by 0.71–1.01 t/ha (6 million grains/ha) and foreign at 0.46–0.45 t/ha (2 and 6 million grains/ha). In a similar test for 2022 and 2023, with Picasso, Eterno, Pabo, Valdai and Moskovskaya 12 varieties and a seeding rate of 4 million (170 kg/ha), it turned out to be more productive than all of them: domestic by 0.40–0.52 t/ha and foreign by 0.78–1.75 t/ha.

Keywords: winter rye, breeding, competitive variety trial, variety sample, stem productivity, productivity

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INTRODUCTION

Winter grain crops have significant advantages over spring crops in terms of productivity, which is associated with the peculiarities of climatic conditions in 2010s (late autumn, low snowfall winter, early spring with dry April and May, 2–3-week periods without precipitation or with insignificant precipitation during the summer) and other factors [1, 2]. Winter rye for the zone of soils with light mechanical composition is a strategic crop that affects food security [3–5]. It has the lowest requirements for soil fertility, fertilizers and chemical plant protection. In terms of total nutritional value, bread from rye flour has a low-calorie content, it is more nutritious due to the content of calcium, phosphorus, fiber, vitamin B1 [6–9].

Taking into account all the above-mentioned circumstances, the Novozybkovskaya farm since 1930 was engaged in winter rye breeding and achieved certain successes: Novozybkovskaya 4 and 24, Krupnozernaya and Novozybkovskaya 150 varieties were created. The Chernobyl accident stopped breeding work and the material was lost.

Starting from 2012, the research was resumed from 300 grains of the former variety Novozybkovskaya 150 obtained from the collection of the N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR), by individual single-family perennial selections. In 2020 a new varietal material SN-251-14-150 of winter rye was created and a patent for a breeding achievement diploid variety of winter rye Novozybkovskaya niva was obtained in 2024[1, 2] [10–14].

The purpose of the research is to compare the yield of different varieties of winter rye on the soils of light mechanical composition of sod-podzolic type in combination with the emerging climatic conditions of the south-west of the Bryansk region.

MATERIAL AND METHODS

The work was carried out during 2020-2024 at the Novozybkovskaya agricultural experimental station located in the south-west of the Bryansk

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region on sod-podzolic sandy soil of light mechanical composition (humus content 1.0–1.2%, sub-mobile phosphorus and exchangeable potassium (according to Kirsanov) – 200–250 and 5–7 mg/kg at slightly acidic reaction of soil solution).

The research is aimed at restoration of winter rye variety Novozybkovskaya 150 by continuous individual and single-family selection in order to create a new variety material on a number of indicators: stalk height, ear length, number of spikelets in an ear, productive bushiness, grain yield per ear, using the method of "halves".

Nursery planting was carried out in the second ten-day period of September. Sowing took place under different moisture conditions: autumn 2020 and 2023 – dry (HTC – 0.5), optimal (HTC – 0.9) in 2019, humidified in 2021– 2022 (HTC – 2.3 and 3.0, respectively). Plants went into wintering in good condition with 5–8 stems tillering[3–5] [12, 15, 16].

When forming winter rye populations of new plant morphotypes in the following years, they were multiplied and studied in a competitive trial with varieties cultivated in the Bryansk region (Valdai (standard), Moskovskaya 12), and foreign varieties with CMS (cytoplasmic male sterility) (Picasso, Pabo, Eterno). The plot area was 5 m^2 in 4–6-fold repetition in 2020–2021 with seeding rates of 2, 4, 6 million germinating grains/ha, in 2022–2023 – 4 million germinating grains/ha. A part of seed material of PR-1 was tested under production conditions. Statistical processing of the data was carried out according to B.A. Dospekhov.

RESULTS AND DISCUSSION

Scientists have noted that selection for high-yielding varieties is not always combined with adaptability to adverse climate factors and therefore they rarely realize their potential, especially under production conditions. Breeding aimed at increasing yield and at the same time for resistance to growing conditions is not always successful.

The results of our research confirm this conclusion: all cultivated winter rye varieties are not adaptive to unfavorable factors of climatic conditions (see Table 1).

The maximum yield of all varieties was observed in 2020 under optimal climatic conditions of vegetation. It is worth noting that selection number SN-251-14-150 was not inferior to the variety with CMS Picasso, which was most widespread at the beginning of the second millennium in the Bryansk region. In 2021 May was abundant in precipitation (HTC – 2.9), June with HTC – 0.5 was dry, which affected the poor grain filling. In the first ten days of July, heavy rain (HTC - 3.5) and "threshed" the ear, which sharply reduced yields: in SN-251-14-150 (2.4–2.5 times), Valday (2.6–3.4), Moskovskaya 12 (2.3–3.1) and Picasso (2.6–3.9 times) relative to the previous year. However, in two years (2020 and 2021) SN-251-14-150 at seeding rates of 2 and 6 million grains/ha exceeded the Picasso variety by 0.46 and 0.45 tons/ha and was of the same level at 4 million grains/ha. Winter rye yield of domestic varieties Valdai (standard) and Moskovskaya 12 was lower than the selection number 251-14-150 by 0.55–0.92 and 0.73–1.01 t/ha, respectively (see Table 2).

In 2022–2023 two foreign varieties Eterno and Pabo were included in the competitive variety trial with the experimentally established optimal seeding rate of 4 million germinating grains/ha. The growing conditions of winter rye were characterized by uneven precipitation: 2022 was more optimal. Two-week dry periods in May and June affected grain yield, reducing it by 17–39% relative to 2020, with a lower value for Moscow 12 and a higher value for Picasso.

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Табл. 1. Метеорологические условия за весеннюю вегетацию озимой ржи
Table 1. Meteorological conditions for the spring growing season of winter rye

Indicator		Year															
		2020				2021				2022				2023			
		Ten-day period															
		IV	V	VI	VII	IV	V	VI	VII	IV	V	VI	VII	IV	V	VI	VII
Air temperature, °C	Average	9,2	13,1	23,6	20,8	7,8	14,5	22,5	25,0	7,1	14,0	23,1	20,6	11,3	15,5	19,6	20,8
	Long-time average annual	7,4	15,0	18,4	20,0	7,4	14,9	18,4	20,0	7,4	14,9	18,5	20,1	7,4	14,9	18,6	20,0
Precipitation, mm	Sum	7,4	107,7	73,9	50,5	41,7	126,7	33,9	103,4	130,9	44,5	35,2	67,0	68,2	26,2	88,8	104,4
	Long-time average annual		53,5	71,1	81,0	37,9	54,1	71,1	80,8	37,8	54,8	70,7	81,0	38,8	54,6	70,3	80,9
HTC	Sum		2,7	1,0	0,8	0,8	2,9	0,5	1,4	0,9	1,0	0,5	1,2	2,2	0,6	1,5	1,7
	Long-time average annual		1,1	1,3	1,3	1,3	1,1	1,3	1,3	1,2	1,1	1,3	1,2	1,1	1,3	1,3	1,2

Табл. 2. Урожайность зерна озимой ржи в конкурсном испытании 2020–2023 гг., т/га
Table 2. Yield of winter rye grain in the competitive trial of 2020–2023, t/ha

Year	Seeding rate, million germinating grains/ha	CH-251-14–150	Valdai (standard)	Moskovskaya 12	Picasso	Pabo	Eterno
2020	2	6,60	5,88	5,90	6,63		
	4	6,28	5,60	5,04	6,42		
	6	6,66	6,10	5,30	6,43		
2021	2	2,65	1,54	1,90	1,71		
	4	2,56	2,15	2,24	2,46		
	6	2,79	1,92	2,11	2,10		
2022	4	4,55	3,90	4,21	3,89	3,77	3,84
2023	4	3,32	2,92	2,85	0,47	2,08	2,46
Average for 2020–2021	2	4,63	3,71	3,90	4,17		
	4	4,42	3,87	3,64	4,44		
	6	4,72	4,01	3,71	4,27		
Average for the norm of 4 million germinating grains/ha		4,18	3,64	3,58	3,31	2,52	3,15
LSD_{05}		0,29	For the first four varieties				

Winter rye grain yield in 2022 showed that it was at the level of the Picasso variety (3.89 t/ha) at 3.77 and 3.84 t/ha for the two new foreign varieties Pabo and Eterno. In 2023 it decreased by 46 and 36%. In 2023 climatic conditions were more arid: for two ten-day periods of April, the whole of May and the first two ten-day periods of June (71 days) 63.3 mm (annual average 125.9 mm) of precipitation was observed. Phases of winter rye development (trumpeting, flowering and the beginning of grain filling) were reduced by 7–10 days in total. Precipitation (117.8 mm) from 25.06 to 10.07 (long-term average 63.1 mm) contributed to the "expiration" of grain with a 44-48% decrease in the yield of domestic varieties.

Results of the data analysis of the studied varieties on grain yield at a seeding rate of 4 million germinating grains/ha varied significantly by year, but on average (for four years) in the

sample SN-251-15-150 it was higher than the variety Valday (standard) by 0.54 t/ha, variety Moskovskaya 12 by 0.60 t/ha and Picasso according to the data of three years (without taking into account 2023) by 0.20 t/ha, taking into account 2023 by 0.87 t/ha.

The seed material of the 2022 harvest for domestic winter rye varieties and varieties with CMS Picasso was used for nursery competitive varietal testing in 2023. By harvesting, 200 plants were preserved on 1 m^2 in the variety Moskovskaya 12 and the sample CH-251-14-150, Eterno – 120, Pabo – 80 and Picasso – 30. Consequently, for cultivation of the Picasso variety in order to obtain high grain yields annual purchase of F1 hybrid seed is necessary, which is not always economically viable, as unfavorable climatic conditions significantly reduce productivity (0.47 t/ha).

Thus, the selection number CH-251-14-150 turned out to be more adapted to soils of light mechanical composition of sod-podzolic type and to those climatic conditions, which were formed during the last years during the growing season.

The variety SN-251-14-150 has significant morphobiological differences of plants relative to the variety with CMS Picasso (see Table 3). It is medium-sized, heterogeneous in stem, characterized by greater width and length of the middle and flag leaf in flowering, the stem is thick, strong and elastic, productive in the autumn and spring tillering, having three types of spikelets forms significantly more spikelets, and due to this higher weight of grain from one spikelet. Considering that the seed material of domestic varieties for PR-1 is used three or four years in the cultivation of winter rye, it can be reported about their economic benefits relative to foreign varieties.

Thus, the selection number CH-251-14-150 turned out to be more adapted to the soils of light mechanical composition of sod-podzolic type and to those climatic conditions, which were formed during the last years during the growing season.

CONCLUSION

The results of the studies on winter rye yield of various domestic and foreign varieties indicate the effectiveness of cultivation of the variety Novozybkovskaya niva, created on light soils of sod-podzolic type. At an optimum seeding rate of 4 million germinating grains/ha (170

Табл. 3. Морфобиологические различия растений озимой ржи
Table 3. Morphobiological differences of winter rye plants

Variety sample	Morphobiological index								
	Flowering phase								
	Height, cm	Ear length, cm	Middle leaf		Flag leaf		Tillering		Productive bushiness, pcs.
			Width, cm	Length, cm	Width, cm	Length, cm	autumn, pcs.	spring, pcs.	
CH-251-14-150	120-130	16	1,78	24,8	1,2	1,52	13	8	21
Picasso	115-127	12	1,44	21,7	1,1	1,39	11	5	16

Ripening phase

Variety sample	Height, cm	Ear length, cm	Tiering	Internode		Straw thickness (bottom top), mm	Ear type	Number of spikelets, pcs.	Number of productive stems, pcs.	Weight of grain per ear, g
				lower, cm	upper, cm					
CH-251-14-150	127	15	1–3	2–4	35–40	5–6 2,0–2,5	2, 2a,3	42–63	14–16	2,5
Picasso	124	11	1,0	2–3	26–28	3–4 1,5–2,0	2	40–42	7–10	2,0

kg/ha), it is able to give an average of up to 10 productive strong elastic stems, which excludes lodging, with a yield potential of up to 8.0 tons/ha, as it has three types of ear: four-row (type 2) (40%), six-row (type 3) (5%) and branched (type 2a) (55%), where five to six rows in the middle of the last two types of spikelets produce 10 to 24 full-grown grains depending on growing conditions.

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Новый сорт клевера лугового Ассоль

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Одноукосные позднеспелые сорта, которые возделывают в зонах клеверосеяния Западно- и Восточно-Сибирского регионов, не удовлетворяют в полной мере потребностям производства. Они созревают в основном в конце сентября во время обильных осадков, что затрудняет уборку семян и ведет к большим потерям урожая. Низкая урожайность приводит к постоянному дефициту семян. Создание наряду с позднеспелыми раннеспелых сортов актуально для Сибирского региона и Российской Федерации в целом. Представлены исследования по созданию сорта клевера лугового Ассоль раннеспелого типа на тетраплоидной основе с урожайностью сухого вещества 60–70 ц/га, семян – 1,5–2,0 ц/га, зимостойкого, более устойчивого к основным болезням. В условиях искусственного климата методами гибридизации, полиплоидии и отборов создана гибридная популяция 16-9-Т(4×). Дальнейшие исследования продолжены в 2006–2021 гг. в условиях лесостепи Западной Сибири. Проведены отборы зимостойких высокоурожайных форм из сложногибридной популяции 16-9-Т(4×). Созданная популяция испытана в трех циклах конкурсного сортоиспытания (посев 2013, 2015, 2017 гг.). Сорт Ассоль раннеспелого типа на тетраплоидной основе показал высокую зимостойкость – 97%. Продолжительность вегетационного периода составляет 114 дней. Средняя урожайность зеленой массы за два укоса 451 ц/га, сухого вещества – 89,2, семян – 1,67 ц/га. Сорт отличается устойчивостью к мучнистой росе и фузариозу, отзывчив на увлажнение как в первой, так и во второй половине лета, формируя высокий урожай первого и второго укосов. С 2024 г. сорт Ассоль включен в Государственный реестр селекционных достижений, допущенных к использованию по Западно-Сибирскому региону Российской Федерации.

Ключевые слова: клевер луговой, селекция, гибридизация, полиплоидия, отборы, сорт, урожайность

New variety of meadow clover Assol

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Single-cut late maturing varieties cultivated in clover-sowing areas of the Western and Eastern Siberian regions do not fully meet the needs of production. They ripen mostly in late September during heavy rainfall, which makes seed harvesting difficult and leads to high yield losses. Low yields lead to a constant shortage of seeds. Creation of early maturing varieties along with late maturing varieties is relevant for the Siberian region and the Russian Federation as a whole. The research on creation of early maturing meadow clover Assol variety on tetraploid basis with dry matter yield of 60–70 c/ha, seed yield of 1.5–2.0 c/ha, winter-hardy, more resistant to major diseases is presented. A hybrid population of 16-9-T (4×) was established under artificial climate conditions by hybridization, polyploidy and selection methods. Further studies were continued in 2006-2021 in the conditions of the forest-steppe of Western Siberia. Selections of winter-hardy high-yielding forms from the complex-hybrid population

16-9-T (4×) were made. The established population was tested in three cycles of competitive variety trials (sowing of 2013, 2015, 2017). Early maturing Assol variety on tetraploid basis showed high yield – 97.0%. The duration of the vegetation period is 114 days. Average yield of green mass for two harvests was 451 c/ha, dry matter – 89.2, seeds –1.67 c/ha. The variety is characterized by resistance to powdery mildew and fusarium, responsive to moisture both in the first and second half of summer, forming a high yield of the first and second cut. Since 2024 the Assol variety has been included in the State Register of Breeding Achievements approved for use in the West Siberian region of the Russian Federation.

Keywords: meadow clover, breeding, hybridization, polyploidy, selections, variety, yield

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INTRODUCTION

In the conditions of Western Siberia, the problem of fodder supply is acute. Short growing season and lack of heat lead to variation in forage and seed yields of meadow clover and decrease in forage quality in some years [1]. Meadow clover is the most important high-protein crop for fodder production, capable of accumulating nitrogen in the soil, improving physical and chemical properties[1] [2, 3].

114 varieties of meadow clover have been released in different zones of the Russian Federation as of 2024, including 18 on a tetraploid basis. In Siberia, 28 varieties are released, three of them on a tetraploid basis (Delets, Meteor, Assol)[2].

Eight varieties of meadow clover were developed in the breeding center of the Siberian Federal Scientific Centre of Agro-BioTechnologies (SFSCA RAS) from 1976 to 2024 using different selection and genetic methods: four of the late-maturing type on a diploid basis (SibNIIK 10, Rodnik Sibiri, Atlant, Ogonek) and four of the early-maturing type on a tetraploid and diploid basis (Meteor (4×), Pamyati Lisitsyna (4×), Prima (2×), Assol (4×)).

Single-crop late maturing varieties, which are cultivated in clover-sowing zones of the West Siberian and East Siberian regions, do not fully meet the needs of production. They ripen mainly in late September during heavy precipitation, which makes it difficult to harvest seeds and leads to high yield losses (plants sprout and lodge). Low yield leads to a constant shortage of seeds [4–6]. In this regard, the development of early maturing varieties along with late maturing varieties is relevant for the Siberian region and the Russian Federation as a whole [7].

The hybridization method is used in breeding work with meadow clover in the Federal Williams Research Center of Forage Production & Agroecology, where hybrids are obtained from crossing geographically distant wild populations of clover with high-yielding early maturing, but poorly winter-hardy forms. In clover-sowing areas scientific institutions have created new winter-hardy varieties of early-maturing meadow clover, such as Meteor, Ranniy 2, Trio, with high winter-hardiness and early maturity, yield up to 100 kg dry matter/ha and up to 5 kg seeds/ha [8–10].

As a result of a combination of hybridization, polyploidy and selection methods, M.Yu. Novoselov solved a complex problem of meadow

[1]*Novoselova A.S.* Selection and seed production of clover. Moscow: Agropromizdat, 1986, 199 p.

[2]The State Register of Breeding Achievements Approved for Use, vol. 1, Plant varieties, Moscow, 2023, 631 p.

clover breeding for early maturity, where the genetic negative correlation between the traits of winter hardiness and early maturity of meadow clover genotypes on a tetraploid basis was overcome[3] [11]. Winter hardiness of tetraploid forms of meadow clover was increased in the conditions of the West Siberian region using selection methods in extreme conditions.

Tetraploid forms of meadow clover have a number of valuable economic traits, more pronounced in comparison with the original diploid samples. Tetraploids of meadow clover have thicker long branching stems and are more resistant to lodging. Leaves and inflorescences of tetraploids are larger, and foliage of the stems is higher. The vegetative weight gain of tetraploids can reach 15–20% in the first year of life and 30–40% in the second [6, 7], which is confirmed by our studies for 2013–2019. Tetraploids have larger sizes and seed mass (see footnote 3) [6, 7, 12]. Thus, the diploid variety SibNIIK 10 has a mass of 1000 seeds of 1.8 g, tetraploid varieties Assol and Meteor – 2.72 and 2.93 g, respectively. One of the important techniques of adaptive breeding is the selection of source material of meadow clover by a set of morphobiological traits [13].

The purpose of the work is to present the results of research on the development of early maturing meadow clover variety on tetraploid basis with dry matter yield of 60–70 c/ha, seed yield of 1.5–2.0 c/ha, winter-hardy, more resistant to major diseases.

MATERIAL AND METHODS

A complex-hybrid population 16-9-T (4×), which was converted to tetraploid basis (see fig. 1), was created in the Federal Williams Research Center of Forage Production & Agroecology (1996-2005) under artificial climate conditions using hybridization method (VNIIL 4586 × Arlington k-40654) and selections. The authors of the variety are R.I. Polyudina (SFSCA RAS) and M.Yu. Novoselov (Federal Williams Research Center of Forage Production & Agroecology).

The research was continued in the breeding center of SFSCA RAS in the conditions of the forest-steppe of Western Siberia in 2006–2021. Meteorological conditions during the research in the competitive variety trial varied significantly among themselves. Dry and hot were 2014, 2016, wet and cool conditions were in 2018, 2019, close to long-term averages in terms of precipitation and air temperature was 2017. This allowed a sufficiently objective assessment of the created new variety of meadow clover Assol.

Nursery planting for competitive varietal testing of meadow clover was carried out in a special breeding rotation. The technology of nursery establishment is generally accepted for cultivation of meadow clover in clover-sowing zones of Western Siberia[4].

Selections of winter-hardy high-yielding forms from hybrid tetraploid population 16-9-T (4×) were carried out. The created population was tested in three cycles of competitive variety trials (sowing of 2013, 2015, 2017) with two methods of planting: row – for green mass, wide-row – for seeds. The registered area of the plot was 25 m^2. The research results were processed according to B.A. Dospekhov[5].

RESULTS AND DISCUSSION

As a result of the conducted research for 2014–2019 Assol variety showed high winter hardiness – 97%.

The period from spring growth to the first cutting in the new variety is 59–82 days, from the first to the second cutting – 44–51, from growth to maturity – 103–128 days, in the standard Meteor – 59–78, 42–57 and 104–124 days, respectively.

As a result of research for three cycles of the CVT, the yield of fodder mass in the first cutting of Assol varied depending on the weather conditions and on the year of grass use from 133 to 546 c/ha, in the second cutting it varied from 109 to 284 c/ha. Its maximum yield for two harvests (818 kg/ha) was established in conditions of over moistened 2018.

[3] *Novoselov M.Yu.* Selection of meadow clover. Moscow, 1999, 183 p.

[4] Cultivation of meadow clover in Western Siberia: scientific and practical manual. Novosibirsk, 2013, 24 p.

[5] *Dospekhov B.A.* Methodology of field experiment. Moscow: Kolos, 1979, 416 p.

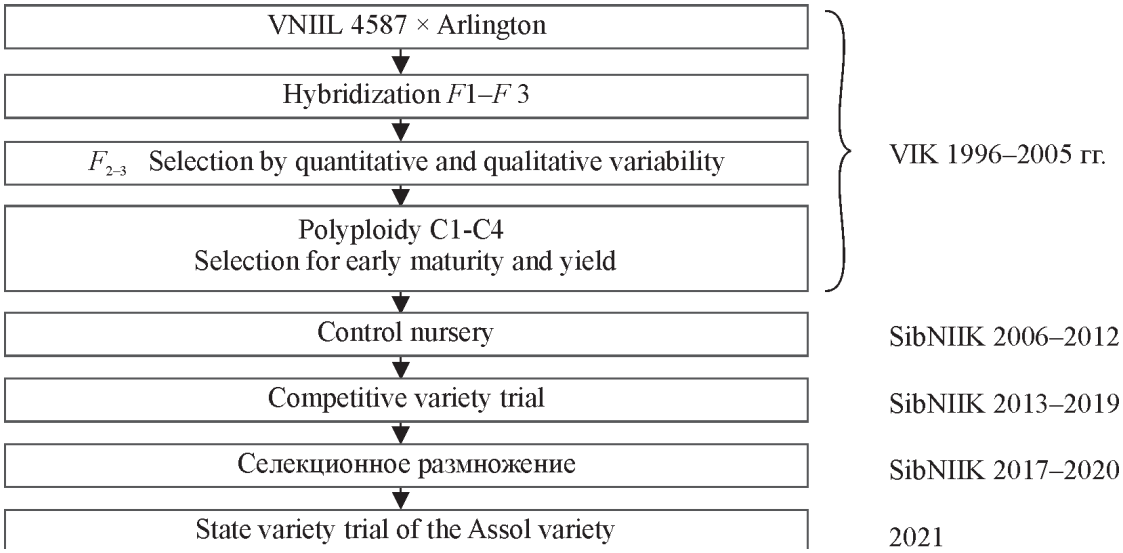

Рис. 1. Схема создания сорта клевера лугового Ассоль
Fig. 1. Scheme for creating the variety of meadow clover Assol

The vegetation period of 2018 was characterized by lower average daily air temperature in May and July (-4.0, -0.9 °C from the long-term average), moisture content in the third ten-day period of April at 52% of the long-term average, in May – 120%, June – 29%. This had a positive effect on the formation of vegetative mass of plants of the first year of use. The yields of green mass in the competitive variety trial of the studied complex-hybrid populations of meadow clover in the first, second ear and in total for two harvests amounted to 384–550, 105–291 and 488–841 c/ha, respectively, seeds – 1.71–3.55 c/ha (see fig. 2).

Dry matter yield for two harvests of the Assol variety was 57–129 c/ha, average for 6 years of study – 89.2 c/ha, which is higher than the standard tetraploid variety Meteor by 9.2%, in comparison with the diploid variety of late maturing type SibNIIK 10 by 29.0% (see Table 1).

Foliage varied in the Assol variety in the first cutting from 36 to 53%, in the second from 36 to 58%, in the tetraploid variety, the standard Meteor, from 34 to 52 and from 37 to 59%, in the diploid variety, the standard SibNIIK 10, from 35 to 47 and from 42 to 61%, respectively. On average for two harvests, foliage varied from 36 to 55% in the standard Meteor, from 36 to 61% in the standard SibNIIIC 10, and from 38 to 55% in the variety Assol (see Table 2).

The Assol variety had a protein content of 14.7%, which is 0.7% higher than the early maturing tetraploid variety Meteor, fiber 24.7% – 1.3% lower than the standard Meteor. Seed yield of Assol varied by years from 1.00 to 2.99 c/ha,

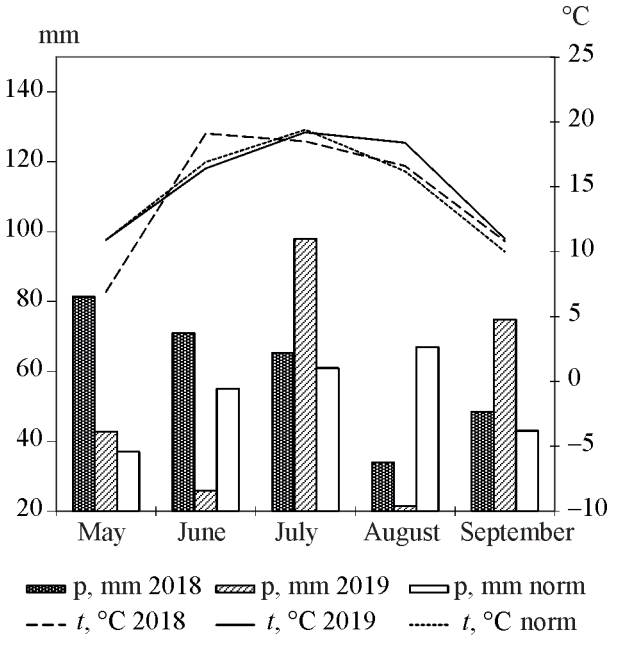

Рис. 2. Среднесуточная температура воздуха и сумма осадков за вегетационный период 2018, 2019 гг. (данные АГМС «Огурцово»)
Fig. 2. Average daily air temperature and precipitation amount for the vegetation period 2018, 2019 (data from meteorological station "Ogurtsovo")

average – 1.67 /ha, in comparison with the tetraploid standard Meteor variety Assol exceeded this indicator by 11.2%, SibNIIK 10 variety by 16.5% (see Table 1).

Seeds ripen in early maturing varieties Assol and Meteor in II–III ten-day periods of August (in dry years July 30–31). This allows harvesting of Assol seeds before harvesting of grain crops, which is important in production conditions. The tetraploid Assol variety has an insemination rate of 19%, Meteor – 18, SibNIIK 10 – 35%.

Complex-hybrid population 16-9-T (4×) together with the Federal Williams Research Center of Forage Production & Agroecology was transferred to the State Variety Trial as variety Assol in 2021. In 2024, the variety was included in the State Register for the West Siberian region. The copyright certificate (No. 82590 dated

Табл. 1. Урожайность клевера лугового сорта Ассоль (конкурсное сортоиспытание), ц/га
Table 1. Yield of meadow clover Assol variety (competitive variety trial), c/ha

Year of sowing	Year of use	Meteor (standard 1), c/ha	SibNIIK 10 (standard 2), c/ha	Assol			LSD_{05}
				c/ha	± to the standard 1 / standard 2	% to the standard 1 / standard 2	
Herbage							
2013	First	227	336	242	15/–94	107/72	16,4
	Second	457	223	506	49/ 283	111/126	47,4
2015	First	328	297	379	51/82	116/128	30,2
	Second	386	279	462	76/183	120/166	27,6
2017	First	680	488	818	138/330	120/168	38,7
	Second	223	173	296	73/123	133/171	26,2
Average for 6 years		384	299,3	451	67/152	17,4/50,7	
Dry matter							
2013	First	53	81	57	4/-24	108/70	3,9
	Second	114	78	129	15/70	113/120	10,7
2015	First	65	59	71	6/12	109/120	9,4
	Second	69	51	81	16/30	117/96	3,1
2017	First	96	101	97	1/–4	101/96	13,2
	Second	92	44	99	7/55	108/225	8,6
Average for 6 years		81,5	69	89	7,5/20	9,2/29	
Seeds							
2013	First	0,9	1,5	1,0	0,1/–0,5	111/66	0,1
2015	First	0,78	2,55	1,02	0,24/–1,53	131/40	0,21
2017	First	2,81	2,0	2,99	0,18/0,99	106/150	0,16
Average for 3 years		1,49	2,0	1,67	0,18/–0,33	11,2/–16,5	

Табл. 2. Облиственность клевера лугового сорта Ассоль (конкурсное сортоиспытание), %
Table 2. Foliage of meadow clover Assol variety (competitive variety trial), %

Year of sowing	Year of use	Foliage			
		Standard 1 (Meteor)	Standard 2 (SibNIIK 10)	Assol	
				%	± to the standard 1 / standard 2
2013	First	55	45	53	–2/8
	Second	45	42	45	0/3
2015	First	36	36	38	2/2
	Second	54	61	55	1/–6
2017	First	48	47	48	0/–1
	Second	46	53	50	4/–3

28.05.2024) and a patent for breeding achievement (No. 13701 dated 28.05.2024) were obtained

Morphobiological and economically valuable traits of meadow clover Assol

The variety is tetraploid, double-cutting type, has a multistemmed plant (41–56 stems). Plant height before the first cutting is 67 cm, before the second – 57 cm. Foliage of stems on average for two harvests is 48%, weight of 1000 seeds is 2.72 g. The period from spring growth to the first harvest ripeness (beginning of flowering, 10%) is 68 days, from the first to the second harvest – 57 days to maturity of heads at 80% – 114 days. At the same time, the early maturing tetraploid variety standard Meteor has a period from regrowth to maturity of 112 days, while the late maturing diploid variety SibNIIK 10 – 124 days.

The average yield of green mass for two harvests is 451 kg/ha, which is higher than the standard by 67 kg/ha (17.4%), dry matter – 89.2 (9.2%), seeds – 1.67 kg/ha (12.2%). The maximum yield of green mass for two harvests is 818 c/ha, which is higher than the standard by 20.3%, seeds – 2.72 c/ha. Protein content is 14.9%. The variety is characterized by resistance to powdery mildew and fusariosis, responsive to moisture both in the first and second half of summer, forming a high yield of the first and second harvests.

Табл. 3. Поражаемость болезнями клевера лугового Ассоль (16-9-Т(4×)) за 2014–2019 гг. (данные Л.Ф. Ашмариной), %
Table 3. Disease incidence of meadow clover variety Assol (16-9-T(4×)) for 2014–2019 (data of L.F. Ashmarina), %

Variety sample	Damage (average for all years)		
	Powdery mildew	Stemphylium leaf spot	Fusariosis
Meteor (standard)	44,3	25,9	19,3
Assol (16-9-Т(4×))	29,1	29,1	15,2
% to the standard	65,69	100,89	78,76

In the competitive variety trial, meadow clover varieties were annually affected by a complex of soil (fusariosis) and leaf-stalk infections (powdery mildew, Stemphylium leaf spot) (see Table 3).

On average, the Assol variety (16-9-T(4×)) was affected below the standard by powdery mildew (29.1% on average) and fusariosis (15.2%), and by Stemphylium leaf spot at the level of the standard Meteor variety (see Table 3).

CONCLUSION

A new high-yielding winter-hardy early-maturing (double-cut) variety of meadow clover on a tetraploid basis Assol was created in the breeding center of the SFSCA RAS together with the Federal Williams Research Center of Forage Production & Agroecology by hybridization, polyploidy and selection. The variety has been included since 2024 in the State Register of Breeding Achievements, allowed for use in the West Siberian region. The variety is being multiplied for introduction into production in farms in the West Siberian region of the Russian Federation.

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Влияние комплекса экологических факторов на яйцекладку перезимовавших самок колорадского жука в условиях лесостепи Приобья

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В статье представлены результаты многолетних исследований по оценке влияния экологических факторов (температуры и влажности воздуха, количества осадков, суммы эффективных температур (СЭТ) и продолжительности светового дня) на начало, продолжительность и окончание яйцекладки перезимовавших имаго колорадского жука в посадках картофеля на территории центрально-лесостепного Приобского агроландшафтного района. За годы исследований процесс откладки яиц начинался 19 июня ± 12 дней при среднесуточной температуре воздуха 18,3 ± 10,7 °С, СЭТ 165,6 ± 78,2 °С, влажности воздуха 66,8 ± 24,3%, количестве осадков 0,4 ± 0,4 мм и продолжительности светового дня 17:19 ± 0:09 ч. Установлено комплексное воздействие всех абиотических факторов. Рассматриваемые факторы на 74,9% определяли число яиц, отложенных в первый день яйцекладки (наибольшее влияние имело количество осадков). Продолжительность периода яйцекладки зависела от экологических факторов на 54,1% (максимальное влияние оказала температура воздуха). Доля влияния всего комплекса факторов составила 75,7% (наибольшее влияние оказала СЭТ). Средняя продолжительность процесса яйцекладки составила 18,8 ± 10 дней при среднесуточной температуре воздуха 19,1 ± 5,8 °С, СЭТ 132,3 ± 77,6 °С, влажности воздуха 66,7 ± 25,2%, количестве осадков 39,6 ± 39,6 мм, продолжительности светового дня 17:15 ± 0:12 ч. За это время перезимовавшие самки откладывали в среднем 0,30 ± 0,27 яйцекладок на одно растение. Изучаемые факторы на 83,3% определяли число яиц, отложенных на дату окончания периода яйцекладки (наибольшее влияние оказало количество осадков). В среднем окончание процесса яйцекладки приходилось на 10 июля ± 10 дней при среднесуточной температуре воздуха 19,0 ± 3,4 °С, СЭТ 306,4 ± 113,9 °С, влажности воздуха 71,4 ± 19,3%, количестве осадков 5,7 ± 5,7 мм и продолжительности светового дня 17:04 ± 0:25 ч. Численность яйцекладок на дату окончания периода откладки яиц составляла 0,1 ± 0,09 экз./раст.

Ключевые слова: *Leptinotarsa decemlineata* Say, яйцекладка, температура и влажность воздуха, сумма эффективных температур, сумма осадков, продолжительность светового дня

Influence of a complex of environmental factors on oviposition of overwintering females of Colorado potato beetle in the conditions of the Priobie forest-steppe

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The article presents the results of long-term research on the influence of environmental factors (air temperature and humidity, precipitation, sum of effective temperatures (SET) and daylight duration) on the beginning, duration and end of oviposition of overwintered imago *Leptinotarsa decemlineata* Say in potato plantings in the central forest-steppe Priobsky agro-landscape area. During the years

of study, the egg-laying process began on June 19 ± 12 days at an average daily air temperature of 18.3 ± 10.7 °C, SET of 165.6 ± 78.2 °C, air humidity of 66.8 ± 24.3%, precipitation of 0.4 ± 0.4 mm, and daylight hours of 17:19 ± 0:09 h. The complex impact of all abiotic factors was found. The factors considered had 74.9% influence on the number of eggs laid on the first day of oviposition (rainfall showed the greatest influence). The duration of the oviposition period depended on environmental factors by 54.1% (air temperature had the maximum influence). The share of influence of the whole complex of factors amounted to 75.7% (SET had the greatest influence). The average duration of the oviposition process was 18.8 ± 10 days with an average daily air temperature of 19.1 ± 5.8 °C, SET of 132.3 ± 77.6 °C, air humidity of 66.7 ± 25.2%, precipitation of 39.6 ± 39.6 mm, and daylight hours of 17:15 ± 0:12 h. During this time, overwintering females laid an average of 0.30 ± 0.27 ovipositors per plant. The studied factors determined the number of eggs laid on the date of the end of the oviposition period by 83.3% (precipitation influenced the most). On average, the end of the oviposition process occurred on July 10 ± 10 days with an average daily air temperature of 19.0 ± 3.4 °C, SET of 306.4 ± 113.9 °C, air humidity of 71.4 ± 19.3%, precipitation of 5.7 ± 5.7 mm, and daylight hours of 17:04 ± 0:25 h. The number of ovipositors at the end of the egg-laying period was 0.1 ± 0.09 eq/plant.

Keywords: *Leptinotarsa decemlineata* Say, oviposition, air temperature and humidity, sum of effective temperatures, sum of precipitation, photoperiod duration

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INTRODUCTION

Abiotic factors have a significant impact on living things. Observations of the reactions of living organisms to environmental factors (temperature, precipitation, humidity, daylight hours) are fundamental for predicting the reproduction and dispersal of these organisms, determining the stages and timing of their development. The obtained data allow explaining the development of species in a particular area, and in relation to phytophages, such information can be used in the development of plant protection systems.

The biology of the Colorado potato beetle has been studied in great detail by many scientists [1-9] [1–16], but a number of issues still lack detailed descriptions. For example, there is no

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information on the complex influence of abiotic factors on the beginning and duration of the oviposition period of overwintering adults, particularly in field conditions. It is known that egg laying and normal development of pest embryos occur at air temperatures of 17...33°C (optimum is in the range of 22...25°C) and relative humidity of air of 60–75%. Egg-laying can take place at an average daily temperature of 12 °C only in those hours when the temperature rises above 20 °C. However, even at 17 °C its intensity is very insignificant[10-12]. Unfavorable conditions for breeding females are temperatures below 14 °C or above 26...27 °C with relative humidity below 40% or above 80%. According to the data obtained in the Leningrad Region, the temperature thresholds of mobility recovery and the beginning of mating after hibernation are lower and are 8…9 °C[13].

Basically, studies cover one or several environmental factors. In most cases, the temperature factor [4, 5] or the temperature factor and photoperiod [8] are taken into account. Most often, the authors specify the ten-day period of the beginning of egg laying and the potato phenophase without specifying abiotic conditions.

With sufficient knowledge about the influence of environmental factors on the development of *L. decemlineata*, there are still no detailed studies on the timing of egg-laying by overwintering adults and the duration of this process (especially under field conditions) for both the Russian Federation and Western Siberia (including the territory of the central Priobie forest-steppe agrolandscape region). Such studies will provide more complete information on the ecology of Colorado potato beetle.

The purpose of this work was to study the influence of a complex of environmental factors on the onset of egg-laying by overwintering adults of *L. decemlineata* and on the duration of the oviposition period in the conditions of the central Priobie forest-steppe agrolandscape region.

MATERIAL AND METHODS

Studies were conducted on potato plantings in the Novosibirsk region: in 2007–2010 - on the basis of the state crop testing site “Iskitimsky”, located in typical conditions of the central forest-steppe Suzun agrolandscape subdistrict, in 2009–2011 and 2014–2019 – on the fields of experimental station “Elitnaya” of the Siberian Federal Scientific Centre of Agro-BioTechnologies RAS in typical conditions of the central Priobie forest-steppe agrolandscape district. The main elements of potato cultivation technology corresponded to those generally accepted for this region[14, 15].

The vegetation periods during the years of research were characterized by various weather conditions: in 2007, 2009, 2015, 2017 and 2018 they were mildly arid (HTC = 1,2–1,3), in 2008, 2010, 2011, 2014, 2016, 2019 – arid (HTC = 0,7–1,0).

Colorado potato beetle oviposition and its duration were evaluated on the varieties Adretta, Agata, Arosa, Cardinal, Nikita, Purple Majesty, Sante, Scarlet, Vitelotte, Zhukovsky Ranny, Zarevo, Lina, Lugovskoy, Lyubava, Nevsky, Sapho, Svitanok Kievsky, Violet, Hoziayushka, Yugana by visual counting of 20 side-by-side plants in two repetitions on the natural background of the crop planting according to gen-

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erally accepted methods[16]. The planting density was 35.7 thousand plants/ha.

Weather conditions were analyzed to determine the factors influencing the date of the beginning of oviposition of overwintering adults and the duration of this process. The relationship of these indicators with environmental conditions was established by means of pair and multiple correlation for the following factors: air temperature and humidity, precipitation, daylight hours and the sum of effective temperatures (SET). Information on the weather conditions was obtained from the agrometeorological bulletins of the Novosibirsk Center for Hydrometeorology and Environmental Monitoring and specialized data sets for climatic studies (weather services, etc.). According to the results of pair and multiple correlation, the percentage of the impact of the studied factors on the date of the beginning and end of oviposition was determined. To establish the dependence of egg-laying duration on the air temperature and humidity, precipitation, daylight hours and SET, regression analysis was performed on the whole set of data and the parameters of the linear regression equation were calculated. All calculations and their primary statistical processing were performed using Snedecor[17] and Microsoft Excel 2010 software packages.

SET was calculated before the beginning of the oviposition period and during the continuation of this process starting from the stable transition of the average daily temperature through 10 °C. The air temperature of 11.5°C[18] was taken as the lower threshold of the Colorado potato beetle development.

RESULTS AND DISCUSSION

During 11 years of research, the dates of the beginning of egg laying by overwintering females of the Colorado potato beetle varied. The earliest date was June 7 (2011), the latest – July 2 (2019). Consequently, the beginning of the oviposition period occurred on June 19 ± 12 days, based on the annual average data. The average number of oviposition was 0.4 ± 0.16 eggs/plant. The minimum value was 0.01 eggs/plant, and the maximum value was 1.9 eggs/plant. Egg laying started at the air temperature of 18.3 ± 10.7 °C, SET 165.6 ± 78.2 °C, air humidity 66.8 ± 24.3% and minimum precipitation (0.4 ± 0.4 mm). The duration of daylight hours during this period was 17:19 ± 0:09 h.

Since the phytophage life cycle depends on meteorological factors (air temperature and humidity, daylight hours, precipitation), the pairwise correlation and the proportion of influence of the studied factors on the number of eggs in ovipositors laid on the first day were calculated. As a result, an average negative relationship between air humidity and the number of eggs laid on the first day was established: the correlation coefficient was -0.7 ± 0.2, and the share of influence of this factor was 47.1%. The influence of other factors was not statistically significant.

Due to the fact that abiotic factors cannot act in isolation, an autocorrelation matrix was constructed (see Table 1) and the influence shares of the studied factors were calculated.

It was determined that the number of eggs laid on the first day was most strongly influenced by air humidity and daylight hours (71.9%; $R = 0.8 \pm 0.2$), the average – by air humidity and temperature, SET and precipitation on the day of egg-laying (47.7–53.0%; multiple correlation for the listed factors was 0.7 ± 0.2). All other factors had a weak influence; their share amounted to 8.3-17.6% with multiple correlation from 0.3 ± 0.3 to 0.5 ± 0.3.

It was found that the share of the combined influence of the entire complex of the studied factors amounted to 74.9%, and the value of the correlation coefficient was 0.87 ± 0.1. The greatest influence was exerted by such factor as the amount of precipitation (the maximum regression coefficient β was equal to 0.021).

As a result of the calculations the multiple regression equation was obtained

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Табл. 1. Автокорреляционная матрица влияния абиотических факторов на численность яйцекладок, отложенных в первый день, $R \pm Sr$ (в среднем за годы исследований)

Table 1. Autocorrelation matrix of the influence of abiotic factors on the number of laid eggs of *Leptinotarsa decemlineata* Say on the first day of egg laying, $R \pm Sr$ (on average over the years of research)

Factor	Air humidity, %	Precipitation, mm	SET, °C	Daylight hours, h
Air temperature, °C	0,7 ± 0,2	0,3 ± 0,3	0,4 ± 0,3	0,5 ± 0,3
Air humidity, %		0,7 ± 0,2	0,7 ± 0,2	0,8 ± 0,2
Precipitation, mm			0,3 ± 0,3	0,4 ± 0,3
SET, °C				0,4 ± 0,1

$$y = 125{,}3387 - 0{,}04175x_1 - 7{,}0534x_2 - \\ - 0{,}03882x_3 + 0{,}00967x_4 - 0{,}000623x_5,$$

$$S_y = 0{,}59 \text{ pcs./plant},$$

where y – oviposition rate, pcs./plant; x_1 – air humidity, %; x_2 – daylight duration, h; x_3 – air temperature, °C; x_4 – precipitation, mm; x_5 – SET, °C (the value of indicators at the date of the beginning of egg laying is indicated).

The equation is applicable for air humidity from 40 to 80%, daylight hours from 17.10 to 17.25 h, air temperature from 13 to 25 °C and precipitation from 0 to 4 mm.

Further, the duration of the oviposition period was determined: average – 18.8 ± 10 days, maximum – 28.7 days (2018), minimum – 8.8 days (2014). During this time, the average daily air temperature reached 19.1 ± 5.8 °C, dropping to 7.6 °C on some days. The SET value for the whole duration of oviposition amounted to 132.3 ± 77.6 °C. This indicator reached its maximum in 2018 (239.4 °C) and its minimum in 2009 (54.7 °C). On average for one day of the oviposition period, the SET reached 7.6 ± 6.6 °C, on some days it was 0.2 °C.

During the experiment, air humidity was relatively stable both on average for the whole period and for one day – 66.7 and 67.7%, respectively. However, during the day this indicator varied from 42.5 to 89.0%. The sum of precipitation averaged 39.6 ± 39.6 mm during the oviposition period. At the same time, in some years there was no precipitation at all during the entire study period (2015), and the maximum amount of precipitation fell in 2017 (93.2 mm). The average daily precipitation during the study years was about 2.0 ± 2.0 mm. Their maximum amount for a day sometimes reached 37 mm. It was found that the whole process of egg laying took place under the long-day photoperiodic regime – 17:15 ± 0:12 h; the differences in the value of this indicator on separate days were insignificant.

By determining the average weather conditions during the whole oviposition period, it was possible to evaluate the influence of individual environmental factors on the process. For this purpose, the pairwise correlation and the share of influence of the factors were calculated. It was found that the proportion of influence of humidity and air temperature on the duration of the oviposition period was 24.5 and 39.5%, respectively. Other environmental factors had a very weak influence on this process: the share of their influence amounted to 1,1–5,2%.

Then the autocorrelation matrix was constructed (see Table 2) and the shares of influence of the studied factors on the duration of the adult oviposition period were calculated in order to establish the complex of the main abiotic factors.

It was found that the duration of the oviposition period was more influenced by air temperature and precipitation (49.9%; $R = 0.7 \pm 0.2$), the average– by air temperature together with air humidity, daylight hours, SET, as well as air humidity and precipitation. The share of influence of these factors was at the level of 39.5–43.8%. The influence of air humidity with SET and day-

light hours was weak (26.0-29.3%; $R = 0.5 \pm 0.3$). The degree of influence of daylight hours in combination with SET was very small (2,1%; $R = 0,1 \pm 0,3$).

According to the results of multiple correlation calculation, a strong influence of all factors on the duration of the oviposition period was revealed (54.1%; $R = 0.74 \pm 0.16$). Air temperature had the greatest influence (maximum regression coefficient β was equal to 0.986).

As a result of the calculations the multiple regression equation was obtained

$$y = 27,8225 – 0,8189x_1 + 0,02591x_2 + \\ + 0,203x_3 – 0,00672x_4 – 0,00144x_5,$$

$$Sy = 0,47 \text{ days},$$

Where y – duration of the oviposition period, days; x_1 – average period of daylight duration, h; x_2 – average period air humidity, %; x_3 – average period air temperature, °C; x_4 – average period precipitation, mm; x_5 – average period SET, °C.

The equation is applicable for daylight hours from 17.00 to 17.25 h, air humidity from 55 to 75%, air temperature from 13 to 25 °C, precipitation from 0 to 100 mm, SET from 50 to 240 °C.

Abiotic environmental factors affect not only the duration of oviposition but also the number of ovipositions laid. It was calculated that, on average, overwintering females laid 0.30 ± 0.27 ovipositions per plant during the oviposition period. Analysis of the relationship between this index and the environmental conditions showed that the SET gained during the oviposition period had a strong effect on the number of ovipositions laid (56.4%; $r = 0.8 \pm 0.2$). The effect of other factors was not statistically significant.

Significant influence of several abiotic factors on the number of laid eggs was detected.

The maximum influence was exerted by daylight hours and SET (82.1%; $R = 0.9 \pm 0.1$), and strong influence was exerted by SET with air temperature and humidity and rainfall (56.4-58.5%; $R = 0.8 \pm 0.2$). The other factors had weak and very weak influence.

In addition, the significance of the whole complex of the studied factors was considered. It was found that there was a strong relationship between the number of ovipositioning and the environmental factors ($R = 0.87 \pm 0.12$), with the share of influence of the whole complex of factors amounting to 75.7%. The greatest influence was exerted by SET (the maximum regression coefficient β was equal to 0.977).

As a result of the calculations the multiple regression equation was obtained

$$y = –33,8378 + 2,1057x_1 – 0,02586x_2 – – \\ 0,06151x_3 + 0,00312\,x_4 + 0,00601x_5,$$

$$Sy = 0,28 \text{ pcs./plant},$$

where y – average number of ovipositions, pcs./plant; x_1 – average period of daylight duration, h; x_2 – average period air humidity, %; x_3 – average period air temperature, °C; x_4 – average period precipitation, mm; x_5 – average period SET, °C.

The equation is applicable for daylight hours from 17.00 to 17.25 h, air humidity from 55 to 75%, air temperature from 13.0 to 25 °C, precipitation from 0 to 100 mm, SET from 50 to 240 °C.

Табл. 2. Автокорреляционная матрица влияния погодных факторов на продолжительность периода яйцекладки, $R \pm Sr$ (в среднем за годы исследования)

Table 2. Autocorrelation matrix of the influence of factors on the duration of oviposition, $R \pm Sr$ (on average over the years of research)

Factor	Air humidity, %	Precipitation, mm	SET, °C	Daylight hours, h
Air temperature, °C	0,6 ± 0,4	0,7 ± 0,2	0,6 ± 0,3	0,6 ± 0,3
Air humidity, %		0,7 ± 0,2	0,5 ± 0,3	0,5 ± 0,3
Precipitation, mm			0,3 ± 0,3	0,3 ± 0,3
SET, °C				0,1 ± 0,3

The environmental conditions and ranges of variability of the weather conditions at which the egg-laying process ended were determined. The end of this process on average for the years of research fell on July 10 ± 10 days. However, in some years its end was recorded both on June 27 (2015) and July 19 (2018). The number of ovipositions during this period was 0.1 ± 0.09 pcs./plant. The completion of egg laying took place at an air temperature of 19.0 ± 3.4 °C, SET of 306.4 ± 113.9 °C, and air humidity of 71.4%. The amount of precipitation was insignificant (5.7 ± 5.7 mm), and the duration of daylight hours was 17:04 ± 0:25 h. It was found that the end of oviposition occurred in a wide range of accumulated temperatures from 192.5 (2009) to 431.9 °C (2017). Also, rainfall varied widely during this period, from 0 (2008, 2011, 2015, 2018) to 37 mm (2019).

It was revealed that the number of ovipositions at the end of the egg-laying process was strongly influenced by the amount of precipitation (59.8 %; $r = 0.8 \pm 0.2$). At the same time, air temperature and humidity had no appreciable effect.

Calculation of multiple correlation and the proportion of the influence of the studied factors showed that the number of laid eggs at the end of oviposition was very much influenced by a complex of factors such as precipitation and air humidity (76.3%; $R = 0.9 \pm 0.2$). In addition, precipitation combined with air temperature, daylight hours and SET had a significant effect on the completion of this process (59.5-65.8%; $R = 0.8 \pm 0.2$). The other studied factors had a weak influence on the end of the oviposition period.

According to the results of multiple correlation calculations, the complex influence of all the studied factors is very strong ($R = 0.91 \pm 0.09$), the share of influence of the factors on the number of oviposition is 83.3%. Among all the factors, precipitation had the greatest influence on the date of the end of the oviposition period (the maximum regression coefficient β was equal to 1.031).

The following multiple regression equation is obtained:

$$y = 0{,}00865 + 0{,}00315x_1 - 0{,}00338x_2 + \\ + 0{,}00955x_3 + 0{,}00661x_4 + 0{,}000183x_5,$$

$$Sy = 0{,}01 \text{ pcs./plant},$$

where y – the number of ovipositions, pcs./plant; x_1 – daylight duration, h; x_2 – air humidity, %; x_3 – air temperature, °C; x_4 – precipitation, mm; x_5 – SET, °C (the value of the indicators on the date of the end of egg laying is indicated).

The equation is applicable for daylight hours from 16.30 to 17.25 h, air humidity from 50 to 85%, air temperature from 15.0 to 23 °C, rainfall from 0 to 40 mm, SET from 190 to 435 °C.

CONCLUSION

Based on the results of long-term studies, it was found that in the conditions of Western Siberia in the central Priobie forest-steppe agrolandscape region, the oviposition process of overwintering adults and the number of eggs laid by them were strongly influenced by a complex of factors: air temperature and humidity, precipitation, the sum of effective temperatures and daylight hours.

Significant influence of paired factors was observed. The beginning of oviposition was determined by air humidity and daylight hours by 71.9%. The duration of the oviposition period was 49.9% dependent on air temperature and precipitation. The number of oviposition was significantly influenced by the duration of daylight hours and SET (82,1%). The end of the oviposition period was maximally influenced by air humidity and precipitation (76.3%). It is also confirmed that individual abiotic factors cannot influence the beginning, course and end of the egg-laying process. Each stage has its own determining complexes of factors.

With the help of the obtained equations, based on the analysis of long-term data, it is possible to predict the date of the beginning of oviposition of overwintering adults of the Colorado potato beetle, its duration and the number of laid eggs, taking into account the weather conditions.

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Влияние регуляторов роста на продуктивность семян подсолнечника

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Представлены результаты изучения эффективности различных регуляторов роста на деляночных участках подсолнечника сорта СПК кондитерского направления. Научные исследования проведены в 2021, 2022 гг. в условиях недостаточного и неустойчивого увлажнения степной зоны Кабардино-Балкарии. В опытах применяли регуляторы роста Альбит, ТПС; Циркон, Р; Гуми, Р; Азофокс, Р; Амицид Микро, Р; Эпин-Экстра, Р и Амино, Р. Деляночные опыты закладывали в восьми вариантах методом рендомизации в трех ярусах. Вариант 1 был контрольным (без обработки). Площадь каждой делянки составила 21 м^2, повторность трехкратная. В ходе исследований изучены такие показатели, как средний диаметр корзинки (см), масса 1000 семян (г) и средняя урожайность семян (т/га). На растениях подсолнечника под действием регуляторов роста Альбит, ТПС; Эпин-Экстра, Р; Амино, Р интенсивность развития ложной мучнистой росы была меньше на 4,1; 4,2 и 4,3% относительно контроля (без обработки) соответственно. Урожайность семян подсолнечника в результате применения регуляторов роста Альбит, ТПС (вариант 2), Гуми, Р (вариант 4), Эпин-Экстра, Р (вариант 7) и Амино, Р (вариант 8) повысилась и составила 4,1; 3,5; 4,2 и 4,3 т/га соответственно. Однократное использование разных регуляторов роста с низкой концентрацией увеличило продуктивность подсолнечника в вариантах 2 (Альбит, ТПС), 7 (Эпин Экстра, Р), 8 (Амино, Р) в среднем на 1,4 т/га в сравнении с вариантом без обработки. Диаметр корзинок увеличился в вариантах 2 (Альбит), 6 (Амицид Микро, Р), 7 (Эпин-Экстра), 8 (Амино) в среднем на 5,6 см по отношению к контролю.

Ключевые слова: подсолнечник, регуляторы роста, ложная мучнистая роса, диаметр корзинки, масса 1000 семян, урожайность

EFFECT OF GROWTH REGULATORS ON SUNFLOWER SEED PRODUCTIVITY

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The results of studying the effectiveness of different growth regulators on the plots of sunflower variety SPK of confectionery direction are presented. Scientific research was conducted in 2021, 2022 under the conditions of insufficient and unstable moistening of the steppe zone of Kabardino-Balkaria. Growth regulators Albit, RP; Zircon, S; Gumi, S; Azofox, S; Amicid Micro, S; Epin-Extra, S and Amino, S were used in the experiments. The plot experiments were laid in eight variants by the method of randomization in three tiers. Variant 1 was the control (no treatment). The area of each plot was 21 m^2, threefold repetition. Indicators such as average calathid diameter (cm), 1000 seed weight (g) and average seed yield (t/ha) were studied. On sunflower plants under the action of growth regulators Albit, RP; Epin-Extra, S; Amino, S, the intensity of false powdery mildew development was lower by 4.1; 4.2 and 4.3% relative to the control (without treatment), respectively. Sunflower seed yield as a result of application of growth regulators Albit, RP (variant 2), Gumi, S (variant 4), Epin-Extra, S (variant 7) and Amino, S (variant 8) increased and amounted to 4.1; 3.5; 4.2 and 4.3 t/ha, respectively. Single use of different growth regulators with low concentration increased sunflower productivity in vari-

ants 2 (Albit, RP), 7 (Epin Extra, S), 8 (Amino, S) by an average of 1.4 t/ha compared to the variant without treatment. The diameter of the calathids increased in variants 2 (Albit), 6 (Amicid Micro, S), 7 (Epin-Extra), 8 (Amino) by an average of 5.6 cm relative to the control.

Keywords: sunflower, growth regulators, downy mildew, calathid diameter, weight of 1000 seeds, yield

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Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Sunflower is the main oilseed crop in the North Caucasus region and is of great importance for the food and processing industries[1, 2] [1]. In this regard, the role of new high-yielding sunflower varieties and hybrids with high oil content in their seeds is quite significant.

The yield and quality of sunflower seeds and hybrids depend on the implementation of a range of agronomic, breeding, genetic, biological, and chemical measures. It is also necessary to find ways to increase the oil content and resistance of this crop to harmful organisms [2, 3].

Currently, much attention is being paid to the development and introduction into production of plant protection products, including growth regulators that improve seed quality and quantity. The pesticide market is filled with a large number of different types of growth stimulants[3] [4, 5]. Their widespread use in sunflower production creates favorable conditions for improving the immune status against adverse environmental factors and disease pathogens[4]. The positive effect of new preparations on the growth and development of sunflowers is obvious, but the effectiveness of growth regulators in Kabardino-Balkaria has not been sufficiently studied.

The purpose of the study is to present the results of scientific experiments aimed at improving the integrated protection system for new promising sunflower varieties and hybrids against major pests.

MATERIAL AND METHODS

Field experiments were conducted, calathid diameter, weight of 1000 seeds and yield were determined in accordance with the methods [5–7].

The biological yield of sunflower seeds was calculated using the formula [6]

$$Y\ c/ha = \frac{P \cdot N \cdot W}{10\ 000},$$

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where P – plant stand density, m^2; N – number of seeds in the calathid, pcs.; W – 1000 seeds, g; 10 000 – conversion factor in c/acre.

Statistical data processing was carried out by R.R. Usmanov [7].

The experiments used the growth regulators Albit, RP; Zircon, S; Gumi, S; Azofox, S; Amicid Micro, S; Epin-Extra, S and Amino, S. The plot experiments were laid out in eight variants using the randomization method in three tiers. Variant 1 was the control (without treatment). The plot area for each variant of the experiment was 21 m^2, with three replicates. The object of the study was the SPK sunflower variety.

The seed quality assessment was carried out in the laboratory of chemical analysis and biological research at the Institute of Agriculture, a branch of the Federal Scientific Center "Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences" (IA KBSC RAS) using the following equipment: Infrared analyzer "InfraScan-1050", analytical scales "OHAUS", laboratory sieves, drying oven, technical scales VLTK-500, moisture meter.

The steppe zone of Kabardino-Balkaria has a hot continental climate, with average monthly temperatures in July ranging from 22 to 41 °C and insufficient and unstable humidity. The average annual precipitation in the zone is 435–480 mm, of which 310–350 mm falls during the growing season of sunflowers.

The soil of the experimental plots is southern chernozem, located in a relatively narrow strip between ordinary chernozems and dark chestnut soils. Southern chernozems are characterized by a low humus content in horizon A (3.5–5.0%) and a very gradual distribution across the soil profile. These soils are mainly used intensively for the cultivation of cereals, sunflowers, and corn for grain and silage. The humus content in the arable layer is 3.0–4.9%, nitrogen – 0.21–0.35%, exchangeable potassium – 361–430 mg/kg, mobile phosphorus – 15.6–28.7% [8, 9].

RESULTS AND DISCUSSION

An integrated protection system involves a comprehensive approach to selecting protective measures that reduce the pesticide load on the sunflower agro-biocenosis. Plant growth regulators and microfertilizers act as growth enhancers.

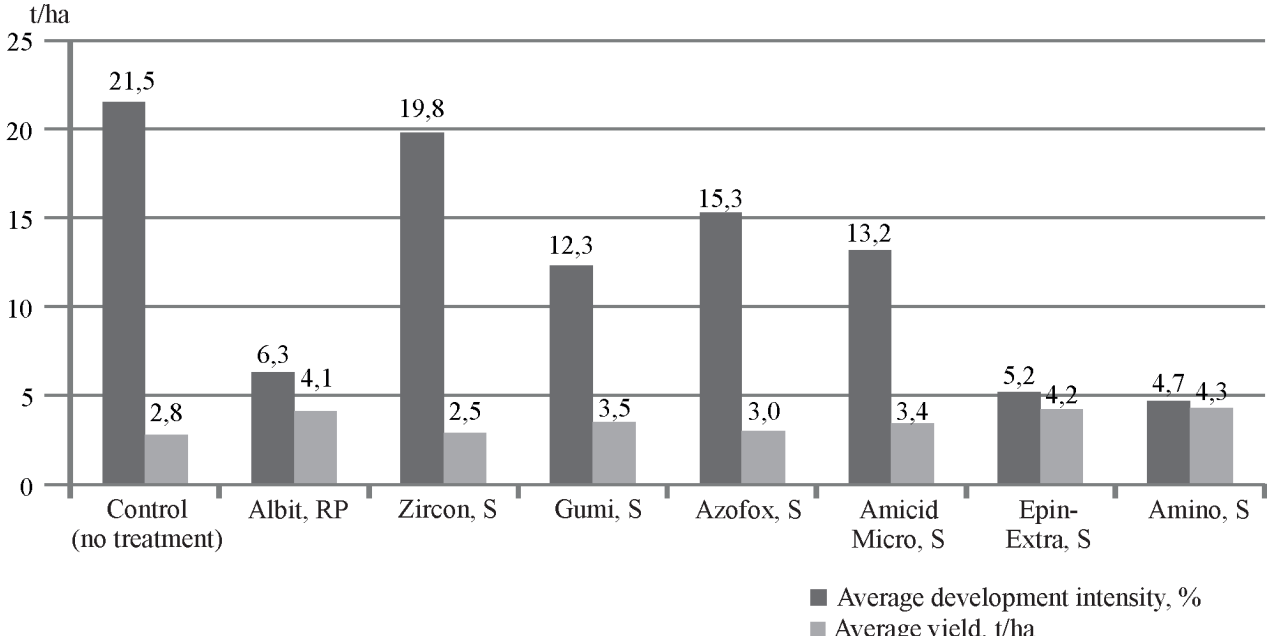
The tested growth regulators increased the resistance of the SPK sunflower variety to adverse environmental factors and the pathogen of downy mildew (*Plasmopara helianthi* Novot.) to varying degrees. Among sunflower diseases, downy mildew (false mildew) remains the most widespread disease to date. This disease manifests itself in the early stages of vegetation before the formation of the calathids. During this period, the average ten-day HTC was 0.8, but the relative immunity of the studied variety kept the development of the disease to a minimum. The upper leaves were free of infection due to dry and hot weather in June and July. The average diameter of the calathids was determined from morphological indicators.

The results of field assessment of the susceptibility of the SPK variety to downy mildew indicate an increase in sunflower resistance to this disease when using a growth regulator in the first period of vegetation. The use of growth regulators to varying degrees inhibited the harmfulness of downy mildew in different ways (see the figure).

In the experiment, variants 2, 7, and 8 stood out, where the weight of 1,000 seeds was higher than the control (without treatment) by 31.7, 29.9, and 44.9 g, respectively. If the weight of seeds is evaluated as a percentage, it increased by an average of 32.6% compared to the control. Based on these data, it should be noted that in the specified variants, flower setting was active, and the seeds were plump everywhere. The weight of 1,000 seeds was lowest in variants 3 (Zircon, P), 5 (Azofox, P), and 6 (Amicid Micro, P), amounting to 109.5, 119.4, and 120.5 g, respectively.

As a result of using growth regulators Albit, RP, Epin-Extra, Amino, S, the intensity of downy mildew development was low—4.1, 4.2, and 4.3%, respectively (see the figure). This favored the most intensive process of leaf photosynthesis, which contributed to completeness of the calathid flowering.

Analysis of the table data indicates that the average diameter of the calathids increased in variants 2 (Albit), 6 (Amicid Micro, S), 7



Влияние регуляторов роста на интенсивность развития ложной мучнистой росы (%) и продуктивность семян (т/га) подсолнечника (Кабардино-Балкария, степная зона, 2022–2023 гг.)

Effect of growth regulators on false powdery mildew intensity (%) and seed productivity (t/ha) of sunflower (Kabardino-Balkaria, steppe zone, 2022–2023)

(Epin-Extra), 8 (Amino) by an average of 5.6 cm (relative to the control). The average weight of 1,000 seeds in all variants of the experiment using growth regulators increased.

Seed formation is the most critical period of sunflower vegetation, when the number of seeds in the calathid and their size are determined.

Analysis of yield by experimental variants indicates an increase in sunflower seed productivity compared to the control. The most effective variants were 2 (Albit, RP), 7 (Epin-Extra, S), and 8 (Amino, S), where the yield was 4.1, 4.2, and 4.3 tons/ha, respectively. Variant 3 (Zircon, S) proved to be the least effective in terms

Влияние регуляторов роста на основные качественные и количественные показатели семян подсолнечника сорта СПК в условиях степной зоны КБР (2022, 2023 гг.)

Effect of growth regulators on the main qualitative and quantitative indicators of the SPK variety sunflower seeds in the conditions of the steppe zone of the CBR (2022, 2023)

Option number	Preparation	Rate of application, ml/ha	Average diameter of the calathide, cm	Average weight of 1000 seeds, g	Average seed yield, t/ha
1	Control (without treatment)	–	19,0	108,8	2,8
2	Albit, RP	40	24,3	140,5	4,1
3	Zircon, S	500	21,5	109,5	2,9
4	Gumi, S	100	23,5	122,8	3,5
5	Azofox, S	0,5	23,6	119,4	3,0
6	Amicid Micro, S	0,5	24,7	120,5	3,4
7	Epin-Extra, S	40	24,6	138,7	4,2
8	Amino, S	100	24,6	153,7	4,3
	$LSD_{0,5}$				0,6

of yield and weak in terms of seed performance (see the figure) This indicates a weak process of setting of the central flowers.

CONCLUSION

1. The intensity of downy mildew development on sunflower plants treated with the growth regulators Albit, RP, Epin-Extra, S, and Amino, S was 4.1, 4.2, and 4.3% lower than the control (untreated) group, respectively.

2. The average diameter of the calathids increased in variants 2 (Albit), 6 (Amicid Micro, S), 7 (Epin-Extra), 8 (Amino) by an average of 5.6 cm compared to the control.

3. A single application of various growth regulators with low concentrations increased sunflower productivity in variants 2 (Albit, RP), 7 (Epin-Extra, S), and 8 (Amino, S) by an average of 1.4 tons/ha compared to the untreated variant.

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ИНФОРМАЦИЯ ОБ АВТОРЕ

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Потенцирование неспецифической иммунологической памяти для индукции противоинфекционной резистентности

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Инфекционные заболевания сельскохозяйственных животных – одна из наиболее актуальных проблем современного животноводства. Повсеместно используемая специфическая вакцинопрофилактика далеко не всегда эффективна из-за генетической вариабельности и мутационной изменчивости антигенов возбудителя («антигенный дрейф»), широкой распространенности смешанных полиэтиологических инфекций, гетерогенности иммунного ответа и сниженной иммунорезистентности. Современные специфические вакцины направлены на протекцию против определенного патогена (или в случае мультивалентности) – против нескольких конкретных патогенов и основаны на индукции долговременного адаптивного, т.е. антиген-специфического иммунитета, обусловленного формированием Т- и В-клеток памяти. В последнее десятилетие установлено, что вакцины, содержащие микроорганизмы, такие как БЦЖ, обеспечивают устойчивость не только в отношении специфического патогена (например, в случае БЦЖ – против *M. tuberculosis*), но и в отношении широкого круга других возбудителей. Основным механизмом этой широкой гетерологической устойчивости является повышенная реактивность клеток врожденной иммунной системы, в первую очередь моноцитов-макрофагов. В ответ на первичный стимул (тренинг) эти клетки претерпевают ряд эпигенетических и метаболических перестроек, сенсибилизируются и, сталкиваясь со вторым стимулом (с тем же или другим возбудителем), обеспечивают долговременную протекцию против множества вирусных и бактериальных инфекций. В формировании неспецифической или «тренированной» иммунологической памяти (НИП) важная роль принадлежит метаболитам мевалонатного метаболического пути. В настоящей работе в экспериментах *in vitro* и *in vivo* верифицирована гипотеза о способности ингибитора фарнезилпирофосфатсинтазы – аминобисфосфоната (блокатора мевалонатного пути на уровне фарнезилпирофосфата) – потенцировать БЦЖ-индуцированную НИП. Установлено, что аминобисфосфонат золедронат индуцирует в моноцитах фенотип НИП и вызывает неспецифическую протекцию в отношении стафилококковой инфекции у мышей. Кроме того, золедронат значительно усиливает БЦЖ-индуцированную НИП, вызывая синергичный протективный эффект. Обнаруженный нами феномен потенцированной НИП может лечь в основу создания принципиально новых мощных универсальных вакцин.

Ключевые слова: неспецифическая иммунологическая память, тренированный врожденный иммунитет, БЦЖ, золедронат, *Staphylococcus aureus*

Potentiation of nonspecific immunologic memory for induction of anti-infection resistance

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Infectious diseases of farm animals are one of the most pressing problems of current livestock sector. The commonly used specific vaccine prophylaxis is not always effective due to the genetic variability and mutational variability of pathogen antigens ("antigenic drift"), the widespread prevalence of mixed polyetiological infections, heterogeneity of the immune response and reduced immune resistance. Existent specific vaccines are aimed at protecting against a specific pathogen or, in the case of multivalency, against several specific pathogens, and are based on the induction of long-term adaptive, i.e. antigen-specific immunity due to the formation of T- and B-memory cells. In the last decade, it has been established that vaccines containing microorganisms, such as BCG, provide resistance not only to a specific pathogen (for example, in the case of BCG – against *M. tuberculosis*), but also to a wide range of other pathogens. The main mechanism of this broad heterologous resistance is the increased reactivity of the innate immune system cells, primarily monocytes-macrophages. In response to the primary stimulus ("training"), these cells undergo a number of epigenetic and metabolic rearrangements, become "sensitized" and, when confronted with a second stimulus, the same or another pathogen, provide long-term protection against many viral and bacterial infections. Metabolites of the mevalonate metabolic pathway play an important role in the formation of non-specific or "trained" immunological memory (“trained immunity”, TI). In the present work, the hypothesis of the ability of the farnesyl pyrophosphate synthase inhibitor, aminobisphosphonate (a blocker of the mevalonate pathway at the farnesyl pyrophosphate level), to potentiate BCG-induced TI was verified in *in vitro* and *in vivo* experiments. It has been found that the aminobisphosphonate zoledronate induces the TI phenotype in monocytes and causes nonspecific protection against staphylococcal infection in mice. In addition, zoledronate significantly enhances BCG-induced TI, causing a synergistic protective effect. The phenomenon of potentiated TI that we have discovered can form the basis for the development of fundamentally new powerful universal vaccines.

Key words: non-specific immunological memory, trained innate immunity, BCG, zoledronate, *Staphylococcus aureus*

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INTRODUCTION

In modern livestock farming, which is associated with intensification of production, it is necessary to find new ways to prevent and treat infectious diseases that cause economic losses. The spread of pathogens is facilitated by the characteristics of animal breeding and husbandry technologies, especially in large industrial complexes, where a large number of animals are concentrated in limited areas, as well as the production of large quantities of products in a relatively short period of time. As a result, immunodeficiencies arise [1, 2]. The widespread use of antibiotics leads to the emergence of resistant pathogenic and conditionally pathogenic microflora [3].

Diseases of viral and bacterial etiology most often occur in a mixed infection form. At the same time, the structure, species composition of pathogens, and factors contributing to the occurrence and course of enzootic outbreaks vary for each farm [1, 4]. Specific vaccine prophylaxis is not always effective due to mutational variability and the emergence of strains for which existing

vaccines are suboptimal due to the widespread prevalence of mixed polyetiological infections, as well as due to immune response disorders and reduced immune resistance in animals [5].

However, vaccinating animals is the most cost-effective and sustainable method of controlling infectious diseases. Specific anti-infective vaccines are immunobiological preparations containing attenuated or killed microorganisms, their antigens, or nucleic acids encoding them, targeted against specific pathogens and inducing long-term adaptive (antigen-specific) immunity, ensuring an enhanced and faster immune response upon re-encounter with a specific pathogen (its antigen) and thus resistance to that pathogen. Long-term protection of the body through specific vaccines is due to the production of corresponding antibodies and the formation of T and B memory cells, which can be quickly reactivated upon re-encountering the pathogen. Modern specific vaccines may contain recombinant proteins or DNA and mRNA encoding the desired antigen as antigens, but their main feature is their narrow focus on a specific type of pathogen[1].

Over the past decade, epidemiological, clinical, and experimental data have made it clear that vaccines containing microorganisms, such as BCG, provide resistance not only to a specific pathogen (e.g., in the case of BCG, against *M. tuberculosis*), but also to a wide range of other pathogens [6, 7]. It has become clear that the main mechanism of this broad heterologous immunity is the increased reactivity of cells of the innate immune system, primarily monocytes and macrophages. In response to the initial stimulus (training), these cells undergo a series of epigenetic and metabolic changes, become "sensitized" and, when confronted with a second stimulus (the same or a different pathogen), provide long-term protection against a variety of infections. The formation of nonspecific or "trained" immunological memory (referred to in foreign literature as "trained immunity") involves not only peripheral monocytes-macrophages (Mn-Mf), but also their precursors in the bone marrow. Thanks to the long-lasting metabolic restructuring and epigenetic reprogramming of myelopoiesis precursors in the bone marrow, the state of trained immunity can persist for many months—up to a year or more[2] [8, 9].

The main metabolic changes involved in the formation of the phenotype of nonspecific or "trained" immunological memory (NSIM) in Mn-Mf are the switching of ATP synthesis from oxidative phosphorylation to aerobic glycolysis (the so-called Warburg phenomenon), activation of glutaminolysis and the mevalonate metabolic pathway[3] [9]. Moreover, the key metabolite of the mevalonate pathway, mevalonic acid, is capable of inducing the NSIM phenotype in Mn-Mf on its own [10]. We hypothesized that BCG-induced NSIM formation could be potentiated by inhibiting mevalonate metabolism and blocking prenylation processes through the inhibition of farnesyl pyrophosphate synthase. Classic inhibitors of this enzyme are aminobisphosphonates, such as zoledronic acid. This means that the NSIM-mediated protective effects of BCG can be significantly enhanced by aminobisphosphonates, such as zoledronate (ZD).

If feasible, the phenomenon of potentiated NSIM could form the basis for the creation of fundamentally new drugs with anti-infective properties against a wide range of pathogens. In this study, *in vitro* and *in vivo* experiments verified the hypothesis that the farnesyl pyrophosphate synthase inhibitor aminobisphosphonate can potentiate BCG-induced NSIM. *Staphylococcus aureus* (*S. aureus*) bacteria were used as a non-specific infectious agent.

The purpose of the study was to investigate the possibility of increasing the nonspecific anti-infective resistance of the body based on the formation of a BCG-induced NSIM phenotype and the possibility of its potentiation by zoledro-

[1]*Chambers M.A., Graham S.P., La Ragione R.M.* Challenges in veterinary vaccine development and immunization // Vaccine Design, 2016, N 1404, pp. 3–35.DOI: 10.1007/978-1-4939-3389-1_1.

[2]*Netea M.G., Quintin J., Van Der Meer J.W.M.* Trained immunity: a memory for innate host defense // Cell Host & Microbe, 2011, N 9, pp. 355–361. DOI: 10.1016/j.chom.2011.04.006.

[3]*Cheng S.C., QuintinJ., CramerR.A. et al.* mTOR-and HIF-1alpha-mediated aerobic glycolysis as metabolic basis for trained immunity // Science, 2014, N 345 (6204), p. 1250684. DOI: 10.1126/science.1250684.

nate in Mn-Mf and in mice with regard to experimental infection with *S. aureus*.

MATERIAL AND METHODS

The study used the BCG vaccine strain ("Tuberculosis vaccine, BCG"; AO SPA 'Microgen', Russia), the *Staphylococcus aureus* strain from the collection of microorganisms of the Novosibirsk Research Institute of Tuberculosis of the Ministry of Health of Russia, and zoledronate (Pliva Hrvatska DOO, Croatia).

The research was conducted in two stages. The formation of the BCG-induced NSIM phenotype in human monocyte-macrophage cells and the possibility of its potentiation by zoledronate were studied in vitro. Monocytes were obtained from the peripheral venous blood of healthy donors by isolating mononuclear cells using the Bouym method (1968) by centrifugation in a density gradient of 1.077 g/cm^3 of Ficoll solution (PanEco) followed by fractionation, using the ability of monocyte-macrophage series cells to adhere to the substrate. For this purpose, mononuclear cells were cultured for 60 minutes at 37 °C in an atmosphere containing 5% CO_2, at a concentration of 2×10^6 cells/ml on Petri dish glass in RPMI-1640 medium (PanEco, Russia) with the addition of penicillin-streptomycin antibiotics (OOO "Biolot", Russia), 2 mM L-glutamine (OOO "Biolot", Russia), and 10% fetal bovine serum (Fetal Bovine Serum-12A, Capricorn Scientific, Germany). Then, the monolayer was washed from unattached cells, removed with a cooled (4–6 °C) Versen solution, centrifuged at 1000 rpm for 10 minutes, resuspended in nutrient medium, with the addition of embryonic serum, and transferred to 48-well plates at a concentration of 8×10^5 cells/ml. The purity of the fraction was checked by flow cytometry using antibodies to $CD14^+$.

To induce the NSIM phenotype, live microbial cells of the BCG vaccine strain were added to the culture medium at a dose of 5 μg/ml, incubated for 24 hours, then the monocytes were washed from the non-phagocytosed bacteria, and zoledronate was added to some of the cultures at a concentration of 100 μM/ml. Intact cells served as a negative control. The experiment was performed in three replicates, each time using monocytes from different donors. For each subgroup, 8 wells of a 48-well culture plate were used.

After 3 days, the culture medium was replaced with one containing zoledronate, and on the 6th day, a second (permissive) stimulus was added – LPS *Escherichia coli* O111: B4 ("Sigma-Aldrich", USA) at a dose of 10 ng/ml. After 24 hours, the metabolic changes characteristic of NSIM were verified by the activation of aerobic glycolysis with increased glucose consumption and lactate accumulation. The lactate level in the supernatant was determined spectrophotometrically using the Lactate-Novo kit ("Vector-best"), and the glucose level was determined using the Glucose-Novo kit ("Vector-best").

The second stage was the *in vivo* study. The experiments were approved by the local ethics committee of the Novosibirsk Research Institute of Tuberculosis of the Russian Ministry of Health (protocol No. 54 dated November 11, 2022) and conducted in compliance with all international and Russian ethical standards, including Directive 2010/63/EU of the European Parliament and of the Council on the protection of animals used for scientific purposes.

C57Bl/6 mice, females weighing 20–22 g, obtained from the IMBT FBIS SSC VB "Vector" breeding facility, were randomly divided into 8 groups of 8 animals each:

1st	0.9% NaCl solution
2nd	0.9% NaCl solution + *S. aureus*
3rd	zoledronate 0.5 μg/mouse + *S. aureus*
4th	zoledronate 1,0 μg/mouse + *S. aureus*
5th	zoledronate 2,5 μg/mouse + *S. aureus*
6th	zoledronate 10 μg/mouse + *S. aureus*
7th	BCG 10^6 CFU/mouse + *S. aureus*
8th	BCG 10^6 CFU/mouse, zoledronate 2,5 μg/mouse + *S. aureus*

Live BCG microbial cells were administered intraperitoneally to the animals at a dose of 10^6 CFU/mouse. Zoledronate was administered into the retroorbital sinus (r/o) at test doses of 100 μl/mouse. On day 8, the animals were infected

with *S. aureus* r/o. at a dose of 10^7 CFU/mouse. Intact animals that were administered a 0.9% NaCl solution and mice infected with *S. aureus* at the same dose served as the control group. The study used a "renal model" to quantitatively assess the severity of *S. aureus* infection based on the formation of abscesses in the kidneys[4, 5].

Mice were removed from the experiment on the 4th and 9th days after infection by dislocation of the cervical vertebrae. Organs (spleen and kidney) were collected under sterile conditions, homogenized in a 0.9% sodium chloride solution at a rate of 1 ml per 0.1 g of organ weight, and cultured on nutrient agar for the cultivation of microorganisms (GRM agar, GNTS Applied Microbiology and Biotechnology), incubated at 37 °C for 16–18 hours. The number of colony-forming units (CFU) was determined by the Gold sector plating method. The results were expressed in lgCFU/organ.

For morphological studies, histological paraffin sections were prepared from the tissue of the right kidney, stained with hematoxylin and eosin, photographed under a PrimoVert microscope (Carl Zeiss, Germany) using the ZEN 2. 3 lite software with a digital recording system at ×400 magnification, and morphometry of the abscess foci was performed by counting 80 fields of view in each group of animals.

Statistical data processing was performed using the STATISTICA 10.0 software package (StatSoftInc., USA). The results are presented as the mean value and standard error of the mean ($M \pm m$). The significance of differences between mean values was assessed using Student's t-test. The differences were considered significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Visual morphological changes in the cell culture treated with BCG could be observed as early as the second day, and by the end of the experiment, the difference compared to the control cultures was significant (see fig. 1). Intact monocytes adhered evenly to the surface of the culture mat substrate, had a rounded shape, and showed virtually no change in morphology throughout the incubation period. In contrast, cells treated with BCG mycobacteria were unevenly distributed across the surface during adhesion, increased in size, often acquired a spindle-shaped form, and on the fourth day began to form conglomerates that transitioned into granuloma-like formations.

The activation of aerobic glycolysis is a characteristic feature of the formation of the NSIM phenotype in monocyte-macrophage cells and indicates that metabolic reprogramming has taken place. This leads to an increase in glucose consumption by cells and lactate production in them. Exposure to secondary stimuli—bacteria or their molecules—leads to an even greater increase in glycolytic activity and bactericidal activity.

Fig. 2 shows data on changes in lactate and glucose levels in supernatants of monocyte monolayers preincubated with BCG and/or zoledronate as a primary stimulus, followed by the addition of bacterial lipopolysaccharide (LPS) as a secondary stimulus, mimicking the repeated encounter of cells with the pathogen.

Cells stimulated by LPS increased lactate production and glucose consumption; under the influence of BCG, these effects were more pronounced, and the addition of LPS after preliminary BCG treatment increased lactate levels and glucose consumption even more effectively. Clearly, the data obtained confirm the ability of BCG to induce the formation of NSIM. Zoledronate provoked an increase in lactate production and glucose consumption by cells, i.e., like BCG, it was capable of inducing NSIM. It should be noted that when added to monocytes together with BCG, it potentiates the action of the latter, and the effect of LPS in this case confirms the ability of zoledronate to enhance BCG-induced NSIM.

[4]*Gruber I.M., Astashkina E.A., Lebedinskaya O.V., et al.* Immunogenic activity of secreted protein-containing compounds of *Staphylococcus aureus* No. 6 // Epidemiology and vaccination prevention, 2015, N 4 (83), pp. 86–93. DOI: 10.31631/2073- 3046-2015-14-4-86-93.

[5]*Cheng A.G., McAdowM., KimH.K., BaeT., Missiakas D.M., Schneewind O.* Contribution of coagulases towards *Staphylococcus aureus* disease and protective immunity // PLOS Pathogens, 2010, N 6 (8), E 1001036. DOI: 10.1371/journal.ppat.1001036.

Since the *in vitro* results confirm our hypothesis about the potentiation of the BCG-induced NSIM phenotype in monocyte-macrophage series cells by zoledronate, the next stage of the study was to evaluate the effect of zoledronate on the protective action of BCG *in vivo* against "non-specific" infection, i.e. not tuberculosis, but infections caused by other pathogens. *S. aureus* is used – a pathogen that occupies one of the leading places in infectious pathology of domestic and farm animals. Against the background of viral infections and/or reduced immunity (due to violations of feeding and housing standards), it can cause serious pathological processes such as septicemia, staphyloderma, respiratory diseases, mastitis, etc. In addition, *S. aureus* is resistant to many drugs, easily developing antibiotic resistance [4].

The first group of mice (four from each of the eight groups) was removed from the experiment on the fourth day, when abscessed bacterial foci formed in the tissues. The second group of ani-

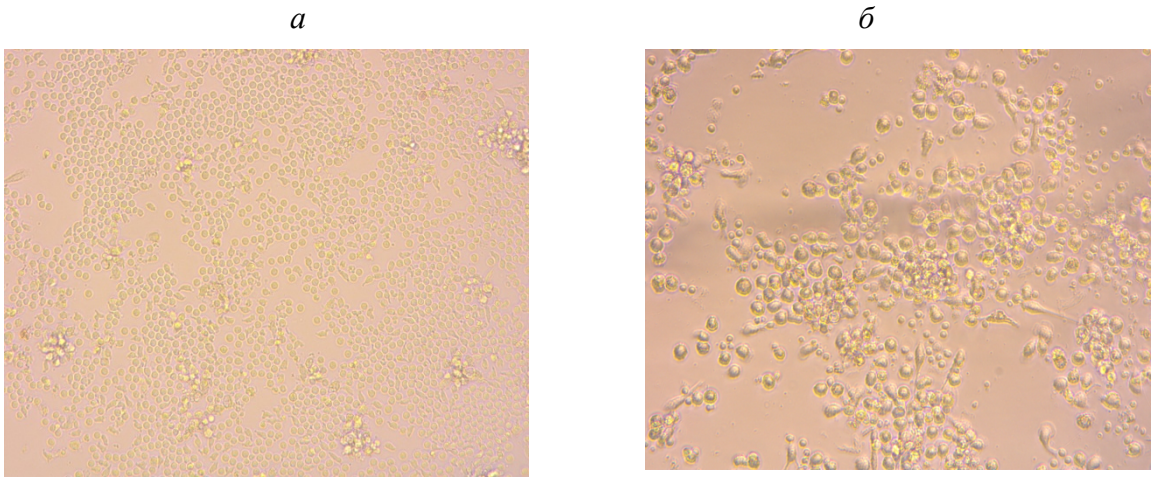

Рис. 1. Моноциты, 96 ч инкубации (×200); *а* – интактные; *б* – обработанные («тренированные») БЦЖ

Fig. 1. Monocytes, 96 hours of incubation (magnification ×200); *а* – intact, *б* – treated ("trained") with BCG

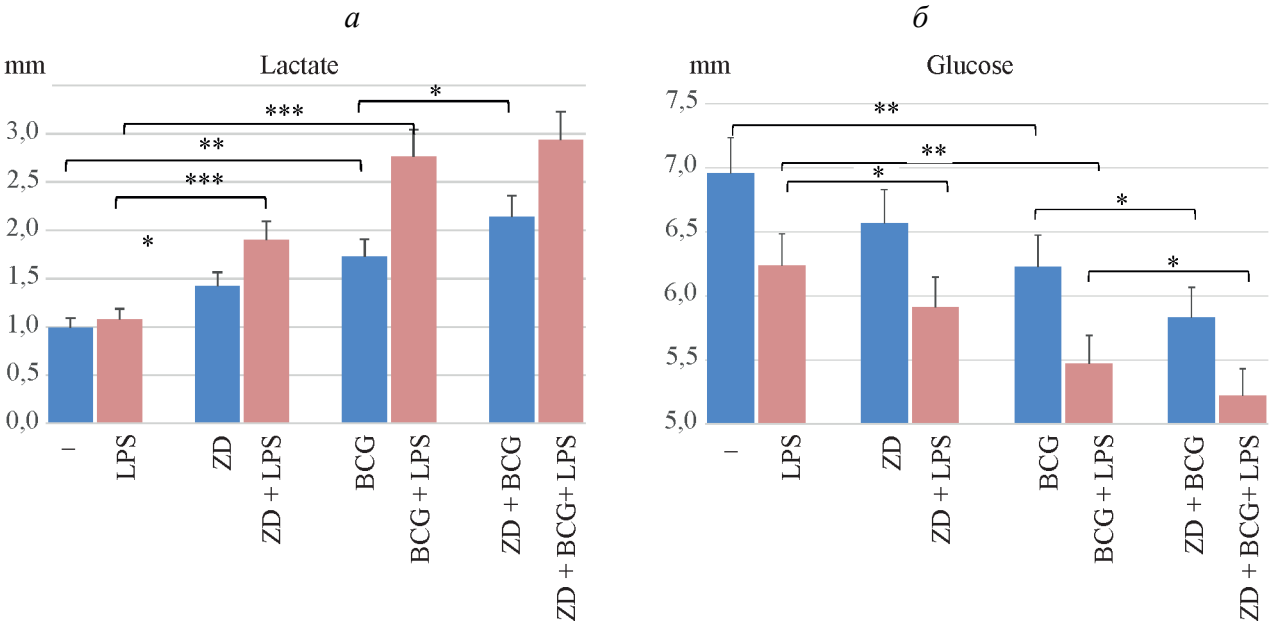

Рис. 2. Продукция лактата (*а*) и потребление глюкозы (*б*) моноцитами человека при индукции НИП; $M \pm m$; $*p \le 0{,}05$; $**p \le 0{,}01$; $***p \le 0{,}001$

Fig. 2. Lactate production (*а*) and glucose consumption (*б*) by human monocytes upon induction of trained immunity, M ± m, $*p \le 0.05$, $**p \le 0.01$, $***p \le 0.001$

mals was removed on the ninth day, when gradual elimination of bacteria was observed. In the experimental group "NaCl," *S. aureus* was isolated from the kidneys but not from the spleen (see Table 1).

On the fourth day after infection, zoledronate at doses of 2.5 and 10 μg and on the ninth day at doses of 0.5, 1.0, and 2.5 μg sharply reduced the number of mice with positive cultures. However, on the 4th day, zoledronate statistically significantly increased (with a few exceptions) the bacterial load in organs, especially at the maximum dose (10 μg), probably due to its apoptotic effect on immunocompetent cells. BCG did not affect the number of animals with positive cultures or the bacterial load in the kidneys, but on the 4th day it provoked bacterial growth in the spleen. Thus, in our experiment, zoledronate had a certain protective effect, while BCG had no positive effect. At the same time, the combined effect of BCG + ZD led to a significant reduction in the content of *S. aureus* content in the kidneys compared to the "0.9% NaCl solution" variant and the "zoledronate 2.5 μg", "zoledronate 0.5 μg", "zoledronate 1 μg", "zoledronate 10 μg", and "BCG 10^6 CFU" variants.

Morphometric analysis showed that on the fourth day after infection, zoledronate dose-dependently inhibited abscess formation (see Table 2). By the 9th day, inhibition continued at low doses of zoledronate (0.5–1.0 μg), paused at medium doses (2.5 μg), and was replaced by increased formation at high doses (10 μg) (probably due to the apoptotic effect of high doses). BCG had virtually no effect on abscess formation. However, the combined action of BCG and zoledronate was most effective, powerfully suppressing abscess formation. These data are consistent with the results of *S. aureus* isolation from organs.

Thus, zoledronate is capable of independently inducing the NSIM phenotype in human monocytes and causing nonspecific protection against staphylococcal infection in mice: at a dose of 2.5 μg/mouse, it forms protection against *S. aureus*, and at a dose of 0.5 μg/mouse, it accelerates recovery in 100% of animals. In addition, and extremely importantly, zoledronate is capable of potentiating BCG-induced NSIM, causing a synergistic protective effect.

Табл. 1. Результаты посевов из гомогенатов почек и селезенок мышей через 4 и 9 сут после инфицирования *S. aureus* в дозе 10^7 КОЕ/мышь.

Table 1. Results of the cultures from mouse kidney and spleen homogenates 4 and 9 days after infection with *S. aureus* at a dose of 10^7 CFU/mouse.

Experimental group	Number of (+) organ seeded/to the number of the infected, %		Kidneys, lg CFU/organ		Spleen, lg CFU/organ	
	24 hours					
	4th	9th	4th	9th	4th	9th
0,9% NaCl solution	100	100	5,5 ± 0,25	3,5 0 ± 1,75	0	0
Zoledronate, μg: 0,5	100#	0	6 ± 0,03*°#	0	3,25 ± 1,38*°#	0
1,0	100#	50 ± ,5*°	6 ± 0,03*°#	6,75 ± 0,22*°#	0	0
2,5	50 ± 12,5*°	50 ± 12,5*°	6 ± 0,03*°#	3,75 ± 0,22	0,87 ± 0,11*°#	0
10,0	50 ± 12,5*°	100#	7,02 ± 0,02*°#	5,0 ± 0,5*°#	7,02 ± 0,02*°#	0
BCG 10^6 CFU	100	100	5,5 ± 0,35	3,5 ± 0,18	5,63 ± 0,11*#	0
BCG 10^6 CFU, zoledronate 2,5 μg	50 ± 12,5*°	50 ± 12,5*°	4,38 ± 0,37*°	3,5 ± 0,18	0°	0

Note. Here and in Table 2, statistically significant ($p \leq 0.05$) differences from the values of the corresponding indicators are shown: *0,9% NaCl solution; ° BCG 10^6 CFU; # BCG 10^6 CFU, zoledronate 2,5 μg.

CONCLUSION

Currently, many research groups around the world are studying the NSIM phenotype, as its study opens up broad prospects for the development of new methods of vaccine prevention and treatment of infectious diseases [11, 12]. Our data show the possibility of forming enhanced, potentiated NSIM and, thus, a path to the creation of the most powerful non-specific vaccines. The specific result of our research shows that one way to obtain potentiated NSIM may be the use of aminobisphosphonates, which enhance BCG-induced protection against nonspecific infection caused by *S. aureus*.

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Табл. 2. Формирование абсцессов в почках мышей, инфицированных *S. aureus* в дозе 10^7 КОЕ/мышь.
Table 2. Formation of abscesses in the kidneys of mice infected with *S. aureus* at a dose of 10^7CFU/mouse.

Experimental group	Total number of abscesses	Fields of vision with abscesses, %	Total number of abscesses	Fields of vision with abscesses, %
	4th 24 hours		9th 24 hours	
0,9% NaCl solution	34,0 ± 0,57	81,25 ± 0,85	24,0 ± 0,41	60,00 ± 0,58
Zoledronate, μg: 0,5	33,25 ± 0,63	83,75 ± 0,47*°	0	0
1,0	30,0 ± 0,41*	81,25 ± 0,85	19,0 ± 0,41*°	35,00 ± 0,58*°#
2,5	13,0 ± 0,41*°#	40,00 ± 0,58*°	13,25 ± 0,85*°	23,75 ± 0,25*°#
10,0	16,0 ± 0,82*°#	42,50 ± 0,29*°	27,0±0,41*°	63,75±0,75*#
BCG 10^6 CFU	32,0 ± 1,22	80,00 ± 0,58	23,0 ± 1,08	61,25 ± 0,48
BCG 10^6 CFU, zoledronate 2,5 μg	10,75 ± 0,48*°	32,50 ± 1,04*°	7,75 ± 0,25*°	20,00 ± 0,58*°

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Видовой состав микрофлоры, выделяемой от сельскохозяйственной птицы

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В ходе проведенного исследования изучен видовой состав микрофлоры, выделяемой от сельскохозяйственной птицы на птицеводческих предприятиях Омской области. С этой целью были отобраны 392 пробы патолого-анатомического материала (кровь из сердца, головной и костный мозг, печень, желчный пузырь, кишечник) от цыплят-бройлеров (62,2%), перепелов (16,3), кур-несушек (12,6) и индеек-бройлеров (8,9%). Индикацию и идентификацию микроорганизмов осуществляли по общепринятым в микробиологии методикам. Выделенные культуры отнесены к четырем семействам: Enterobacteriaceae – 39,7%, Enterococcaceae – 36,5, Staphylococcaceae – 23,1, Pseudomonadaceae – 0,6%. Основное число патогенных и условно-патогенных микроорганизмов идентифицированы как *Escherichia coli* (23,8%), *Enterococcus faecalis* (21,9) и *Staphylococcus aureus* (19,2%). Наиболее широкий спектр микроорганизмов выделен из содержимого кишечника птиц. При этом преобладающими видами являлись *E. coli* (27,2%), *E. faecalis* (21,2), *S. aureus* и *Enterococcus faecium* (по 17,3%). При исследовании крови из сердца, головного и костного мозга лидирующее место занимали *E. faecalis* (21,8–30,3%), *S. aureus* (18,2–22,7) и *E. coli* (14,1–21,8%). При изучении микрофлоры, выделяемой из печени, чаще всего фиксировались *S. aureus* (36,8%) и *E. coli* (26,3%), также большую долю составили *Proteus mirabilis* и *E. faecalis* (по 15,8%). Микробиологическое исследование желчного пузыря установило доминирование *S. aureus*, *Enterobacter agglomerans*, *E. faecium* и *E. coli*. Наибольшее разнообразие видов выделено от цыплят-бройлеров. Результаты микробиологических исследований позволили определить этиологически значимые микроорганизмы, участвующие в развитии инфекционной патологии у сельскохозяйственной птицы на территории Омской области, что можно использовать при составлении схем лечебно-профилактических мероприятий в птицеводческих хозяйствах региона для обеспечения их эпизоотического благополучия.

Ключевые слова: микрофлора, сельскохозяйственная птица, эпизоотология, микробиология

Species composition of microflora isolated from poultry

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In the course of the research the species composition of the microflora isolated from poultry at poultry farms of the Omsk region was studied. For this purpose, 392 samples of pathologic-anatomical material (blood from heart, brain and bone marrow, liver, gall bladder, and intestine) were collected from broiler chickens (62.2%), quail (16.3), laying hens (12.6), and broiler turkeys (8.9%). Indication and identification of microorganisms were carried out according to the methods generally accepted in microbiology. The isolated cultures belonged to 4 families: Enterobacteriaceae (39.7%), Enterococcaceae (36.5), Staphylococcaceae (23.1), Pseudomonadaceae (0.6%). The largest number of the isolated pathogenic and opportunistic microorganisms were identified as *Escherichia coli* (23.8%), *Enterococcus faecalis* (21.9) and *Staphylococcus aureus* (19.2%). The widest range of microorganisms was isolated from the contents of the intestines of the birds. The leading places were occupied by *E. coli* (27.2%), *E. faecalis* (21.2), *S. aureus* and *Enterococcus faecium* (17.3% each). In the study of blood from the heart, brain and bone marrow, *E. faecalis* (21,8–30,3%), *S. aureus* (18,2–22,7) and *E. coli* (14,1–21,8%) took the leading position. When studying the microflora isolated from the liver, *S. aureus* (36.8%) and *E. coli* (26.3%) were most often recorded, *Proteus mirabilis* and *E. faecalis* also accounted for a large proportion (15.8% each). Microbiological examination of the

gallbladder established the dominance of *S. aureus*, *Enterobacter agglomerans*, *E. faecium* and *E. coli*. The greatest variety of microbial species was isolated from broiler chickens. The results of microbiological studies made it possible to identify etiologically significant microorganisms involved in the development of infectious pathology in agricultural poultry in the Omsk region. This information can be used to develop treatment and prevention strategies in poultry farms in the region to ensure their epizootic well-being.

Keywords: microflora, agricultural poultry, epizootology, microbiology

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Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Thanks to advances in breeding, poultry productivity is increasing every year while the time required to raise them is decreasing. However, in order to achieve maximum production rates, it is necessary to strictly comply with all veterinary and sanitary rules for keeping poultry. Recently, diseases caused by conditionally pathogenic microflora, or so-called opportunistic infections, have become widespread in poultry farming. Certain conditions, in particular immunosuppression, are necessary for their occurrence and spread. More often, the following are isolated from the organs and tissues of birds: *Salmonella*, *Staphylococcus aureus*, *Escherichia coli*, *Pasteurella multocida*[1] [1–5]. Today, antibacterial drugs are one of the most commonly used groups of medicines. Resistance to antimicrobial drugs is rapidly spreading worldwide, and their uncontrolled use is harmful not only to poultry and livestock farming, but also to humans who consume agricultural products produced by these industries [6–14].

Poultry farms often underestimate the importance of microbiological monitoring. By studying the composition of microorganisms circulating among poultry, it is possible to determine their sensitivity to antimicrobial drugs so that, if necessary, treatment can be prescribed to quickly resolve the problem and reduce economic losses for the farm. It should be noted that not only the spectrum of microorganisms is important, but also their location in various organs and tissues. Thus, studying the species composition of microflora is one of the most important stages in developing an effective treatment and prevention plan to ensure the epizootic well-being of poultry farms.

The purpose of the study is to determine the species composition of microflora isolated from farm poultry in the Omsk region.

The objectives are:

1) to identify etiologically significant microorganisms involved in the development of bacterial infections at poultry farms in the Omsk region;

2) to study the microbial landscape of various organs and tissues of farm poultry;

3) to identify the predominant pathogens by type of farm poultry.

MATERIAL AND METHODS

The study was conducted in 2021–2023 by employees of the poultry veterinary department of the Omsk Agricultural Research Center. The

[1]*Novikova O.B.* Development of methods for the prevention and improvement of diagnostic methods for bacterial diseases in birds: extended abstract of the thesis of Doctor of Science in Veterinary Medicine. St. Petersburg, 2021, 45 p.

object of the study was biomaterial from 392 dead birds received from poultry farms and poultry farming enterprises in the Omsk region: from broiler chickens – 62.2%, quails – 16.3, laying hens – 12.6, broiler turkeys – 8.9%. The samples were taken from different organs and tissues: blood from the heart, gallbladder, brain, and bone marrow (from all individuals), liver, and intestines (if there were visible pathological changes). In total, 1,960 samples were tested for bacteria.

The detection and identification of microorganisms was carried out in accordance with generally accepted microbiological methods using simple and differential diagnostic media: 1) Endo agar – for the detection of enterobacteria; 2) magnesium medium and BSA (bismuth sulfite agar) – to determine the presence of salmonella; 3) staphylococcus agar – to isolate staphylococci; 4) enterococcus agar – to determine the presence of enterococci[2, 3]. The pathogenicity of staphylococcal cultures was tested using the plasma coagulation reaction with rabbit citrate plasma[4]. Genus and species identification was carried out on the Olkenitsky medium, on the Giss medium with sugars[5, 6] and using multimicrotests for biochemical identification of staphylococci (MMT C) and enterobacteria (MMT E). The morphology of the isolated pathogens was studied in smears from agar cultures stained according to Gram (see footnote 6).

RESULTS AND DISCUSSION

Microorganisms belonging to the following families were isolated from the biomaterial studied from various bird species: Enterobacteriaceae – 39.7%, Enterococcaceae – 36.6, Staphylococcaceae – 23.1, Pseudomonadaceae – 0.6%. *E. coli*, *S. aureus*, and *Enterococcus faecalis* were most frequently identified in birds (see the figure). In addition to the above pathogens, a significant number of *Enterobacter agglomerans*, *E. cloacae*, *Proteus mirabilis*, and *Enterococcus faecium* were isolated. The data obtained are confirmed by other studies [4, 7, 8].

In the samples of biomaterial from the heart, brain, and spinal cord, *E. faecalis*, *S. aureus*, and *E. coli* were the leading pathogens in varying percentages (see Table 1). When studying the microflora isolated from the liver, *S. aureus* (36.8%) and *E. coli* (26.3%) were the most prevalent, with *P. mirabilis* and *E. faecalis* also accounting for a large proportion (15.8% each). Microbiological examination of the gallbladder of dead birds revealed the dominance of *S. aureus* (29.7%), *Enterobacter agglomerans* (22.2%), *E. faecium* (18.5%), and *E. coli* (14.8%).

The widest range of microorganisms was isolated from the intestines of birds. The leading positions were occupied by *E. coli* (27.2%), *E. faecalis* (21.2%), *S. aureus*, and *E. faecium* (17.3% each). Species such as *Staphylococcus capitis*, *S. xylosus*, *S. simulans*, *S. auricularis*, *S. cohnii*, *S. haemolyticus*, *S. werneri*, *S. lentus*, *Edwardsiella tarda*, *Morganella morganii*, *Yersinia enterocolitica*, *Providencia rettgeri*, and *Plesiomonas shigelloides* were isolated only from the intestines in 0.3–2.5% of cases.

It should be noted that different bird species differ not only in the spectrum of microorganisms they excrete, but also in the frequency of their fixation (see Table 2).

In laying hens, *E. coli* (31.9%), *S. aureus* (25.5%), and *E. faecalis* (17.0%) played a leading role in the pathology. The number of *E. faecium* and *Citrobacter freundii* was 6.4% each, and *Pseudomonas aeruginosa* was isolated in 2.2% of cases.

The greatest diversity of microorganisms was recorded in pathological material from broiler chickens. The prevalence of *E. coli* (24.8%), *E. faecalis* (22.2%), *S. aureus* (18.1%), and *E. faecium* (15.1%) was identified. The remaining

[2]Guide to microbiological diagnosis of infectious diseases / edited by K.I. Matveev. Moscow: Medicine, 1973, 624 p.

[3]*Skala L.Z., Sidorenko S.V., Nekhorosheva A.G., Lukin I.N., Grudina S.A.* Practical aspects of modern clinical microbiology. Moscow, 2004, 312 p.

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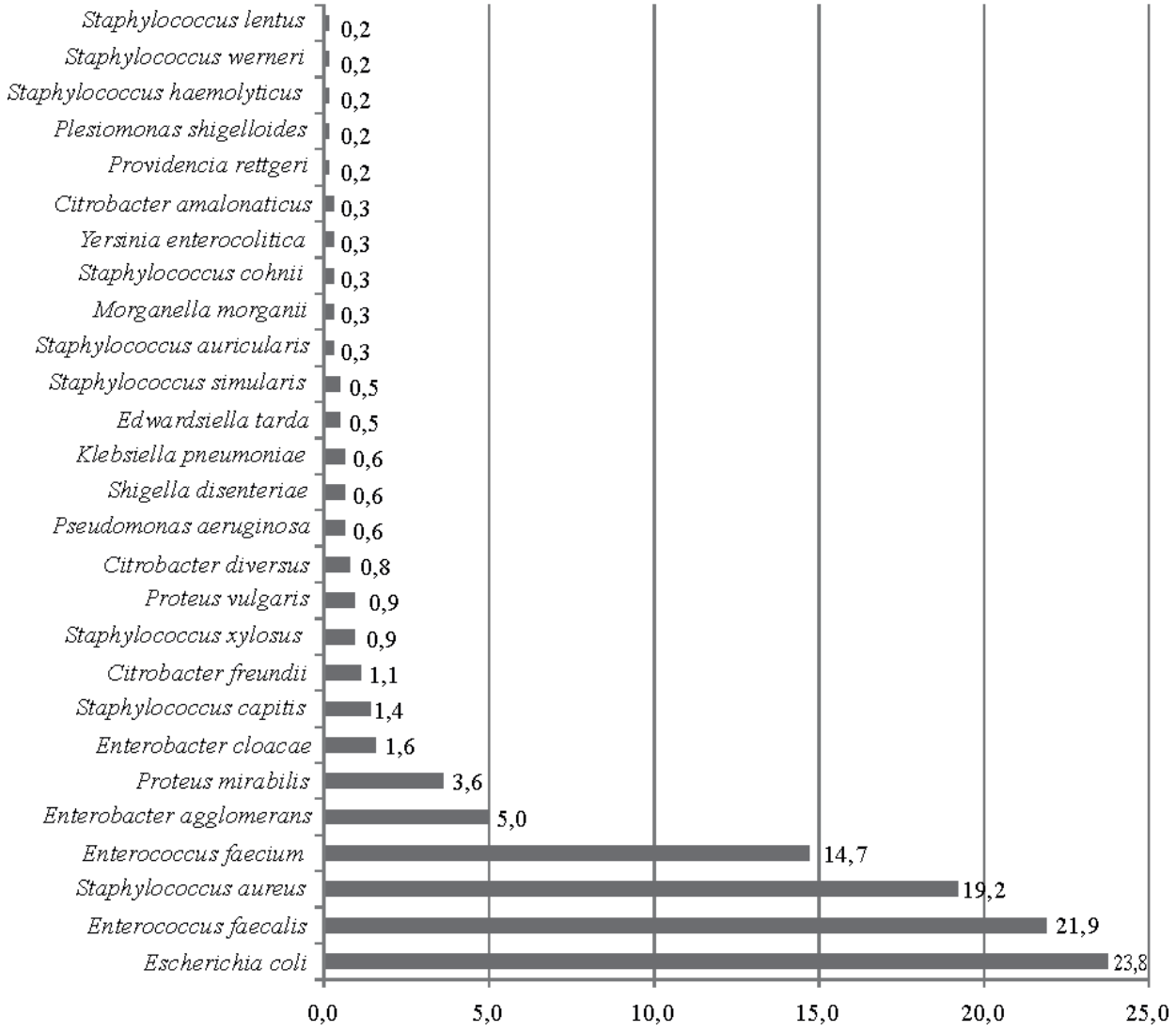

Видовой состав микрофлоры, выделенной от сельскохозяйственной птицы, %
Species composition of microflora isolated from poultry, %

23 species of microorganisms were isolated in 0.2–3.7% of cases.

E. faecalis (33.3%), *S. aureus* (16.7%), *E. coli* (13.5%), and *P. mirabilis* (13.3%) were frequently isolated from broiler turkeys.

Quails were found to have the smallest species composition of microorganisms, the majority of which were *S. aureus* (26,4%), *E. agglomerans* (18,9), *E. faecium* (18,8), *E. faecalis* (17,0%).

CONCLUSION

The study found that *E. coli*, *E. faecalis*, and *S. aureus* are the dominant bacteria in the development of bacterial infections at poultry farms in the Omsk region, accounting for 23.8%, 21.9%, and 19.2% of the isolated cultures, respectively.

In the process of studying the microbial landscape in various organs and tissues of farm poultry, the widest range of microorganisms was isolated from the intestines, blood from the heart, and brain. The following species were most frequently recorded: *E. faecalis* (21,2–25,6%), *S. aureus* (17,3–22,7), *E. coli* (14,1–27,2), *E. faecium* (10,9–17,3) and *E. agglomerans* (3,0–9,0%)

Among laying hens, the following predominated: *E. coli* (31,9%), *S. aureus* (25,5), *E.*

Табл. 1. Спектр микроорганизмов, выделенных из органов и тканей сельскохозяйственной птицы, %

Table 1. Spectrum of microorganisms isolated from poultry organs and tissues, %

The isolated culture	Test material					
	blood from the heart	brain cord	bone marrow	liver	gall bladder	intestine
Escherichia coli	21,8	14,1	21,2	26,3	14,8	27,2
Staphylococcus aureus	22,7	18,6	18,2	36,8	29,7	17,3
Enterococcus faecalis	21,8	25,6	30,3	15,8	14,8	21,2
Enterobacter agglomerans	5,0	9,0	6,1	–	22,2	3,0
Proteus mirabilis	6,7	5,1	12,1	15,8	–	1,1
Enterococcus faecium	10,9	12,8	9,1	–	18,5	17,3
Staphylococcus capitis	–	–	–	–	–	2,5
Enterobacter cloacae	2,5	6,4	3,0	–	3,7	–
Staphylococcus xylosus	–	–	–	–	–	1,6
Proteus vulgaris	–	–	–	5,3	–	1,4
Shigella disenteriae	0,8	–	–	–	–	0,8
Klebsiella pneumoniae	0,8	–	–	–	7,4	0,3
Citrobacter freundii	2,5	2,6	–	–	–	0,5
Citrobacter diversus	2,5	1,3	–	–	–	0,3
Edwardsiella tarda	–	–	–	–	–	0,8
Staphylococcus simulans	–	–	–	–	–	0,8
Pseudomonas aeruginosa	1,7	2,6	–	–	–	–
Staphylococcus auricularis	–	–	–	–	–	0,5
Morganella morganii	–	–	–	–	–	0,5
Staphylococcus cohnii	–	–	–	–	–	0,5
Yersinia enterocolitica	–	–	–	–	–	0,5
Providencia rettgeri	–	–	–	–	–	0,3
Plesiomonas shigelloides	–	–	–	–	–	0,3
Citrobacter amalonaticus	–	1,3	–	–	–	0,3
Staphylococcus haemolyticus	–	–	–	–	–	0,3
Staphylococcus werneri	–	–	–	–	–	0,3
Staphylococcus lentus	–	–	–	–	–	0,3

Табл. 2. Частота обнаружения исследуемых микроорганизмов у различных видов сельскохозяйственной птицы, %

Table 2. Frequency of detection of investigated microorganisms in different poultry species, %

The isolated culture	Laying hens	Broiler chickens	Turkey broiler chickens	Quails
Escherichia coli	31,9	24,8	13,5	13,2
Staphylococcus aureus	25,5	18,1	16,7	26,4
Enterococcus faecalis	17,0	22,2	33,3	17,0
Enterobacter agglomerans	4,3	3,7	3,3	18,9
Proteus mirabilis	2,1	3,5	13,3	–
Enterococcus faecium	6,4	15,1	6,7	18,8
Staphylococcus capitis	–	1,8	–	–
Enterobacter cloacae	–	1,4	–	5,7
Staphylococcus xylosus	–	1,2	–	–
Proteus vulgaris	2,1	1,0	–	–
Shigella disenteriae	–	0,8	–	–
Klebsiella pneumoniae	–	0,8	–	–
Citrobacter freundii	6,4	0,6	3,3	–
Citrobacter diversus	2,1	0,6	3,3	–
Edwardsiella tarda	–	0,6	–	–
Staphylococcus simulans	–	0,6	–	–
Pseudomonas aeruginosa	2,2	0,4	3,3	–
Staphylococcus auricularis	–	0,4	–	–
Morganella morganii	–	0,4	–	–
Staphylococcus cohnii	–	0,4	–	–
Yersinia enterocolitica	–	0,4	–	–
Providencia rettgeri	–	0,2	–	–
Plesiomonas shigelloides	–	0,2	–	–
Citrobacter amalonaticus	–	0,2	3,3	–
Staphylococcus haemolyticus	–	0,2	–	–
Staphylococcus werneri	–	0,2	–	–
Staphylococcus lentus	–	0,2	–	–

Note. In Tables 1, 2: «–» – no microorganisms isolated.

faecalis (17,0%). The most diverse range of microorganisms was observed in broiler chickens: *E. coli* (24,8%), *E. faecalis* (22,2), *S. aureus* (18,1%). Most of the microorganisms isolated from broiler turkeys belonged to *E. faecalis* (33,3%), *S. aureus* (16,7), *E. coli* (13,5%). Quails were found to have mainly *S. aureus* (26,4%), *E. agglomerans* (18,9) and *E. faecium* (18,8%).

Thus, the monitoring studies conducted made it possible to identify etiologically significant microorganisms involved in the development of bacterial infectious pathology in farm poultry in the Omsk region.

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СЕРАФИМА ЯКОВЛЕВНА СЫЕВА

Руководителю Горно-Алтайского научно-исследовательского института сельского хозяйства – филиала Федерального Алтайского научного центра агробиотехнологий Серафиме Яковлевне Сыевой 26 февраля 2025 г. исполнилось 65 лет. Стаж научной деятельности одного из ведущих ученых-аграрников Республики Алтай кандидата биологических наук, доцента, заслуженного деятеля науки Республики Алтай С. Я. Сыевой составляет 37 лет.

Серафима Яковлевна родилась в 1960 г. в с. Малый Яломан Онгудайского района Горно-Алтайской автономной области. По окончании средней школы трудовую деятельность с 1977 по 1979 г. начала рабочей Ининского козоводческого совхоза. В 1979–1985 гг. училась в Московской сельскохозяйственной академии им. К.А. Тимирязева, по окончании которой работала главным специалистом в Ининском козоводческом совхозе Онгудайского района.

Научную деятельность Серафима Яковлевна начала с 1988 г. в качестве младшего научного сотрудника Горно-Алтайской сельскохозяйственной опытной станции, затем работала заведующей аналитической лабораторией (1993–1999 гг.), ученым секретарем Горно-Алтайского научно-исследовательского института сельского хозяйства (1999–2008 гг.), заместителем директора по научной работе (2008–2017 гг.). С 2017 г. С.Я. Сыева – руководитель Горно-Алтайского научно-исследовательского института сельского хозяйства.

В 2005 г. Серафима Яковлевна защитила диссертацию кандидата биологических наук, в 2007 г. ей присвоено ученое звание «доцент» по специальности «ботаника». Она автор и соавтор 147 печатных работ, в том числе трех монографий, двух патентов на изобретения и ряда методических рекомендаций.

Круг научных интересов Серафимы Яковлевны охватывает широкий спектр проблем, связанных с изучением природной флоры Горного Алтая, биохимии кормовых растений, состояния природных кормовых угодий горных территорий, научного обеспечения лугового кормопроизводства и развития АПК. С 2011–2018 гг. под ее руководством выполнены исследования по разработке системы агротехнологий производства продукции растениеводства, мероприятий эффективного использования природно-ресурсного потенциала агроландшафтов, интродукции кормовых растений в Республике Алтай. С 2019 г. С.Я. Сыева является научным руководителем исследований по тематике института в рамках Программы фунда-

ментальных научных исследований государственных академий наук Российской Федерации. Под руководством и участием С.Я. Сыевой успешно выполнен ряд научных проектов грантов Российского фонда фундаментальных исследований и Республики Алтай. В 2006, 2009 и 2014 гг. Серафиме Яковлевне присуждены дипломы СО РАСХН за лучшую завершенную научную работу.

Серафима Яковлевна успешно совмещает научную и педагогическую деятельность, преподает на кафедре агротехнологий и ветеринарной медицины Горно-Алтайского государственного университета. Под ее руководством выполнено 17 выпускных квалификационных работ и магистерских диссертаций.

Серафима Яковлевна является заместителем председателя научно-технического совета Министерства сельского хозяйства Республики Алтай, а также членом совета по образованию и науке при правительстве Республики Алтай, правления Регионального отделения общественной организации «Женщины Алтая», Региональной общественной организации «Совет солдатских матерей Республики Алтай».

С.Я. Сыева принимает активное участие в организации и проведении международных и региональных конференций, совещаний. При ее непосредственном участии осуществлялась редакционная подготовка научных изданий, материалов международных конференций и сборников научных трудов.

С.Я. Сыева удостоена множества наград регионального и федерального уровня. В 2020 г. ей присуждено почетное звание «Заслуженный деятель науки Республики Алтай».

Поздравляем Серафиму Яковлевну с юбилеем и желаем осуществления всех творческих планов на благо сибирской аграрной науки и практики, дальнейших успехов в научно-педагогической деятельности, крепкого здоровья и счастья!

Коллектив Горно-Алтайского
научно-исследовательского института
сельского хозяйства

AUTHOR GUIDELINES

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

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

general agriculture and crop production;

plant breeding, seed production and biotechnology;

agrochemistry, soil science, plant protection and quarantine;

fodder production;

infectious diseases and animal immunology;

private zootechnics, feeding, technology of feed preparation and production of livestock products;

breeding, selection, genetics, and animal biotechnology;

technologies, machinery and equipment for the agro-industrial complex;

food systems.

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

Section name	Code and name of the scientific specialty in accordance with the Nomenclature of Scientific Specialties, for which academic degrees are awarded
Agriculture and chemicalization	4.1.1. General agriculture and crop production 4.1.3. Agrochemistry, soil science, plant protection and quarantine
Plant growing and breeding	4.1.1. General agriculture and crop production 4.1.2. Plant breeding, seed production and biotechnology
Plant protection	4.1.3. Agrochemistry, soil science, plant protection and quarantine
Fodder production	4.1.1. General agriculture and crop production 4.1.2. Plant breeding, seed production and biotechnology 4.1.3. Agrochemistry, soil science, plant protection and quarantine
Zootechnics and veterinary medicine	4.2.3. Infectious diseases and animal immunology 4.2.4. Private zootechnics, feeding, technology of feed preparation and production of livestock products 4.2.5. Breeding, selection, genetics, and animal biotechnology
Mechanization, automation, modelling and dataware	4.3.1. Technologies, machinery and equipment for the agro-industrial complex
Agriproducts processing	4.3.3. Food systems
Problems. Opinions Scientific relations From the history of agricultural science Brief reports From dissertations	4.1.1. General agriculture and crop production 4.1.2. Plant breeding, seed production and biotechnology 4.1.3. Agrochemistry, soil science, plant protection and quarantine 4.2.3. Infectious diseases and animal immunology 4.2.4. Private zootechnics, feeding, technology of feed preparation and production of livestock products 4.2.5. Breeding, selection, genetics, and animal biotechnology 4.3.1. Technologies, machinery and equipment for the agro-industrial complex 4.3.3. Food systems

RECOMMENDATIONS TO THE AUTHOR BEFORE SUBMITTING AN ARTICLE

Submission of an article to the journal "Siberian Herald of Agricultural Science" implies that:

an article has not been published before in any other journal;

an article is not subject to review in any other journal;

all co-authors agree with the publication of the current version of the article.

Before submitting an article, it is necessary to make sure that the file (files) contains all the information required in Russian and English, tables and figures provide the source of the information presented, all references are written correctly.

PROCEDURE FOR SENDING MANUSCRIPTS OF ARTICLES

1 Submission of the article is carried out through the electronic editorial board on the journal's website https://sibvest.elpub.ru/jour/index. After preliminary registration of the author, choose the option "Send a manuscript" in the upper right corner of the page. Then download the manuscript (in *.doc or *.docx format) and the accompanying documents. When you have finished uploading, be sure to select the option "Send a Letter", in which case the editorial board will be automatically notified of the receipt of the new manuscript.

Accompanying documents to the manuscript of an article:

a scanned copy of a letter from the organization confirming authorship and permission to publish (sample cover letter);

a scanned copy of the author's note in the form provided (sample author's note), in which consent must be expressed for the open publication of the article in the printed version of the journal and its electronic copy in the Internet;

a scanned copy of the manuscript with the authors' signatures. The author, by signing the manuscript and sending it to the editorial office, thereby transfers the copyright for the publication of this article to SFSCA RAS;

author questionnaires in Russian and English (sample author questionnaire);

a scanned copy of your post-graduate school transcript (for full-time postgraduate students).

2. All manuscripts received by the editorial board are registered via the electronic editorial system. The author's personal account shows the current status of the manuscript.

3. Non-reviewed materials (scientific chronicles, reviews, book reviews, materials on the history of agricultural science and activities of institutions and scientists) are sent to the e-mail: sibvestnik@sfsca.ru and are registered by the executive secretary.

ARTICLE DESIGN PROCEDURE

The text of the manuscript is printed in Times New Roman font, type size 14 with 1.5 spacing, all margins 2.0 cm, page numbering at the bottom. The size of a manuscript should not exceed 15 pages (including tables, illustrations and bibliography); the articles placed in the sections "From dissertations" and " Brief reports" should not exceed 7 pages.

Article design structure:

UDC

2. Title of an article in Russian and English (no more than 70 characters).

3. Surnames and initials of the authors, full official name of the scientific institution where the research was conducted in Russian and English.

If authors from different institutions took part in the preparation of the article, it is necessary to indicate the affiliation of each author to a particular institution using the superscript index.

4. Abstract in Russian and English. The size of the abstract should not be less than 200-250 words. The abstract is a brief and consistent presentation of the material of the article on the main sections and should reflect the main content, follow the logic of the presentation of the material and description of the results in the article with the provision of specific data. The abstract should not include the newly introduced terms, abbreviations (with the exception of common knowledge), references to the literature. The abstract should not emphasize the novelty, relevance and personal contribution of the author; the place of research should be indicated to the district (region), specific organizations should not be mentioned.

5. Keywords in Russian and English. There should be up to 5–7 words by the topic of the article. It is desirable that the keywords support the abstract and the title of the article.

6. Information on the conflict of interests or its absence. The author should notify the editor on the real or potential conflict of interests by including the information in the appropriate section of the article. If there is no conflict of interests, the author should also inform the editor about it.

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

7. Acknowledgements in Russian and English. This section lists all sources of funding for the study, as well as acknowledgements to people who contributed to the article but are not the authors.

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

INTRODUCTION (problem statement, goal and tasks of the study)

MATERIAL AND METHODS (conditions, methods (methodology) of research, object description, place and time of research)

RESULTS AND DISCUSSION

CONCLUSION

REFERENCES. The number of sources must be at least 15. The list of references includes only peer-reviewed sources: articles from scientific journals and monographs. Self-citation of no more than 10% of the total number. The bibliography list should be designed as a general list in the order of mention in the text, it is desirable to refer to sources 2-3 years old. The rules for the list of references are in accordance with GOST R 7.05-2008 (requirements and rules for compiling a bibliographical reference). In the text the reference to the source is marked by a serial number in square brackets, for example [1]. Literature in the list is given in the languages in which it was published. In the bibliographic description of the publication, it is necessary to include all authors, without abbreviating them by one, three, etc. It is unacceptable to abbreviate the names of articles, journals, publishing houses.

1. If it is necessary to refer to abstracts, dissertations, collections of articles, textbooks, recommendations, manuals, GOSTs, information from websites, statistical reports, articles in socio-political newspapers, etc., such information should be placed in a footnote at the end of the page. Footnotes are numbered in Arabic numerals and placed page by page through continuous page numbering.

Attention! Theoretical, review and problem articles can have any structure, but must contain an abstract, keywords, list of references.

EXAMPLE OF REFERENCES in Russian and English and FOOTNOTES

REFERENCES (in Russian):

Monograph

Klimova E.V. Field crops of Zabaikalya: monograph. Chita: Poisk, 2001. 392 p.

Part of a book

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

Periodical publication

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

REFERENCES (in English):

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

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

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

Transliteration of the authors. English title of the article.

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

Transliteration of the source = English name of the source

Monograph

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

Part of a book

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

Periodical publication

Pakul A.L., Lapshinov N.A., Bozhanova G.V., Pakul V.N. Technological grain qualities of spring common wheat depending on the system of soil tillage. *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.

FOOTNOTES:

Quated $text_1$.

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

Digital Object Identifier – DOI (when the cited material has it) should be indicated at the end of the bibliographic reference.

Example:

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.

The DOI of the article should be checked on the website http://search.crossref.org/ or https://www.citethisforme.com. To do this, enter the title of the article in English in the search bar.

FIGURES, GRAPHS, TABLES, SCREENSHOTS, PHOTOGRAPHS AND FORMULAS

The figures must be of good quality, suitable for printing. All figures must have captions. The caption must be translated into English. Figures should be numbered in Arabic numerals according to the order in the text. If there is only one figure in the text, it is not numbered. References to figures should be formatted as follows: “Fig. 3 indicates that ...” or “It is indicated that ... (see Fig. 3)”. The caption under the figure includes a figure number and its title. “Figure 2. Description of vital processes.” The translation of the figure caption should be placed after the figure caption in Russian.

Tables should be of good quality, suitable for printing. Tables suitable for editing are preferred, not scanned or as figures. All tables should have headings. The title of the table should be translated into English. Tables should be numbered in Arabic numerals according to the order in the text. If there is only one table in the text, it is not numbered.

References to tables should be formatted as follows: “Table 3 states that ...” or “It is stated that ... (see Table 3)”. The title of the table includes a table number and its title: “Table 2. Description of Vital Processes.” The translation of the table title should be placed after the table title in Russian.

Photos, screenshots must be uploaded separately as files of the following format*.jpeg files (*.doc and *.docx if the image has additional marks). The resolution of the image should be >300 dpi. The image files should be given a name corresponding to the figure number in the text. In the description of the file a caption should be given separately, which should correspond to the name of the picture placed in the text.

Graphs, charts, histograms, etc. should be attached as a separate file in Microsoft Excel program.

Attention should be paid to the spelling of formulas in the article. All formulas must be editable, i.e. it must be possible to make changes to them. To avoid confusion, it is necessary to write Greek (α, β, π, etc.), Russian (A, a, B, b, etc.) letters and numbers in straight font, Latin letters in italics (*W, Z, m, n*, etc.). Mathematical signs and symbols should also be written in straight font. It is necessary to clearly indicate upper and lower superscript characters (W_1, F_1, etc.).

INTERACTION BETWEEN THE JOURNAL AND THE AUTHOR

The Editorial Board asks the authors to be guided by the above stated rules when preparing the article.

All the articles submitted to “Siberian Herald of Agricultural Science” go through preliminary check for compliance with formal requirements. At this stage the Editorial Board reserves the right to:

• accept the article for review;

• return the article to the author (authors) for revision with a request to correct the mistakes or add the missing data;

• return the article which is designed not according to the journal’s requirements to the author (authors) without consideration;

• reject the article due to its inconsistency to the journal’s goals, lack of originality and little scientific significance.

Correspondence with the authors of the manuscript is maintained through a key contact mentioned in the manuscript.

All scientific articles submitted to the editorial board of the journal “Siberian Herald of Agricultural Science” undergo obligatory double-blind reviewing (author and reviewer do not know about each other). Manuscripts are sent in accordance with their research profile for reviewing to the members of the Editorial Board.

In controversial cases, the editor may involve several specialists in the review process, as well as the Editor-in-Chief. If the reviewer’s opinion is positive, the article is submitted to the editor for preparation for publication.

In case a decision is made to have the manuscript revised, reviewer’s comments and remarks are passed to the author. The latter is given two months to make amendments. If, within this period, the author has not notified the editors about the actions planned, the article is removed from the publication waiting list.

In case there is a decision to reject the article, the notification with the editorial decision is sent to the author.

The designated author (contact author) is sent the final version of the manuscript accepted for publication, which he/she must check.

REVERSAL OF EDITOR/ REVIEWER’S DECISION

In case the author does not agree with the conclusions of the reviewer and/or editor, they can dispute the decision made. In order to do this, the author should:

• amend the manuscript in compliance with the comments substantiated by reviewers and editors;

• clearly outline their stance on the issue under question.

The editors facilitate the second submission of manuscripts that could potentially be accepted but were rejected due to the need of significant amendments or collection of the additional data, and are ready to clearly explain what must be rectified in the manuscript for it to be accepted for publication.

ACTIONS OF THE EDITORIAL BOARD IN CASE OF PLAGIARISM AND DATA FALSIFICATION DETECTION

The Editorial Board of the “Siberian Herald of Agricultural Science” follows the conventional ethical principles for scientific periodicals and guidelines of the “Publication Ethics Code” developed and approved of by the Committee on Publication Ethics (COPE) and demands that all those involved in the publishing process should obey these principles.

ERRORS RECTIFICATION AND ARTICLE WITHDRAWAL

In case of error detection that affect understanding of an article but do not distort the results of research, they can be rectified by replacing the pdf-file of an article. In case of error detection that distort the results of research or in case of plagiarism or misconduct of the author (authors) connected with data falsification, the article can be withdrawn. The withdrawal can be initiated by the editors, the author, organization or private individual. Such article is marked with the note “Article withdrawn”, the page of the article gives the reason for withdrawal. Information about the article withdrawal is sent to data bases where the journal is indexed.