ISSN 0370-8799 (Print)
ISSN 2658-462X (Online)

Volume 51 No 1 2021

SIBERIAN HERALD OF AGRICULTURAL SCIENCE

50 years in the service of agricultural science

No 1
Volume 51

JANUARY – FEBRUARY 2021

SIBERIAN HERALD OF AGRICULTURAL SCIENCE

THE SCIENTIFIC JOURNAL

SIBERIAN HERALD OF AGRICULTURAL SCIENCE

FOUNDERS: SIBERIAN FEDERAL SCIENTIFIC CENTRE OF AGRO-BIOTECHNOLOGIES
OF THE RUSSIAN ACADEMY OF SCIENCES
SIBERIAN BRANCH OF THE RUSSIAN ACADEMY OF SCIENCES

ESTABLISHED IN 1971 6 ISSUES PER YEAR

Volume 51, No 1 (278)
DOI: 10.26898

2021
January – February

The journal is meant for scientists and researchers in agriculture.

The "Siberian Herald of Agricultural Science" publishes original articles on fundamental and applied problems in the following areas: general agriculture and crop production, breeding and seed production of agricultural plants, plant protection, fodder production, farm animals nutrition and feed technology, veterinary microbiology, virology, epizootology, mycology with mycotoxicology and immunology, technologies and means of agricultural mechanization, including surveys, original research, brief reports, as well as chronicles, reviews, book reviews, materials on the history of agricultural science and the activities of research institutions and scientists.

The scientific journal "Siberian Herald of Agricultural Science" is included on the Higher Certification Commission (VAK) List of Russian Reviewed Scientific Periodicals issued in the Russian Federation, in which major scientific results of theses for Doctor and Candidate degrees must be published.

The journal is presented in the international database AGRIS, and is included in the catalogue Ulrich's Periodicals Directory, Browker, USA.

The "Siberian Herald of Agricultural Science" is registered in the Russian Science Citation Index (RSCI) on the basis of Web of Science.

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Editors *E.V. Mosunova, G.N. Yagupova.* Corrector *V.E. Selianina,* Desktop Publisher *N.U. Borisko.* Translator *E.A. Pomanova*
Certificate PI FS77-64832 issued by the Federal Service for Supervision of Media,
Communications and Information Technologies on February 2, 2016
Publisher: Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences
Address: PO Box 463, office 456, SFSCA RAS Building, Krasnoobsk, Novosibirsk District,
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https://doi.org/10.26898/0370-8799-2021-1-1
УДК: 631.51:631.445.25:633.16:631.58(571.12)
Тип статьи: оригинальная
Type of article: original

ЭФФЕКТИВНОСТЬ СИСТЕМ ОСНОВНОЙ ОБРАБОТКИ ПОЧВЫ ПРИ ВОЗДЕЛЫВАНИИ ЯЧМЕНЯ

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Установлена эффективность длительного применения различных систем основной обработки темно-серой лесной почвы в условиях Северного Зауралья. Определено их влияние на эффективность при возделывании ячменя по зерновому предшественнику (яровая пшеница) и зернобобовому (вика на зерно). Исследования проведены в стационарном опыте по изучению отвальной, безотвальной, комбинированной, дифференцированной, плоскорезной и поверхностной систем основной обработки почвы. Опыты проходили в течение третьей – шестой ротаций (1996–2018 гг.) двух зернопаровых севооборотов, развернутых во времени и в пространстве. Первый севооборот: чистый пар – озимая рожь – яровая пшеница – яровая вика – яровой ячмень, второй: чистый пар – озимая рожь – яровая пшеница – яровая пшеница – яровой ячмень. При возделывании ячменя по зернобобовому предшественнику (яровой вике) экономически целесообразным оказалось применение систем основной обработки с элементами минимизации. В нее входили безотвальная и комбинированная обработки с безотвальным рыхлением стойками СибИМЭ на глубину 20–22 см; дифференцированная с плоскорезной на 12–14 см и дискование на 10–12 см. Данные приемы обеспечили близкие отвальной системе условия формирования продуктивности и практически одинаковую урожайность ячменя, получение чистого дохода и коэффициента энергетической эффективности. На фоне без удобрений урожайность составила 2,97–3,03 т/га, с применением $N_{40}P_{40}P_{40}$ – 3,47–3,65 т/га. При размещении ячменя по повторной пшенице самой эффективной оказалась отвальная система обработки с чистым доходом 14,67 тыс. р./га на фоне без удобрений и 22,75 тыс. р./га на фоне их применения с энергетическим коэффициентом 2,65 и 2,75. Применение ресурсосберегающих приемов обработки по повторной пшенице приводило к снижению урожайности зерна ячменя на 0,09–0,40 т/га, снижению чистого дохода при возделывании ячменя в сравнении с зернобобовым предшественником на 31,0–44,1%.

Ключевые слова: система основной обработки, севооборот, предшественник, яровой ячмень, урожайность, эффективность производства

EFFICIENCY OF BASIC TILLAGE SYSTEMS IN THE CULTIVATION OF BARLEY

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The effectiveness of long-term use of various basic tillage systems of dark grey forest soil in the conditions of the Northern Trans-Urals was established. Their impact on the efficiency of barley cultivation depending on the grain (spring wheat) or legume forecrop (vetch for grain) was determined. The research was carried out in a stationary experiment covering moldboard, non-moldboard, combined, differentiated, stubble-mulch and surface systems of basic soil tillage. The experiments took place during the third–sixth rotations (1996–2018) of two grain-fallow crop rotations spread in time and space. The first crop rotation was: bare fallow – winter rye – spring wheat – spring vetch – spring barley, the second crop rotation: bare fallow – winter rye – spring wheat – spring wheat – spring barley. When cultivating barley following the legume forecrop (spring vetch), it was economically feasible to use basic tillage systems with the elements of minimization. It included non-moldboard and combined tillage with subsurface loosening by a plow with SibIME tines to a depth of 20-22 cm differentiated with stubble-mulch at 12-14 cm and disk harrowing at 10-12 cm. These methods provided conditions for the formation of productivity close to the moldboard system and practically the same yield of barley, net income and energy efficiency coefficient. Without fertilizers, the yield was 2.97-3.03 t/ha, with the use of $N_{40}P_{40}P_{40}$ it was 3.47-3.65 t/ha. When planting barley following wheat sown twice, the most effective was moldboard tillage system with a net income of 14.67 thousand rubles/ha without fertilizers and 22.75 thousand rubles/ha with fertilizers and energy coefficient of 2.65 and 2.75. The use of resource-saving tillage methods with repeated wheat led to a decrease in the yield of barley grain by 0.09–0.40 t/ha, and a decrease in the net income of barley cultivation compared to the legume forecrop by 31.0–44.1%.

Keywords: basic tillage system, crop rotation, forecrop, spring barley, yield, production efficiency

Для цитирования: *Перфильев Н.В., Вьюшина О.А., Власенко А.Н.* Эффективность систем основной обработки темно-серой лесной почвы при возделывании ячменя // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 11–17. https://doi.org/10.26898/0370-8799-2021-1-1

For citation: Perfilyev N.V., Vyushina O.A., Vlasenko A.N. Efficiency of basic tillage systems in the cultivation of barley. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1. pp. 11–17. https://doi.org/10.26898/0370-8799-2021-1-1

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

INTRODUCTION

In the Tyumen region, the crop production area under barley occupies 22% of the sowing of grain and leguminous crops. The demand for this crop is due to the high fodder qualities of grain for animal husbandry and the processing industry, good adaptive ability to natural factors, increased responsiveness to fertilization, which leads to high productivity of crop cultivation [1-3].

In the Northern Trans-Urals, in production conditions, during the main soil cultivation, methods of moldboard-free and flat-cut cultivation and disking which are energetically less expensive than plowing are increasingly used. Scientific studies on this issue do not give an unambiguous answer on the comparative efficiency of technologies of different intensity, as well as on their influence on the efficiency of barley production in comparison with the traditional technology based on plowing [4–10].

The purpose of the study is to determine the effectiveness of long-term use of various systems of the main processing of dark gray forest soil in the conditions of the Northern Trans-Urals during the cultivation of barley for grain (spring wheat) and leguminous (vetch for grain) predecessor.

MATERIAL AND METHODS

The studies were carried out in the stationary experiment of the Scientific Research Institute of Agriculture of the Northern Trans-Urals - a branch of the Tyumen Scientific Center of the SB RAS in 1996–2018. The scientific experiment took place during the third - sixth rotations of two grain-fallow crop rotations spread in time and space. The first crop rotation: clean

fallow - winter rye - spring wheat - legumes (vetch for grain) - spring barley, the second: clean fallow - winter rye - spring wheat - spring wheat - spring barley. The soil is dark gray forest heavy loamy. The depth of the humus horizon is 25–27 cm, the humus content is 4.2–5.0%, the pH of the salt extract is 6.0–6.4. The total absorbed bases in the plowing layer is 18.6–25.6 mEq. / 100 g of soil.

The tillage systems were as follows:

– moldboard: the main cultivation for barley and other crops of crop rotation with the Lemken plow to a depth of 20-22 cm;

– non-moldboard: annual loosening with SibIME tines to a depth of 20-22 cm;

– combined: for barley and wheat for winter rye, loosening with SibIME tines to a depth of 20-22 cm, for winter rye, spring vetch and second wheat - plowing with a Lemken plow by 20-22 cm;

– differentiated: for winter rye, in steam and for spring wheat for winter rye, loosening with a flat cutter Smaragd-6 to a depth of 12-14 cm, for vetch and second wheat - plowing with a Lemken plow by 20-22 cm, for spring barley and after harvesting surface processing by disking of a large barrel drum 2.5 x 10–12 cm.

Pre-sowing treatment for all studied systems of the main treatment consisted in early spring harrowing with BZSS-1.0 tooth harrows in four tracks, pre-sowing cultivation with the Smaragd-6 cultivator to the depth of seeding. Sowing of Acha variety barley was carried out with a SZP 3.6 seeder. The seeding rate is 5 million viable seeds / ha. Mineral fertilizers, according to the method, were applied before presowing cultivation with a rate of $N_{40}P_{40}K_{40}$ kg of ai. per 1 hectare of crop rotation area. For the destruction of weeds, herbicides were used in all studied variants.

The plot area was (5.5–6.0 × 63 m) 346–378 m^2, the accounting area was 100 m^2. According to the meteorological conditions of the growing season, 6 years were dry, 17 years - close to the average long-term conditions. The laying technique and the experiment were carried out according to the method of B.A. Dospekhov[1] using computer programs of O.D. Sorokin[2], the bioenergetic and economic efficiency was calculated according to methodological recommendations[3,4].

RESULTS AND DISCUSSION

In the grain-fallow crop rotation, when placed on leguminous crops, resource-saving processing systems provided almost equal barley yield to the moldboard system. Without fertilizers, it amounted to 2.97–3.03 t / ha, with the use of fertilizers - 3.47–3.65 t / ha (see Table 1). This can be explained by the fact that favorable agrophysical conditions and conditions for plant nutrition, especially nitrogen, were formed by resource-saving backgrounds and by the moldboard processing system [11].

The replacement of leguminous crops in the grain-fallow crop rotation with second wheat and its use as a precursor for barley has led to a steady decrease in barley yields for non-moldboard, stubble- mulch and for disking. In comparison with the plowing system without mineral fertilizers, it decreased by 0.09-0.27 t / ha (3.8-11.4%), with the use of fertilizers - by 0.07-0.40 t / ha (2.0-11.1%). This is explained by the deterioration of the nitrogen nutrition of plants for non-moldboard and shallow treatments, especially for the repeated grain precursor [12–15].

Indicators of economic and energy efficiency indicate that they to a decisive extent depended on the value of the yield, which, in turn, depended on the tillage system, the predecessor and the background of fertilization. So, with a decrease in direct costs for resource-saving processing systems without fertilizers by 1.2-4.1%, with the use of fertilizers by 0.33-2.8%, the cost of gross barley production without and with the use of fertilizers for the legume predecessor as well as the yield were close to the control vari-

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Табл. 1. Урожайность, прямые затраты и чистый доход при возделывании ячменя в зернопаровых севооборотах в зависимости от систем основной обработки почвы (1996–2018 гг.)

Table 1. Yield, direct costs and net income of barley cultivation in grain-fallow crop rotations depending on basic tillage systems (1996-2018)

Basic tillage system	Fertilizer background	Yield, t/ha		Direct costs, thousand rubles/ha	Net income, thousand rubles/ha	
		vetch	wheat		vetch	wheat
Moldboard	Without fertilizers	2,97	2,37	8,88	20,63	14,67
	With fertilizers	3,53	3,60	13,022	22,06	22,75
Non-moldboard	Without fertilizers	3,02	2,10	8,75	21,26	12,12
	With fertilizers	3,65	3,27	12,89	23,38	19,61
Combined	Without fertilizers	3,03	2,23	8,75	21,36	13,41
	With fertilizers	3,60	3,53	12,89	22,89	22,19
Differentiated	Without fertilizers	2,94	2,14	8,74	20,44	12,49
	With fertilizers	3,47	3,31	12,98	21,48	19,91
Surface tillage	Without fertilizers	3,06	2,10	8,77	21,64	12,10
	With fertilizers	3,59	3,20	12,98	22,70	18,82
Stubble-mulch	Without fertilizers	2,92	2,28	8,52	20,50	14,14
	With fertilizers	3,54	3,46	12,64	22,52	21,73
LSD_{05}	Without fertilizers	0,11	0,20			
	With fertilizers	0,14	0,26			

ant of the technology based on plowing. On the contrary, with a decrease in the yield of barley for recycled wheat, the decrease in the cost of gross production for resource-saving processing systems without fertilizers was 3.8-11.4%, with the use of fertilizers - 1.9-11.1% (see Table 1, 2).

For the legume predecessor with similar yield values, the net income, the energy coefficient for the studied processing systems were also similar. Without and with the use of fertilizers, the differences in net income (20.5–21.6 and 21.5–23.4 thousand rubles / ha, respectively) between the moldboard and resource-saving processing systems did not exceed, respectively, the background of fertilizers 0.6– 3.7% and 2.6–6.0%. According to this predecessor, in grain-fallow crop rotation for barley, along with the moldboard system, the use of non-moldboard loosening with SibIME tines to a depth of 20–22 cm is economically justified; with non-moldboard and combined systems the use of the Smaragd cultivator to a depth of 12–14 cm and processing of BDT-2.5 to a depth of 10–12 cm with stubble- mulch and surface processing systems is appropriate. The energy coefficient for these processing systems without fertilizers was 3.43–3.46, with fertilizers - 2.78–2.81, for the moldboard system, respectively, the fertilizer backgrounds were 3.23 and 2.69, i.e. exceeded the control variant of the moldboard system by 0.09–0.14.

Cultivation of barley after repeated wheat, especially without fertilization, significantly reduced the profitability of its cultivation in comparison with the legume predecessor. Thus, the decrease in net income in this case for the moldboard processing system was 28.9%, for resource-saving systems - 31.0-44.1%. With the use of fertilizers with a moldboard processing system, there was no decrease in net income, depending on the predecessor, for resource-saving processing systems, a decrease of 3.0–17.1%.

When barley was placed on repeated wheat with a moldboard system of main processing, the net income without fertilizers amounted

Табл. 2. Экономическая и энергетическая эффективность возделывания ячменя в зернопаровых севооборотах при различных системах основной обработки почвы (1996–2018 гг.)

Table 2. Economic and energy efficiency of barley cultivation in grain-fallow crop rotations with different systems of basic soil tillage (1996-2018)

Basic tillage system	Fertilizer background	Energy coefficient		Cost price 1 tone of grain		Gross product value, thousand rubles/ha	
		vetch	wheat	vetch	wheat	vetch	wheat
Moldboard	Without fertilizers	3,32	2,65	2,99	3,75	29,51	23,55
	With fertilizers	2,69	2,75	3,69	3,62	35,68	35,78
Non-moldboard	Without fertilizers	3,43	2,38	2,89	4,17	30,01	20,87
	With fertilizers	2,81	2,52	3,53	3,94	36,27	32,50
Combined	Without fertilizers	3,44	2,53	2,89	3,92	30,11	22,16
	With fertilizers	2,78	2,72	3,58	3,65	35,78	35,08
Differentiated	Without fertilizers	3,33	2,42	2,98	4,10	29,22	21,27
	With fertilizers	2,67	2,55	3,74	3,92	34,46	32,89
Surface tillage	Without fertilizers	3,46	2,38	2,87	4,18	30,41	20,87
	With fertilizers	2,76	2,46	3,62	4,06	35,68	31,80
Stubble-mulch	Without fertilizers	3,41	2,66	2,92	3,74	29,02	22,66
	With fertilizers	2,78	2,72	3,57	3,66	35,18	34,38

to 14.67 thousand rubles / ha, with their use - 22.75 thousand rubles / ha. At the same time, without fertilizers, this indicator turned out to be the closest to the moldboard processing system during stubble- mulch processing and processing with SibIME tines to a depth of 20–22 cm in the combined system (lower than the control by 3.6–8.6%).

With the use of fertilizers, the combined and stubble- mulch processing systems were inferior to the moldboard in terms of net income by only 2.5–4.5%. For the rest of the studied soil cultivation options, the net income was lower than with the moldboard system: without fertilizers by 2.18–2.57 thousand rubles / ha (14.8–17.5%), with the use of fertilizers by 2, 84-3.93 thousand rubles / ha (12.5-17.3%). Our data on productivity and economic efficiency are largely consistent with the results of studies obtained in the European part of Russia [16, 17].

CONCLUSION

1. It is economically most expedient to use the main processing systems with elements of minimization on the dark gray forest soils of the northern forest-steppe of the Northern Trans-Urals during the cultivation of barley as the final crop in the grain crop rotation according to the legume predecessor (spring vetch): non-moldboard and combined with non-moldboard loosening by SIBIME tines at 20-22 cm, differentiated with stubble- mulch processing by 12-14 cm and disking by 10-12 cm. These processing systems after legumes for barley provided the formation of almost equal to the moldboard processing system barley yield: without fertilizers - 2.97-3, 03 t / ha, using N40P40P40 - 3.47–3.65 t / ha, net income.

2. The use of resource-saving methods of processing in grain crop rotation clean fallow - winter rye - spring wheat - spring wheat - spring barley for repeated wheat led to a decrease in the yield of barley grain by 0.09–0.40 t / ha, a decrease in net income when cultivating barley

in comparison with the legume predecessor by 31.0–44.1%.

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Дата поступления статьи 12.10.2020
Received by the editors 12.10.2020

https://doi.org/10.26898/0370-8799-2021-1-2
УДК: 632.93: 631.524.5:633.11
Тип статьи: оригинальная
Type of article: original

ВЛИЯНИЕ ПРЕДПОСЕВНОЙ ОБРАБОТКИ СЕМЯН ЯРОВОЙ ПШЕНИЦЫ НА ЛИНЕЙНЫЕ РАЗМЕРЫ И ГЕОМЕТРИЧЕСКИЕ ХАРАКТЕРИСТИКИ ЗЕРНА

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Представлены результаты оценки воздействия биопрепаратов и протравителя семян на технологические качества зерна мягкой яровой пшеницы Новосибирская 31. Эффективность применения биологических средств защиты растений изучали в полевом эксперименте, заложенном в 2020 г. в условиях лесостепи Приобья. Предпосевная обработка семян включала следующие варианты: контроль (без обработки); Триходермин, П (*Trichoderma viride,* титр более 6 млрд спор/г), норма расхода – 15 кг/т семян; Споробактерин, СП (*Bacillus subtilis* + *Trichoderma viride*, штамм 4097), норма расхода – 0,5 кг/т семян; Скарлет, МЭ, химический эталон (имазалил (100 г/л) + тебуконазол (60 г/л), норма расхода – 0,3 л/т семян. Применение препаратов способствовало росту урожайности на 0,40 и 0,52 т/га при использовании Триходермина и Споробактерина соответственно и на 0,08 т/га при применении фунгицида Скарлет. При этом масса 1000 зерен увеличилась на 0,84; 0,80 и 0,96 г соответственно относительно контроля. Препараты Триходермин и Споробактерин оказывали достоверное влияние на рост зерновки в длину и ширину относительно контроля – на 5,4–6,9 и 9,6%, Скарлет – на 10,6 и 13,9% соответственно. Предпосевная обработка семян способствовала росту таких показателей зерновки, как объем (на 19,6–29,3%), площадь поверхности (на 12,1–19,2%), сферичность (на 6,3–7,8%). В большей степени они увеличивались при применении фунгицида Скарлет. Получение более крупного зерна привело к росту содержания эндосперма на 0,76–1,14%. Показана тесная коррелятивная связь между показателями массы 1000 зерен и линейными размерами зерна (r = 0,92–0,98), а также с объемом зерновки, сферичностью и содержанием эндосперма (r = 0,98–0,99). Предпосевная обработка семян яровой пшеницы обеспечивает получение зерна с улучшенными технологическими свойствами.

Ключевые слова: мягкая яровая пшеница, биопрепараты, протравитель зерна, фунгицид, линейные размеры зерна, геометрические характеристики зерна

EFFECT OF PRE-SOWING TREATMENT OF SPRING WHEAT SEEDS ON LINEAR SIZES AND GEOMETRIC GRAIN CHARACTERISTICS

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The results of assessing the effect of biological preparations and a seed disinfectant on the technological qualities of grain of soft spring wheat Novosibirskaya 31 are presented. The effectiveness of the use of biological plant protection products was studied in the field experiment, laid down in 2020 in the forest-steppe conditions of the Ob region. Pre-sowing seed treatment included the following options: control (without treatment); Trichodermin, P (Trichoderma viride, titer more than 6 billion spores/g), consumption rate – 15 kg/t seed; Sporobacterin, SP (Bacillus subtilis + Trichoderma viride, strain 4097), consumption rate – 0.5 kg/ton of seeds; Scarlet, ME, chemical standard (imazalil (100 g/l) + tebuconazole (60 g/l), consumption rate – 0.3 l/t of seeds. The use of the preparations contributed to an increase in yield by 0.40 and 0.52 t/ha when using Trichodermin and Sporobacterin, respectively, and by 0.08 t/ha when using fungicide Scarlet. In this case, the mass of 1000 grains increased by 0.84, 0.80 and 0.96 g, respectively, relative to the control. The preparations Trichodermin and Sporobacterin had a significant effect on the growth of grain in length and width relative to the control – by 5.4-6.9 and 9.6%, Scarlet – by 10.6 and 13.9%, respectively. Pre-sowing seed treatment contributed to the growth of such indicators of the caryopsis as volume (by 19.6–29.3%), surface area (by 12.1–19.2%), and sphericity (by 6.3–7.8%).

To a greater extent, they increased with the use of fungicide Scarlet. Getting larger grain led to an increase in the endosperm content by 0.76–1.14%. A close correlation has been shown between the indicators of the mass of 1000 grains and the linear grain sizes (r = 0.92–0.98), as well as with the grain volume, sphericity and endosperm content (r = 0.98–0.99). Pre-sowing treatment of spring wheat seeds provides grain with improved technological properties.

Keywords: soft spring wheat, biological preparations, grain disinfectant, fungicide, grain linear dimensions, grain geometrical characteristics

Для цитирования: *Власенко Н.Г., Буралакова С.В.* Влияние предпосевной обработки семян яровой пшеницы на линейные размеры и геометрические характеристики зерна // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 18–24. https://doi.org/10.26898/0370-8799-2021-1-2

For citation: Vlasenko N.G., Burlakova S.V. Effect of pre-sowing treatment of spring wheat seeds on linear sizes and geometric grain characteristics. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1. pp 18–24.. https://doi.org/10.26898/0370-8799-2021-1-2

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

INTRODUCTION

The technological properties of grain are a set of signs and quality indicators that characterize its state in the technological processes of processing, affecting the yield and quality of flour [1, 2]. The technological properties of grain are derived from a group of primary properties that can be subdivided into physicochemical, biochemical, structural-mechanical, thermophysical, and also anatomical structure of grain. The linear dimensions and shape of the caryopsis affect the degree of injury to seeds and the quality of grain conditioning. For this reason, in breeding practice, they try to select leveled shortened grains of a round shape [3]. Grain volume and shape are related to the endosperm content, which provides the actual flour yield; the outer surface area determines the intensity of the interaction of the grain with the surrounding atmosphere; the ratio of the volume and the outer surface of the grain is the so-called determining size, the role of which is manifested in the processes of heat transfer during storage, drying and hydrothermal treatment of grain [4–6]. The shapes and sizes of seeds are variable and depend on both soil and weather conditions during the growing season. When studying the physic mechanical properties of seeds, not only average sizes are important, but also all indicators of variability of individual properties of seeds of grain crops [6, 7]. Much attention is paid to studies of the parameters of caryopses. Their linear dimensions, shape and anatomical structure are influenced not only by weather conditions, but also by the cultivation technology, as well as the characteristics of the genotypes of varieties [8].

The pre-sowing seed treatment with biological and chemical preparations leads to an increase in the yield of spring wheat and contributes to the production of grain with a higher weight [9, 10].

The purpose of the research is to study the effect of pre-sowing seed treatment on its linear and some geometric characteristics.

MATERIAL AND METHODS

The effectiveness of the use of biological plant protection products was studied in the field experiment, laid down in 2020 at the station of the Siberian Research Institute of Agriculture and Chemicalization of the Siberian Federal Scientific Center of AgroBioTechnologies of the Russian Academy of Sciences. The scientific experiment took place in the forest-steppe conditions of the Ob region on the crops of spring wheat Novosibirskaya 31 (medium-early variety, growing season 70–76 days), which was placed along the steam predecessor. Sowing was carried out on May 14 with a seeding rate of 6 million germinating grains / ha. Pre-sowing seed treatment included the following options:

– control (without treatment);

– Trichodermin, P (Trichoderma viride, titer more than 6 billion spores / g), consumption rate - 15 kg / t of seeds;

– Sporobacterin, SP (Bacillus subtilis + Trichoderma viride, strain 4097), consumption rate - 0.5 kg / t of seeds;

– Scarlet, ME, chemical standard (imazalil (100 g / l) + tebuconazole (60 g / l), consumption rate - 0.3 l / t of seeds.

The consumption rate of the working fluid is 10 l / t of seeds. The area of the accounting plot is 14.7 m^2, the arrangement is sequential in one tier, the repetition is four times. Wheat yields were taken into account by direct combining, and were brought to 100% purity and 14% moisture. The weight of 1000 grains was determined in the resulting crop.

The following indicators of the grain were studied: length, width, thickness[1], and their volume, surface area, sphericity, and endosperm content[2] were also calculated. The sample volume was 100 grains. Grain products were assessed using an electronic micrometer in the Micro Capture Pro program. Statistical analysis of experimental data was carried out using the Snedecor[3] software package.

The meteorological data for the growing season of 2020 significantly differed from the long-run annual average in terms of the temperature regime and the amount of precipitation. The month of May of the current season especially stood out in terms of temperature and moisture regime. The air temperature this month exceeded the long-run annual average by 6.2 ºC, the amount of precipitation was 1.5 times higher than the norm. In June, the air temperature was at the level of the long-run annual average, the arrival of atmospheric moisture on average per month was 2.4 times lower than the norm. In July, the temperature regime exceeded the average annual indicators by 0.6 ºC, precipitation fell 1.2 times more than the norm. August was warm enough: the air temperature exceeded the long-run annual average by 2.8 ºC. The arrival of atmospheric moisture in the first ten-day period of the month was 1.7 times lower than the norm, in the second ten-day period precipitation was 2.2 times more than the long-run annual average.

RESULTS AND DISCUSSION

In the variants of the experiment with the treatment of seeds with biological preparations, a significant increase in the yield of wheat was obtained relative to the control: when the seeds were treated with Trichodermin - by 0.4 t / ha, Sporobacterin - by 0.52 t / ha (see Table 1).

The dressing of the seed with Scarlet under the conditions of the current year did not affect the grain yield. However, the weight of 1000 grains significantly increased compared with the control in all variants of the experiment by 0.80-0.96 g, in the variant with the use of Scarlet fungicide it was the greatest.

When using the preparations, the linear dimensions of the grain significantly changed: the length increased by 5.4 and 6.9% when the seeds were treated with biological preparations, by 10.6% when using a chemical preparation, the width - by 9.6 and 13.9%, respectively (see

Табл. 1. Влияние предпосевной обработки семян биопрепаратами и фунгицидом на урожайность и массу 1000 зерен яровой пшеницы Новосибирская 31

Table 1. Influence of pre-sowing seed treatment with biological products and fungicide on yield and weight of 1000 grains of spring wheat Novosibirskaya 31

Option	Yield, t/ha	The mass of 1000 grains, g
Control	1,81	30,83
Trichodermin	2,21	31,67
Sporobacterin	2,33	31,63
Scarlet	1,89	31,79
LSD_{05}	0,26	0,63

[1]Talanov I.P. Plant growing. Workshop: textbook. manual for academic undergraduate 2nd ed. Moscow: Yurayt Publishing House, 2018.288 p.

[2]Egorov G.A. Flour technology. Practical course. M.: DeLi print, 2007.143 p.

[3]Sorokin O.D. Applied statistics on the computer. 2nd ed. Novosibirsk, 2012. 282 p.

Table 2). Of the three dimensions (length, width and thickness), thickness is the most characteristic of the milling properties of the grain. A high correlation was found between the grain thickness of common wheat and the content of endosperm in it [11]. When growing wheat which was treated before sowing with preparations, the thickness of the grain increased by 3.2-3.5% compared with the control.

The linear dimensions of the grain determine its size, which is the most important indicator of the quality of the grain. Coarse grain has more endosperm and fewer shells, therefore, the higher the yield of finished products from grain [12]. In variants where Trichodermin and Sporobacterin were used for pre-sowing seed treatment, the volume of the grain increased by 19.6 and 21.3% compared with the control, but to a greater extent it increased when using the fungicide Scarlet - by 29.3% (see Table 3). The surface area of the grain also turned out to be 12.1–19.2% higher in the variants with the treatment of seeds with preparations; it was the largest when the fungicide Scarlet was applied. The sphericity of the grain also increased by 6.3-7.8% when sown with treated seeds.

The geometric characteristics of the grain made it possible to calculate the endosperm content in it. This indicator, when growing wheat from seeds treated with biological products, increased by 0.76-0.83%, with a chemical fungicide - by 1.14%.

The smallest variation in the grain length was observed in the control and when using the Scarlet fungicide (V = 7.44 and 7.54%). Variation in the grain width indicator was at the level of 10.16–11.37%. The variation in the thickness of the grain decreased from 9.01% in the control to 7.12– 7.28% in the experiment. A correlation was revealed between the mass indices of 1000 grains and the linear grain sizes: length, width and thickness (r = 0.92; 0.98 and

Табл. 2. Влияние предпосевной обработки семян биопрепаратами и фунгицидом на линейные размеры зерна яровой пшеницы Новосибирская 31

Table 2. Influence of pre-sowing seed treatment with biological products and fungicide on the linear grain size of spring wheat Novosibirskaya 31

Option	Indicator				
	Size, mm	Mean square deviation, *S*, %	Variation coefficient, *V*, %	Sample relative error, S_x, %	Test, t_{f095} и t_{theor}
Grain length (n = 100)					
Control	6,33 ± 0,37	0,47	7,44	1,04	–
Trichodermin	6,67 ± 0,57	0,67	10,11	1,42	8,22 ≥ 1,98
Sporobacterin	6,77 ± 0,60	0,76	11,15	1,57	12,20 ≥ 1,98
Scarlet	7,00 ± 0,41	0,53	7,54	1,07	44,08 ≥ 1,98
Grain width (n = 100)					
Control	2,73 ± 0,22	0,28	10,16	1,45	–
Trichodermin	2,99 ± 0,26	0,32	10,75	1,51	19,00 ≥ 1,98
Sporobacterin	2,99 ± 0,27	0,34	11,37	1,61	17,15 ≥ 1,98
Scarlet	3,11 ± 0,25	0,32	10,26	1,46	40,46 ≥ 1,98
Grain thickness (n = 100)					
Control	2,82 ± 0,21	0,25	9,01	1,25	–
Trichodermin	2,91 ± 0,16	0,21	7,12	1,02	4,35 ≥ 1,98
Sporobacterin	2,92 ± 0,17	0,21	7,23	1,02	4,82 ≥ 1,98
Scarlet	2,91 ± 0,17	0,21	7,28	1,02	3,91 ≥ 1,98

Табл. 3. Влияние предпосевной обработки семян биопрепаратами и фунгицидом на геометрические показатели зерна яровой пшеницы Новосибирская 31

Table 3. Influence of pre-sowing seed treatment with biological products and fungicide on the geometric parameters of spring wheat grain Novosibirskaya 31

Option	Grain volume, mm^3	Grain surface area, mm^2	Grain sphericity	Endosperm content, %
Control	25,47 ± 3,99	63,95 ± 6,81	0,64 ± 0,04	82,48 ± 0,61
Trichodermin	30,46 ± 5,39	71,67 ± 9,00	0,68 ± 0,04	83,24 ± 0,83
Sporobacterin	30,90 ± 5,10	73,13 ± 9,00	0,68 ± 0,04	83,31 ± 0,78
Scarlet	32,93 ± 4,26	76,21 ± 7,66	0,69 ± 0,04	83,62 ± 0,65

0.97), as well as with the grain volume, sphericity and endosperm content (r = 0.98 –0.99). The length-to-width ratio for wheat grains decreased from 2.32: 1 in the control to 2.23: 1, 2.26: 1 and 2.25: 1 in variants with the use of Trichodermin, Sporobacterin and Scarlet. The ratio of width to thickness, on the contrary, increased slightly - from 0.97: 1 in the control to 1.03: 1; 1.02: 1 and 1.07: 1 in experimental versions. Nevertheless, the obtained grain was characterized by a rather favorable ratio of linear dimensions for the conditions of its processing.

CONCLUSION

Seed treatment with biological products Trichodermin, Sporobacterin and Scarlet fungicide influenced not only grain yield and 1000 grain weight, but also linear dimensions and geometric characteristics of grain. The length of the grain increased by 5.4–10.6%, the width by 9.6–13.9, and the thickness by 3.2–3.5%. These indicators increased to the greatest extent with the use of a chemical fungicide. This led to an improvement in the geometrical characteristics of the grain: the volume of the grain increased by 19.6–29.3%, the surface area by 12.1–19.2, and its sphericity by 6.3–7.8%. The endosperm content in grain also increased by 0.76–1.14%. In addition, the ratio of the grain length to its width was reduced from 2.32: 1 in the control to 2.23: 1; 2.25: 1 and 2.26: 1 when using preparations. Thus, the preparations Trichodermin, Sporobacterin and Scarlet, which were used for pre-sowing seed treatment, had a positive effect on the technological properties of the grain of the new harvest.

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Дата поступления статьи 10.10.2020
Received by the editors 10.10.2020

https://doi.org/10.26898/0370-8799-2021-1-3
УДК: 635.21:632.4:574.34
Тип статьи: оригинальная
Type of article: original

РОЛЬ СОРТА И ПРЕДШЕСТВЕННИКА В ДИНАМИКЕ ЧИСЛЕННОСТИ *RHIZOCTONIA SOLANI* В ПОЧВЕ

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Проведены многолетние (2014–2019) исследования динамики численности гриба *Rhizoctonia solani* Küch. в почве под сортами картофеля Purple Majesty, Vitelotte и Фиолетовый и предшественниками (картофель, овес и горчица сарептская). Исследования проходили в Новосибирской области в почвенно-климатических условиях, типичных для лесостепной зоны Западной Сибири. Для изучения особенностей динамики численности гриба *R. solani* в посадках картофеля осуществляли отбор почвенных проб под растениями в течение всего периода вегетации. Количество пропагул ризоктонии в почве определяли с помощью метода множественных почвенных таблеток. Установлены разница в численности и скорости накопления гриба *R. solani* под различными сортами, а также влияние на этот процесс предшествующих культур. Под сортом Purple Majesty наблюдали два пика численности гриба: первый (48,7 пропагулы/100 г почвы) – в период полных всходов, второй (57,2 пропагулы/100 г почвы) – в конце фазы созревания культуры. У сортообразцов Vitelotte и Фиолетовый наблюдали один пик в динамике численности гриба в конце периода созревания (59,0 и 49,1 пропагулы/100 г почвы соответственно). Наименьшая численность гриба *R. solani* в почве в среднем за период вегетации отмечена под сортом Фиолетовый – 33,3 пропагулы/100 г почвы. У сортов Purple Majesty и Vitelotte данный показатель составлял 41,5 и 40,4 пропагулы/100 г почвы соответственно. При возделывании в монокультуре сорта картофеля Agata идет быстрое и значительное накопление гриба *R. solani* в почве (от 34,6 до 126,8 пропагулы/100 г почвы). Если данный сортообразец культивируется после горчицы сарептской или овса, численность возбудителя варьирует в меньшей степени (25,1–52,2 и 19,8–41,0 пропагулы/100 г почвы соответственно). Резких подъемов численности пропагативных структур фитопатогена в почве не отмечено.

Ключевые слова: ризоктониоз картофеля, сорт, предшественник, динамика численности, почва

THE ROLE OF VARIETY AND FORECROP IN THE POPULATION DYNAMICS OF *RHIZOCTONIA SOLANI* IN SOIL

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Long-term studies (2014–2019) of the population dynamics of the fungus Rhizoctonia solani Küch. were carried out in the soil on the Purple Majesty, Vitelotte and Fioletovy potato varieties and preceding crops (potatoes, oats and tendergreen). The study was carried out in Novosibirsk region in the soil and climatic conditions typical of the forest-steppe zone of Western Siberia. To study the peculiarities of *R. solani* fungus population dynamics in potato plantations, soil samples were taken from under the plants during the entire growing season. The accumulation of rhizoctonia propagules in the soil was determined using the method of multiple soil pellets. The difference in the amount and rate of accumulation of the fungus *R. solani* on different varieties, as well as the influence of previous crops on this process, was established. Two peaks of the fungus accumulation were observed on the Purple Majesty variety: the first (48.7 propagules/100 g of soil) – during the full germination period, the second (57.2 propagules/100 g of soil) – at the end of the crop maturation phase. One peak was observed in the population dynamics of the fungus on Vitelotte and Fioletovy varieties, at the end of the ripening period (59.0 and 49.1 propagules/100 g soil, respectively). The smallest amount of *R. solani* fungus in the soil on average during the growing season was noted on the Fioletovy variety – 33.3 propagules/100 g of soil. In the Purple Majesty and Vitelotte varieties, this figure was 41.5 and

40.4 propagules/100 g of soil, respectively. When potato variety Agata was cultivated as monoculture, there was a rapid and significant accumulation of the fungus *R. solani* in the soil (from 34.6 to 126.8 propagules/100 g of soil). When this variety was cultivated following tendergreen or oats, the amount of the pathogen varied to a lesser extent (25.1–52.2 and 19.8–41.0 propagules/100 g of soil, respectively). No sharp increases in the number of propagative structures of the phytopathogen in the soil were noted.

Keywords: potato rhizoctonia, variety, forecrop, population dynamics, soil

Для цитирования: *Малюга А.А., Чуликова Н.С.* Роль сорта и предшественника в динамике численности *Rhizoctonia solani* в почве // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 25–32. https://doi.org/10.26898/0370-8799-2021-1-3

For citation: Malyuga A.A., Chulikova N.S. The role of variety and forecrop in the population dynamics of *Rhizoctonia solani* in soil. *Sibirskii vestnik sel'skokhoyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2021, vol. 51, no. 1, pp. 25–32. https://doi.org/10.26898/0370-8799-2021-1-3

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

INTRODUCTION

The complexity of controlling a disease such as rhizoctoniasis is determined by the ecological plasticity and broad specialization of the pathogen, the complexity of its pathological process. Rhizoctonia solani Küch. mushroom can exist in a wide range of temperatures and soil moisture, so the disease is harmful both at low and high temperatures and at high and low soil moisture.

Currently, 16 anastomotic groups of the causative agent of potato rhizoctoniae have been described. Their number may increase as research expands. Some groups are widely specialized and affect a wide range of plants, others - only certain species, some groups, such as Ag 6, Ag 7, Ag 10, and Ag BI, are not plant pathogens[1] [1-3]. Isolates from the anstomotic groups Ag 1, Ag 2, Ag 4 and Ag 5 are widely specialized, the Ag 3 group is highly specialized, which affects only nightshades, AG 8 - cereals and potatoes, AG 9 - cruciferous plants and potatoes, AG 11 - wheat [2–9].

A number of strains of the fungus that infect potatoes can develop on the remains of corn, straw, especially in the post-harvest period, when there are no main sources of food.

The source of infection is diseased potato plants and tubers, as well as many cultivated and weed plants (sow thistle, horsetail, quinoa, etc.). The causative agent of the disease has several modes of transmission. The main factor in the transmission of the pathogen from year to year is the soil. The number of the pathogen in the cultivated soils of Siberia ranges from 0 to 20 propagules per 100 g of air-dry soil; the soils are more infected after planting potatoes. Diseased potato tubers are one of the main factors in the transmission of the pathogen: its frequency ranges from 29 to 70%. Transmission of the pathogen during the season also occurs through basidiospores at high air humidity (86–96% or more) by airborne droplets, but this transmission mechanism has additional importance. Thus, the circulation of the pathogen in nature occurs due to a combination of soil and tuberous transmission mechanisms from year to year with additional airborne droplets during the season. It is necessary to use techniques and methods that reduce the initial stock of infection of the pathogen in the soil and on tubers to protect potato plantings from rhizoctonia disease [10].

A simple disinfection of tubers is often not enough when fighting the causative agent of rhizoctonia. The accumulation of a significant amount of infection in the soil of crop rotations of specialized potato and vegetable farms can lead to a massive damage to potato plants by

[1]Carling D.E., Sumner D.R. Rhizoctonia. University of Alaska, Fairbanks, Palmer, AK 99645 and University of Georgia, Tifton, GA 31793 (representatively). 1990. 10 p.

rhizoctonia even in cases of exclusion of seed infection. The main role in the development of rhizoctonia is played by soil inoculum (pseudosclerotia of R. solani Kühn. stay in the soil for 2–6 years even in the absence of potatoes)[2] [11]. It is necessary to know the number of propagative structures of the pathogen in the soil and the role of varieties and precursors in the pathological process to successfully build a strategy and tactics for protecting potatoes from this disease.

The purpose of this work is to reveal the population of the fungus R. solani Kühn. in the soil under the potatoes of different kinds and under the crop cultivated after different predecessors.

MATERIAL AND METHODS

The studies were carried out in the Novosibirsk region in the soil and climatic conditions typical of the forest-steppe zone of Western Siberia.

The soil cover of the station is represented by a typical for the region leached medium loamy chernozem with the following agrochemical characteristics of the topsoil layer (0-30 cm): humus (according to Tyurin) about 5.0%, total nitrogen (according to Kjeldahl) - 0.34 mg / 100 g of soil , phosphorus and potassium (according to Chirikov) - 29.0 and 13.0 mg / 100 g of soil, respectively, pH = 6.7-6.8.

The growing seasons of 2014–2019 were characterized by different weather conditions. The HTI (hydrothermal index) for the potato growing season (May - August) according to Selyaninov in 2014 was 0.71, 2015 - 1.33, 2016 - 0.76, 2017 and 2018. - 1.30, 2019 - 1.00. Consequently, a slight drought was observed in 2014, 2016 and 2019 turned out to be insufficiently moistured, in 2015, 2017 and 2018 the level of heat and moisture supply was optimal for plants.

The main elements of potato cultivation technology corresponded to those generally accepted for the area [12]. Potato agricultural technology included non-moldboard fall tillage, early spring harrowing, cultivation (15–20 cm) and ridge tillage. Furrow planting was carried out followed by covering with soil. Planting care included the following techniques:

– herbicidal treatments (Metrifar 70, WSG (a.i. metribuzin 700 g / kg, consumption rate 0.7-1.4 l / ha) and Boxer, EC (a.v. prosulfocarb 800 g / l, consumption rate 3– 5 l / ha));

– inter-row cultivation, hilling;

– vegetation treatments against pests (Decis, EC (a.i. alpha-cypermethrin 100 g / l, consumption rate 0.1 l / ha));

– treatments against diseases (Revus Top, SC (a.v. difeconazole 250.0 g / l and mandipropamide 250.0 g / l, consumption rate 0.6 l / ha)).

Before harvesting, the foliage was desiccated with Reglon Super, WS (d.v. diquat 150 g / l, consumption rate 2 l / ha).

The experience was laid according to the methodology for conducting field studies[3]. The experiment was repeated twice, the number of plants in the replication was 20. Planting density 35.7 thousand plants / ha, feeding area 0.4 by 0.7 m.

The experiments were carried out by means of natural colonization of the soil by the causative agent of potato rhizoctonia disease (potatoes were planted on the same plot of land for 2 years in a row, which made it possible to form the above background). The peculiarities of the dynamics of the R. solani population under the colored potato varieties Purple Majesty, Vitelotte, and Violet were studied by planting them on a soil infectious background after potatoes on potatoes. Early potato varieties Agata were planted after various predecessors (potatoes, oats, and Sarepta mustard), also cultivated against the soil infectious background of R. solani.

Soil samples were taken under the plants before planting (May), during the full germination phase (June), during the budding period

[2]Shaldyaeva E.M., Pilipova Yu.V., Shatunova M.P. Optimization of the phytosanitary state of vegetable and specialized crop rotations in Western Siberia. Phytosanitary improvement of ecosystems: materials of the second All-Russian congress on plant protection (St. Petersburg, December 5-10, 2005). SPb., 2005. Vol. 1. pp. 585–586.

[3]Dospekhov B.A. Field experiment methodology (with the basics of statistical processing of research results). M.: "Book on demand", 2012. 351 p.

- the beginning of flowering (July) and during the maturation phase of the sample (August - September) before harvesting to study the features of the dynamics of the R. solani fungus population in potato plantings. The accumulation of rhizoctonia propagules in the soil was determined using the method of multiple soil pellets. 40–50 g of soil was taken from an average soil sample and sifted on a sieve with a 2 mm mesh, the moisture content was brought to 18%, and then ground to a homogeneous state. Sowing was performed with pellets using a sampler [13], 10 cups per sample (15 tablets in each cup) and one cup per dry weight (15 tablets) for further conversion to the selective medium of Co and Hora [14].

The population was determined in the spring before planting (initial); in the summer, in the phases of full germination and budding - the beginning of flowering; in the fall before harvesting.

Selective medium of Co and Hora per 1 liter of distilled water: agar - 20.0 g; K^2 HPO^4 1.0 g; $MgSO^4$. $7H_2O$ 0.5 g; KCl - 0.5 g; $FeSO_4$. $7H_2O$ - 0.01 g; $NaNO_2$ - 0.2 g. Sterilization for 35 min at 1 atm. After sterilization, gallic acid (0.4 g), streptomycin (0.05 g) and levomycin (0.05 g) were added.

The number of propagules per 100 g of dry soil was recalculated according to the formula

$$X = \frac{B \cdot 100}{A},$$

where B is the number of propagules in 150 tablets; A - the number of soil in 150 tablets, g; X is the number of propagules in 100 g of soil.

RESULTS AND DISCUSSION

Studies have shown that the amount of R. solani in the soil varied depending on the cultivar (see Fig. 1).

Under the potato variety Purple Majesty, two peaks of the fungus population in the soil were observed: the first (48.7 propagules / 10 g of soil) - during the full germination period, the second (57.2 propagules / 100 g of soil) - at the end of the crop maturation phase. The first peak in numbers was observed at the beginning of the growing season - the period of germination of tubers. This is probably due to the fact that the root exudates of the plants of this host cultivar stimulated the germination of spores of

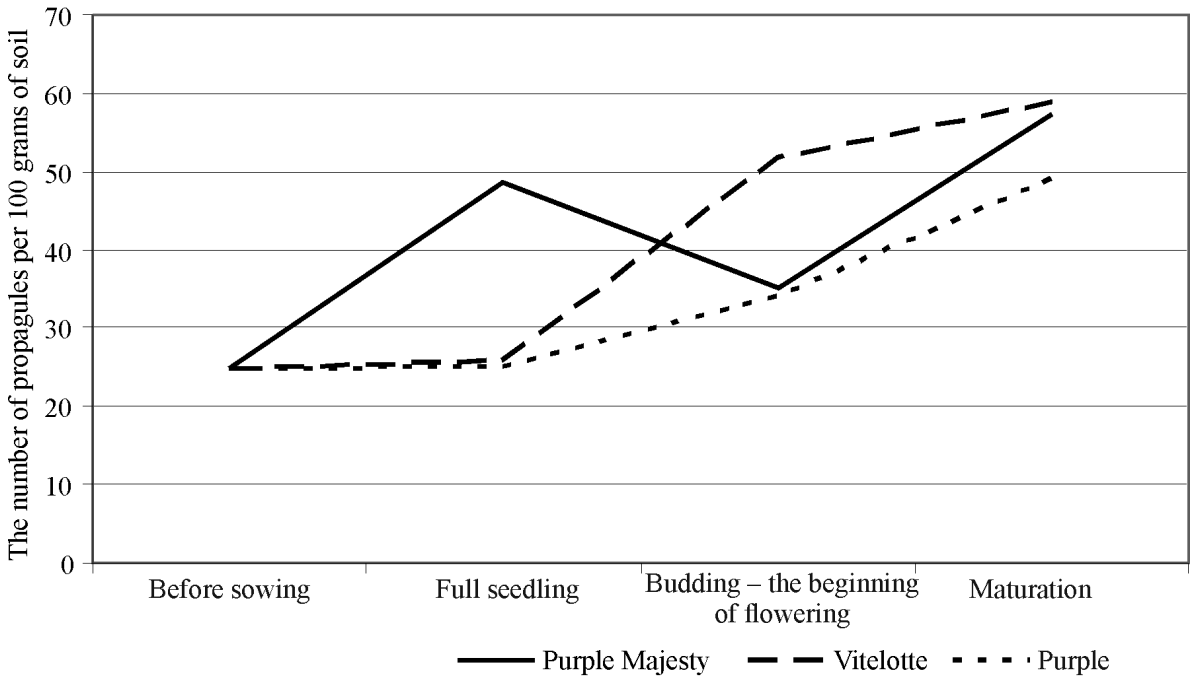

Рис. 1. Динамика численности пропагул *R. solani* в почве под разными сортами картофеля (среднее за 2017–2019 гг.)

Fig. 1. Population dynamics of *R. solani* propagules in soil on different potato varieties (average for 2017–2019)

the fungus R. solani, and the soil was actively colonized by this pathogen. A number of studies have noted that plant exudates affect the development of the causative agent of black scab and can provide both better opportunities for its penetration and infection [15] and suppress the development of the pathogen [16, 17].

The second peak in the abundance of R. solani for this cultivar was observed in the phase of maturation of the culture (August), which is obviously associated with the high saprophytic activity of the fungus. As a result, a large amount of infected plant residues entered the soil [1, 18].

In Vitelotte and Violet cultivars one peak was noted in the dynamics of population (59.0 and 49.1 propagules / 100 g of soil, respectively) at the end of the ripening period. The number of propagules in the soil under these two varieties during planting and during the germination period was almost the same, but by the budding phase - the beginning of flowering, the Vitelotte variety showed a sharp increase in the number of fungi - from 25.9 to 51.9 propagules / 100 g of soil with its further growth to 59.0 propagules / 100 g of soil. This phenomenon may be explained by the fact that by this period potato plants have rapidly accumulated a significant amount of carbohydrates and protein substances which are a good substrate for the development and active use of them by the fungus as a source of nutrition, which, in turn, contributes to a sharp increase in its parasitic properties growth[4].

The Violet variety showed a smooth increase in the number of propagules in the soil in comparison with two other varieties (25.1 propagules / 100 g of soil in the germination phase, 34.2 - budding - the beginning of flowering and 49.1 propagules / 100 g of soil during the ripening period). The indicators of the number of the fungus under this variety were the smallest.

The dynamics of development of the fungus R. solani in soil on the same cultivar grown according to different predecessors also varies. Thus, during the cultivation of potatoes of the Agata variety in monoculture at the beginning of the growing season a decrease in the number of propagules in the soil from 50.4 to 34.6 per 100 g of soil was noted. Subsequently, one peak in the number of the causative agent of rhizoctonia was observed, and the accumulation of the causative agent in the soil was very rapid. This indicator in the phase of full germination was 34.6 propagules / 100 g of soil, in the periods of budding - the beginning of flowering and ripening it was 1.6 and 3.7 times higher, respectively (see Fig. 2).

The dynamics of the fungus R. solani showed two peaks in population when cultivating potatoes of the Agata variety following tendergreen or oats. The first fell on the phase of full germination (June), the second - during the ripening of the culture (August). The first peak on these previous crops coincided with the lowest population of phytopathogen in continuous potato cultivation on potato.

The amount of the pathogen in the soil following oats and tendergreen was 2.5–3.1 times lower than in the monoculture in the ripening phase. The accumulation of the infectious principle in the soil after these predecessors also occurred, but the rate and dynamics of this accumulation in comparison with the monoculture turned out to be somewhat different. Thus, from planting to the germination phase, an increase in the number of the fungus was observed (1.6–1.7 times compared to the initial one), by the period of budding - the beginning of flowering, the amount of the pathogen in the soil gradually decreased, then its rise was observed again. When cultivating the Agata variety following tendergreen the second peak was 1.1 times lower than the first and 1.2 times after oats. It can be assumed that after the decomposition of tendergreen and oat stubble residues, the substances contained in them entered the soil and contributed to the suppression of the pathogen and the improvement of the soil [16, 17].

[4]Pochanina L.D. Features of the pathogenesis of potato rhizoctoniae and immunological assessment of varieties to the disease: author. dis. PhD in Agr. sciences. Samokhvalovichi, 1977.22 p.

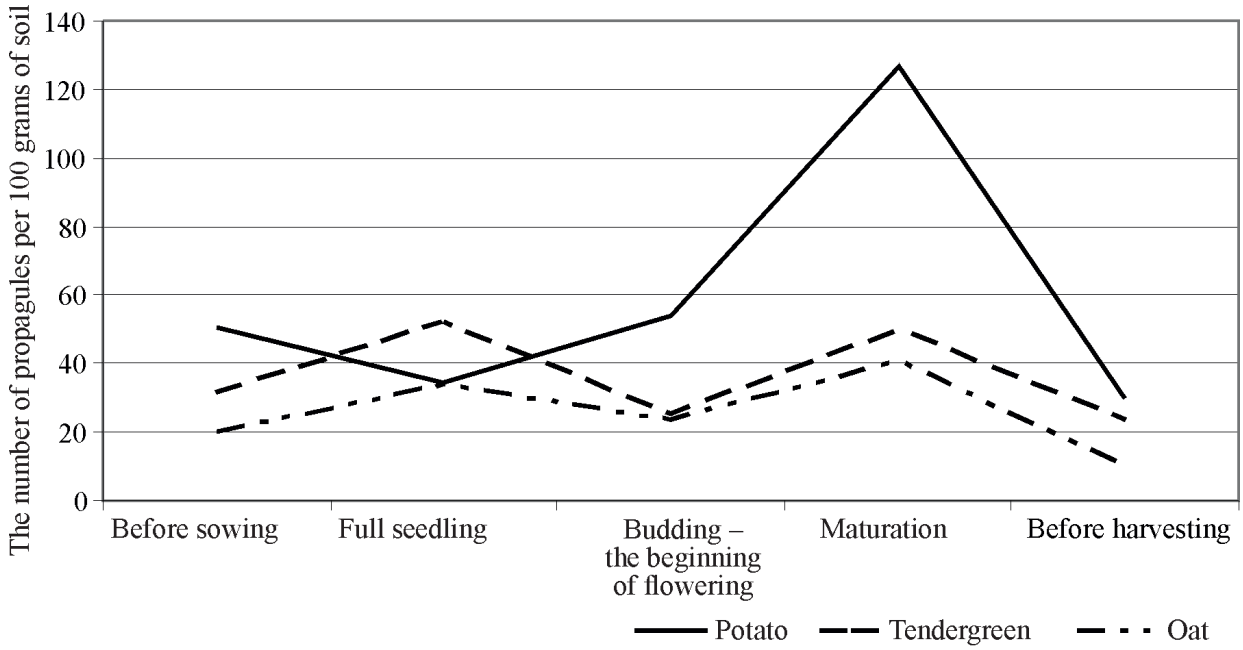

Рис. 2. Динамика численности пропагул *R. solani* при возделывании картофеля сорта Agata по разным предшественникам (среднее за 2014–2016 гг.)

Fig. 2. Population dynamics of *R. solani* propagules in the cultivation of Agata potatoes followed by different forecrops (average for 2014–2016)

CONCLUSION

1. The difference in the number and rate of accumulation of the fungus R. solani under different varieties of potatoes, as well as the influence of previous crops on this process, have been established.

2. The fungus R. solani population dynamics by cultivars differs in the soil. The smallest number of the causative agent of potato rhizoctonia blight in the soil on average during the growing season was noted under the Violet variety - 33.3 propagules / 100 g of soil, in Purple Majesty and Vitelotte - 41.5 and 40.4 propagules / 100 g of soil, respectively.

3. When the Agata potato is cultivated in monoculture, there is a rapid and significant accumulation of the fungus R. solani in the soil (from 34.6 to 126.8 propagules / 100 g of soil). If this specimen is cultivated after tendergreen or oats, then the number of the pathogen varies to a lesser extent (25.1–52.2 and 19.8–41.0 propagules / 100 g of soil, respectively); sharp increases in the number of propagative structures of the phytopathogen in the soil were not observed.

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Дата поступления статьи 09.10.2020
Received by the editors 09.10.2020

https://doi.org/10.26898/0370-8799-2021-1-4
УДК: 06.01.05

Тип статьи: оригинальная
Type of article: original

СКРИНИНГ СОРТООБРАЗЦОВ ПШЕНИЦЫ РОССИЙСКОЙ СЕЛЕКЦИИ НА УСТОЙЧИВОСТЬ К БУРОЙ РЖАВЧИНЕ

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Представлены результаты иммунологической оценки сортообразцов озимой твердой и озимой мягкой пшеницы селекции Аграрного научного центра «Донской» на устойчивость к бурой ржавчине. Опыт проведен на территории Краснодарского края в 2016–2019 гг. Скрининг 86 селекционных образцов (63 сортообразца озимой твердой пшеницы и 23 образца озимой мягкой пшеницы) осуществляли в условиях искусственного инфекционного фона. Для заражения растений использовали популяцию, собранную во время маршрутных обследований производственных и селекционных посевов озимой пшеницы. Оценку сортообразцов проводили по двум критериям: типу реакции (в баллах) и степени поражения (в процентах) в период максимального развития болезни. Скрининг образцов осуществляли в течение трех вегетационных сезонов, для второго и третьего года изучения отбирали устойчивые сортообразцы с типом реакции 1,2 балла и степенью поражения не больше 10%. Степень поражения на контроле по восприимчивости достигала от 50 до 80%. В результате исследования образцы озимой твердой пшеницы ранжированы следующим образом: устойчивые – 16 образцов, среднеустойчивые – 26, средневосприимчивые – 20, восприимчивые – 1. Среди образцов озимой мягкой пшеницы выделили 6 устойчивых образцов; 11 среднеустойчивых; 5 средневосприимчивых, 1 восприимчивый. За 3 года исследований выявлены 16 устойчивых образцов озимой твердой пшеницы (465/15, 502/15, 515/15, 537/15, 597/15, 663/15, 681/15, 694/15, 730/15, 742/15, 753/15, 979/15, 996/15, 993/12, 1035/15, 417/13) и 6 устойчивых образцов озимой мягкой пшеницы (134/11, 1415/11, 1765/14, 1074/14, 1813/14, Танаис). В результате проведенного скрининга обнаружен высокий процент устойчивых сортообразцов к бурой ржавчине. Выделенные источники устойчивости рекомендованы для включения в программы селекции пшеницы на устойчивость к патогену в Российской Федерации.

Ключевые слова: пшеница озимая, бурая ржавчина, *Puccinia triticina*, источники устойчивости, селекция

SCREENING OF WHEAT VARIETIES OF THE RUSSIAN BREEDING FOR RESISTANCE TO BROWN RUST

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The results of immunological assessment of varieties of durum and soft winter wheat bred by the Agrarian Scientific Center Donskoy for resistance to leaf rust are presented. The experiment was carried out in Krasnodar Territory in 2016–2019. Screening of 86 selection samples (63 varieties of durum winter wheat and 23 samples of soft winter wheat) was carried out in an artificial infectious environment. To infect plants, a population collected during route surveys of production and selection crops of winter wheat was used. The varieties were assessed according to two criteria: the type of

reaction (in points) and the degree of damage (in percent) during the period of maximum disease development. Screening of the samples was carried out during three growing seasons; for the second and third years of the study, resistant varieties were selected with the reaction type of 1.2 points and the degree of damage of no more than 10%. The degree of damage on the susceptibility control reached from 50 to 80%. As a result of the study, the samples of durum winter wheat were ranked as follows: 16 resistant samples, 26 medium-resistant, 20 medium-susceptible, 1 susceptible. Among the samples of soft winter wheat, 6 resistant samples were identified, 11 medium-resistant, 5 medium-susceptible, 1 susceptible. Over 3 years of research, 16 resistant samples of durum winter wheat were identified (465/15, 502/15, 515/15, 537/15, 597/15, 663/15, 681/15, 694/15, 730/15, 742 / 15, 753/15, 979/15, 996/15, 993/12, 1035/15, 417/13) as well as 6 resistant samples of soft winter wheat (134/11, 1415/11, 1765/14, 1074/14, 1813/14, Tanais). As a result of the screening, a high percentage of varieties resistant to leaf rust was found. The sources of resistance that were identified have been recommended to be included in wheat breeding programs for pathogen resistance in the Russian Federation.

Keywords: winter wheat, brown rust, *Puccinia triticina*, sources of resistance, breeding

Для цитирования: *Агапова В.Д., Ваганова О.Ф., Кудинова О.А., Волкова Г.В.* Скрининг сортообразцов пшеницы российской селекции на устойчивость к бурой ржавчине // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 33–41. https://doi.org/10.26898/0370-8799-2021-1-5

For citation: Agapova V.D., Vaganova O.F., Kudinova O.A., Volkova G.V. Screening of wheat varieties of the Russian breeding for resistance to brown rust. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1. pp. 33–41. https://doi.org/10.26898/0370-8799-2021-1-5

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

Финансовая поддержка
Исследования выполнены согласно Государственному заданию Министерства науки и высшего образования РФ в рамках НИР по теме № 0686-2019-0008.
Financial support
The research was carried out in accordance with the State order of the Ministry of Science and Higher Education of the Russian Federation within the framework of research work on the topic No. 0686-2019-0008.

Благодарность
Выражаем благодарность коллективу АНЦ «Донской» за предоставленные для изучения коллекционные образцы пшеницы.
Acknowledgments
We would like to express our gratitude to the team of the Agrarian Scientific Center "Donskoy" for the collection wheat samples provided for the study.

INTRODUCTION

Wheat is one of the most demanded agricultural crops in Russia. According to the Federal State Statistics Service of the Russian Federation it dominates in terms of the crop production area in the country (27.7 million hectares)[1]. The increased interest in this culture can be explained by the high nutritional value of products obtained as a result of grain processing [1]. According to forecasts, by 2050 the demand for wheat will have grown by 60%, and its yield is expected to have declined by 29% due to climatic factors, diseases and pests [2]. The most acceptable and economically profitable way to increase crop yields is the selection of an optimal varietal assortment for the characteristics of the cultivation site [3].

When improved varieties of new selection are used in the production, the yield increases, the adaptability of plants to critical weather conditions goes up, resistance to insect pests and phytopathogens increases, the output increases and the quality of products improves. However, a violation of crop rotation, a change

[1]Federal State Statistics Service. URL: http://rosstat.gov.ru/storage/mediabank/posev_pl1(1).xls (date of the application 29.12.2020).

in the genetic resistance of industrial varieties and the introduction of seed material provoke a change in the species composition of pathogens of agricultural crops [4].

One of the most geographically widespread and common wheat infections is brown rust caused by the obligate biotrophic fungus Puccinia triticina Erikss. Wheat brown rust is a serious problem for many grain-producing regions of the world and can lead to a loss of yield in the range of 10–50% with a high infection [5]. A distinctive feature of P. triticina is a high plasticity of the fungus population, which leads to the selection and accumulation of virulent pathotypes capable of overcoming the race-specific resistance of the sown varieties [6]. To prevent an epiphytotic situation, it is necessary to take into account constantly updated data on the resistance of varieties when they are placed.

A study of the varieties' resistance under conditions of an artificial infectious background in the zones of their regional assignment is important information for breeders. Currently, research on this issue is being carried out in various agroclimatic zones of Russia and abroad [7–10]. A comprehensive program of the Kazakh-Siberian Network (KASIB) made it possible to give an objective ecological assessment of the breeding material and highlight the most promising genotypes. During the variety testing of the KASIB network in 2000–2016 more than 500 varieties of spring soft wheat were considered. It was found that 64.8% of the samples belonged to the susceptible group, 18.5 were partially resistant and 16.7% were highly resistant to brown rust of wheat [11]. Extensive work on this issue is also being carried out by the Agricultural Research Institute of the South-East. 597 collection samples of soft spring breeding CIMMYT (Mexico), the world collection of VIR (St. Petersburg), varieties of domestic breeding and wild wheat species were studied, of which 335 varieties resistant to brown rust were identified [12].

For the screening of samples from the International Center for the Improvement of Corn and Wheat (CIMMYT) for resistance to wheat brown rust in Egypt 716 samples were studied. During three growing seasons (2017–2020) it was determined that 94 wheat genotypes were resistant to brown rust [13]. In Pakistan, as a result of an assessment of 152 lines of common wheat 68 varieties resistant to this infection were identified. The study was carried out on the experimental territory of the Ayub Research Institute of Agriculture (Faisalabad) [14].

This work presents the results of studying the variety samples of the selection of the Agrarian Scientific Center "Donskoy" (Zernograd, Rostov region) for their resistance to brown rust. In the ASC "Donskoy" promising research aimed at obtaining highly productive varieties and hybrids of grain crops, the search for methods for obtaining new starting material, and the analysis of genetic processes have been carried out. The resulting varieties in their physiological and economic qualities correspond to the best foreign and domestic samples, have high ecological plasticity and have complex resistance to the dominant diseases common in the cultivation zones [15].

The purpose of the study is to screen 86 cultivars of the ASC "Donskoy" selection for resistance to the North Caucasian population of the wheat brown rust pathogen under conditions of an artificial infectious background.

MATERIAL AND METHODS

The studies were carried out in 2016–2019 at the experimental field of the Federal Scientific Center for Biological Plant Protection (FSCBPP).

The conditions of the 2017 growing season were characterized by frequent rains and low temperatures, which caused a delay in the maturation of grain crops and contributed to the rapid development of the disease. In the spring of 2018, unstable weather was noted with sharp temperature fluctuations and low precipitation. With abnormally high temperatures in May - June a significant deficit of precipitation was observed (20–30% of the norm). In 2019 weather conditions turned out to be favorable for the development of phytopathogens on grain crops. From the beginning of February to the end of May the air humidity was high (within 65–90%), the temperature for a long time was confined within the optimum for the

development of the pathogen.

The research material consisted of 63 varieties of durum winter wheat and 23 samples of soft winter wheat bred by ASC "Donskoy". Susceptibility control - Michigan Amber cultivar. Infectious material - a combined population of brown rust collected as a result of route surveys of production and selection crops of winter wheat in the Krasnodar, Stavropol Territories and Rostov Region, containing all the virulence genes we have identified [16].

Varieties of winter wheat were sown at the infectious site of the Federal Research Center for Plant Protection and Rehabilitation in rows of 3 linear meters in triplicate, seeding rate - 100-130 seeds per 1 running m. A susceptible cultivar which was the accumulator of infection was placed in every 10 plots.

Inoculation was carried out in spring at a temperature of 10–15 ° C; the plants were infected with a mixture of P. triticina urediniospores and talc in a ratio of 1: 100 (10 mg of pathogen spores / m^2) in the evening under dew or after rain. The duration of the humidified period for the introduction and germination of the pathogen was at least 6 h[2].

To assess the breeding material, the records were carried out during the period of maximum development of the disease. The cultivars were characterized by two parameters: the type of reaction (in points) to brown rust infection and the degree of damage (in percent) on a scale[3] [17]: 0 - completely immune, 0; - practically immune, 1 - highly resistant, 2 - moderately resistant, 3 - moderately susceptible, 4 - highly susceptible.

The collection cultivars were ranked into four groups according to the type of resistance to P. triticina: 1 - resistant (type 1 point; degree of damage 1–5%); 2 - moderately resistant (type 1.2 points; degree of damage 10–20%); 3 - moderately susceptible (type 2.2 (3) points; degree of damage 20-30%); 4 - susceptible (type 2.2 (3) points - more than 30% and type 3.4 points - more than 5%)[4,5].

The research used the material and technical base of the LSRF (large scale research facilities) "Fitotron for the isolation, identification, study and maintenance of races, strains, phenotypes of pathogens" (https://ckp-rf.ru/usu/671925/?sphrase_id = 3644277) and objects of the BRC " State collection of entomoacariphages and microorganisms " of the FSCB-PP.

RESULTS AND DISCUSSION

86 varieties (63 hard winter and 23 winter soft wheat) of the ASC “Donskoy” selection were evaluated with the artificial infection of the North Caucasian population of the brown rust pathogen (see table).

Screening of the samples was carried out during three growing seasons, for the second and third years of the study resistant varieties were selected with a reaction type of 1.2 points and a degree of damage not more than 10. The degree of damage on the control by susceptibility reached from 50 to 80%.

As a result of the study, the samples of durum winter wheat were ranked as follows: resistant - 16 samples (25% of the number studied); medium resistant - 26 (41%); moderately susceptible - 20 (32%); susceptible - 1 (2%).

Samples of soft winter wheat were classified in the same way: resistant - 6 samples (26% of the studied); medium resistant - 11 (48%); moderately susceptible - 5 (22%); susceptible - 1 (4%) (see the figure).

During the three years of the study, 16 resistant samples of durum winter wheat were

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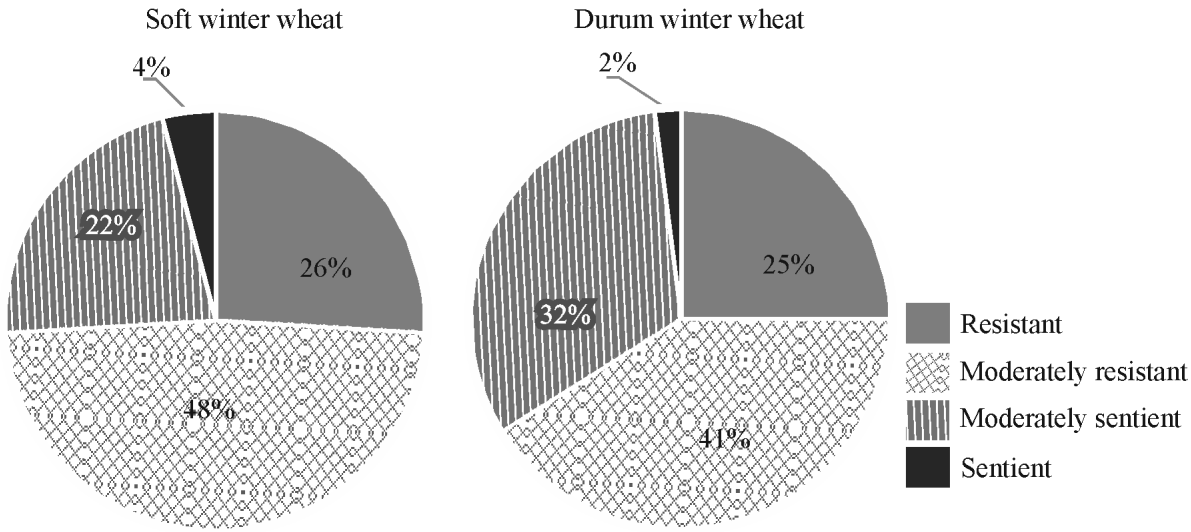
Иммунологическая оценка сортообразцов селекции АНЦ «Донской» (2016–2019 гг.)
Immunological assessment of varieties bred by Agrarian Research Centre Donskoy (2016–2019)

No.	Variety	Year of study			No.	Variety	Year of study		
		first	second	third			first	second	third
Durum winter wheat									
1	484/14	2,3/10	–*	–	33	808/15	2,3/20	–	–
2	533/14	2/5	1,2/10	–	34	820/15	1,2/10	–	–
3	605/14	2,3/10	–	–	35	865/15	2,3/20	–	–
4	627/14	1,2/10	–	–	36	876/15	1,2/20	–	–
5	784/14	2,3/20	–	–	37	907/15	1/5	1/10	–
6	896/14	2,3/20	–	–	38	920/15	1/5	1,2/20	–
7	913/14	2,3/10	–	–	39	961/15	1/5	1,2/10	–
8	465/15	1/5	1,2/5	1/5	40	966/15	1/5	1,2/10	–
9	492/15	1/5	1,2/10	–	41	973/15	1/5	1,2/20	–
10	502/15	1,2/5	1,2/5	1/5	42	979/15	1/5	1/5	1/1
11	515/15	1,2/5	1/1	1,2/5	43	986/15	1/5	1,2/5	1,2/10
12	524/15	1/5	1/1	1,2/10	44	996/15	1/5	1,2/5	1/1
13	528/15	1/5	1/5	1,2/10	45	1014/15	1/5	1,2/5	1,2/20
14	537/15	1,2/5	1,2/5	1/5	46	1035/15	1/5	1,2/5	1,2/5
15	543/15	2,3/20	–	–	47	1040/15	1/5	2,3/20	–
16	546/15	2,3/20	–	–	48	1048/15	2,3/10	–	–
17	550/15	1,2/10	–	–	49	1069/15	1/5	1,2/20	–
18	588/15	2,3/20	–	–	50	1084/15	1/5	2,3/30	–
19	597/15	1,2/5	1,2/5	1,2/5	51	537/11	2,3/15	–	–
20	611/15	1,2/10	–	–	52	737/11	1/5	2,3/20	–
21	631/15	1,2/10	–	–	53	477/12	1/5	1/10	–
22	663/15	1/5	1/5	1/1	54	840/12	1/5	1,2/20	–
23	681/15	1/5	1,2/5	1/5	55	993/12	1/5	1/5	1/5
24	693/15	3/30	–	–	56	114/13	2,3/10	–	–
25	694/15	1/5	1/5	1/5	57	353/13	1/5	1,2/10	–
26	713/15	1,2/5	1,2/10	–	58	417/13	1/5	1/5	1/5
27	721/15	2,3/20	–	–	59	531/13	2,3/20	–	–
28	730/15	1/5	1/5	1/5	60	589/13	2,3/10	–	–
29	742/15	1/5	1/5	1/5	61	655/13	2,3/20	–	–
30	753/15	1/5	1/5	1/5	62	683/13	1,2/5	1,2/10	–
31	773/15	1,2/10	–	–	63	117/14	1/5	1/5	1/10
32	387/15	1/10	–	–					
Soft winter wheat									
1	134/11	1/5	1/5	1/5	13	1545/14	1/1	2,3/30	–
2	1127/10	1/5	1/10	–	14	1580/14	1,2/5	1,2/10	–
3	1415/11	1/5	1/5	1/5	15	1626/14	1,2/5	1/10	–
4	1159/13	1,2/5	1,2/10	–	16	1810/14	2,3/10	–	–
5	1261/13	1/5	1/10	–	17	1813/14	1/5	1/5	1/5
6	1481/13	1/5	2,3/30	–	18	1909/14	1,2/5	1,2/10	–
7	1756/13	1/5	1/10	–	19	1953/14	1/10	–	–
8	1765/13	1/5	1/5	1/5	20	1979/14	1/5	1/5	1/10
9	1074/14	1/5	1/5	1/5	21	1991/14	1/5	2,3/10	–
10	1182/14	2/5	1,2/20	–	22	2028/14	1/5	2/5	1,2/10
11	1309/14	1,2/5	1,2/10	–	23	Tanais	1/5	1/5	1,2/5
12	1441/14	3/30	–	–		Michigan Amber	3/80	3/70	3/50

*Sentient reaction type



Соотношение сортообразцов озимой твердой и мягкой пшеницы по устойчивости к *P. triticina (*2016–2019 гг.)

The ratio of durum and soft winter wheat varieties for resistance to *P. triticina* (2016-2019)

identified (465/15, 502/15, 515/15, 537/15, 597/15, 663/15, 681/15, 694/15, 730/15, 742 / 15, 753/15, 979/15, 996/15, 993/12, 1035/15, 417/13), as well as 6 resistant samples of winter soft wheat (134/11, 1415/11, 1765/14, 1074 / 14, 1813/14, Tanais).

During the screening, a high percentage of varieties resistant to brown rust was found, which indicates the effective breeding work of the ASC "Donskoy" on this trait. They can be used as sources of resistance to P. triticina for wheat breeding in the Russian Federation.

CONCLUSION

Long-term studies carried out at the Federal Research Center for Plant Protection of Natural Resources on artificial infectious backgrounds of P. triticina made it possible to give an objective immunological assessment of winter wheat samples and to isolate varieties with different degrees of resistance. Among 86 varieties of winter wheat bred by ASC "Donskoy" 16 sources of resistance to the causative agent of brown rust among winter durum wheat and 6 - among winter soft wheat were identified.

For perspective breeding of P. triticina-resistant varieties of winter wheat, it is advisable to integrate into crossing both local varieties that retain a long-term high resistance to infection, and varieties from other Russian regions and foreign breeding, showing resistance in certain natural and climatic zones.

The isolated sources of resistance are recommended for inclusion in the programs of wheat breeding for resistance to the pathogen in the Russian Federation.

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Дата поступления статьи 10.10.2020

Received by the editors 10.10.2020

https://doi.org/10.26898/0370-8799-2021-1-5
УДК: 631.584.51
Тип статьи: оригинальная
Type of article: original

КОНКУРЕНТНАЯ СПОСОБНОСТЬ КОМПОНЕНТОВ В СМЕШАННЫХ АГРОЦЕНОЗАХ ЗЕРНОФУРАЖНЫХ КУЛЬТУР

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Представлены результаты анализа урожайности и биологической эффективности одновидовых и смешанных посевов злаковых и бобовых культур в зависимости от зон возделывания. Исследования проведены в лесостепной и степной зонах Западной Сибири и в лесостепной зоне Восточной Сибири, результаты проанализированы через показатели «отношение земельных эквивалентов» и коэффициент агрессивности. В лесостепной зоне Западной Сибири при возделывании на зернофураж преимущество имели двухкомпонентные смеси с нормой высева 60–75% злакового (ячмень или овес) и 35–50% бобового компонентов (горох). Урожайность составила 23–29 ц зерна/га с содержанием переваримого протеина 106–110 г/к.ед. и показателем эффективности использования площади 1,17 ед. Наибольшим коэффициентом агрессивности (плюс 0,53) обладает горох в смеси с пшеницей. В условиях степной зоны Западной Сибири наиболее эффективны двухкомпонентные смеси ячменя и пшеницы с пелюшкой при соотношении злакового и бобового компонентов 60/50% от полной нормы высева культур. Урожайность данных ценозов отмечена на уровне одновидовых посевов, а питательность выше на 6–10%. Показатель «отношение земельных эквивалентов» для данной зоны составил 1,21–1,3 ед. Доля бобового компонента в урожае зерна трехкомпонентных смесей при неблагоприятных сухих условиях степной зоны зарегистрирована незначительной. Значение коэффициента агрессивности бобового компонента снизилось до минус 1,58 и максимально уменьшилась его доля в агроценозе. Для лесостепной зоны Восточной Сибири характерно достаточное увлажнение, что способствовало получению хорошего урожая зерна. Наибольшую урожайность обеспечили смеси овса с горохом (48,5 ц/га) и овса с горохом и ячменем (42,9 ц/га) с показателем «отношение земельных эквивалентов» до 1,45 ед. и коэффициентом агрессивности, близким к нулю. В данной зоне существуют благоприятные условия произрастания культур в бинарных посевах.

Ключевые слова: одновидовые и смешанные посевы, соотношение компонентов, зернофураж, биологическая эффективность, коэффициент агрессивности, зона возделывания

COMPETITIVE ABILITY OF COMPONENTS IN MIXED AGROCENOSIS OF FODDER GRAIN CROPS

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The results of the analysis of yield and biological efficiency of single-species and mixed crops of cereals and legumes, depending on the cultivation zones, are presented. The study was carried out in the forest-steppe and steppe zones of Western Siberia and the forest-steppe zone of Eastern Siberia.

The results were analyzed by means of Land Equivalent Ratio and the coefficient of aggressiveness. In the forest-steppe zone of Western Siberia, two-component mixtures with a seeding rate of 60–75% of cereals (barley or oats) and 35–50% of legumes (peas) had an advantage in cultivation for fodder grain. The yield was 2.3–2.9 t/ha of grain with digestible protein content of 106–110 g per feed unit and the efficiency of the area use of 1.17 units. Peas mixed with wheat had the highest coefficient of aggressiveness (plus 0.53). In the conditions of the steppe zone of Western Siberia, two-component mixtures of barley and wheat with field peas are the most effective with a ratio of cereal and legume components of 60/50% of the total seeding rate of crops. The yield of these cenoses was noted at the level of single-species crops, and the nutritional value was 6–10% higher. Land Equivalent Ratio for this zone amounted to 1.21-1.3 units. The share of the legume component in the grain yield of three-component mixtures under unfavorable dry conditions of the steppe zone was registered insignificant. The value of the coefficient of aggressiveness of the legume component decreased to minus 1.58 and its share in the agrocenosis decreased to the utmost extent. The forest-steppe zone of Eastern Siberia is characterized by sufficient moisture, which contributed to a good grain harvest. The highest yield was provided by a mixture of oats with peas (4.85 t/ha) and oats with peas and barley (4.29 t/ha), with the Land Equivalent Ratio of up to 1.45 units and the coefficient of aggressiveness close to zero. In this zone, there are favorable growth conditions for binary crops.

Keywords: single-species and mixed crops, ratio of components, fodder grain, biological efficiency, coefficient of aggressiveness, cultivation zone

Для цитирования: *Кашеваров Н.И., Садохина Т.А., Бакшаев Д.Ю.* Конкурентная способность компонентов в смешанных агроценозах зернофуражных культур // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 42–50. https://doi.org/10.26898/0370-8799-2021-1-5

For citation: Kashevarov N.I., Sadokhina T.A., Bakshaev D.Yu. Competitive ability of components in mixed agrocenoses of fodder grain crops. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,*2021, vol. 51, no. 1, pp. 42–50. https://doi.org/10.26898/0370-8799-2021-1-5

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

INTRODUCTION

Cultivation of forage crops is currently carried out mainly in single-species crops. Such agrocenoses are highly productive, but potentially unstable, since they completely depend on the external conditions of cultivation [1]. Unlike multicomponent agrocenoses, they are poorly adapted, more susceptible to stresses caused by changes in external conditions, they have fewer opportunities for transforming energy, nutrients, etc. Single-species crops are more vulnerable to the effects of harmful and pathogenic organisms and very actively and unilaterally deplete soil fertility.

A significant reserve for the use of biological environmental factors and an increase in the production of fodder grain is the cultivation of highly productive ecologically stable multicomponent agrophytocenoses with the inclusion of legumes [2, 3]. The effectiveness of mixed crops is determined by the biological compatibility of simultaneously growing components of the agrocenosis, which can be established experimentally [1, 2, 4–7]. Currently, one of the difficult questions in the study of mixed crops is the quantitative assessment of their advantages in comparison with single-species crops [7–10].

The main problem is to determine objective criteria for evaluating the effectiveness of single-species crops and mixed agrocenoses [2, 11, 12]. The biological efficiency of multicomponent crops is determined by comparing the productivity of the mixture with the productivity of two crops of mixed crops on the same area [13].

In the present studies, we studied the relationship of cereals with legumes when cultivated in single-species and mixed crops for grain under different growing conditions. The purpose of the research is to develop principles

for the design of highly productive mixed crops with the participation of a legume component when harvesting for grain, depending on the growing zones.

MATERIAL AND METHODS

The studies were carried out in the forest-steppe and steppe zones of Western Siberia and the forest-steppe zone of Eastern Siberia in 2013–2015. In 2021, the results were analyzed through the Land Equivalent Ratio (LER) and the Coefficient of aggressiveness Ratio (CA) [14]. These indicators are calculated using the formulas:

$$LER = (Y_{AB} / Y_{AA}) + (Y_{BA} / Y_{BB}), \quad (1)$$

where LER is the ratio of land equivalents, Y_{AB} is the yield of crop A in mixed sowing with crop B, t / ha; Y_{BA} - yield of crop B in mixed sowing with crop A, t / ha; Y_{AA} and Y_{BB} - yield of crops A and B, respectively, in clean sowing, t / ha.

$$CA_{AB} = Y_{AB}: (Y_{AA} \cdot Z_{AB}) - Y_{BA}: (Y_{BB} \cdot Z_{BA}), \quad (2)$$

where CA is the coefficient of aggressiveness of culture A in mixed sowing with culture B; Y_{AB} - yield per unit area of crop A in mixed sowing with crop B; Y_{AA} - yield per unit area of crop A in clean sowing; Z_{AB} and Z_{BA} - part of the mixed sowing, initially determined for crops A and B (in %).

The forest-steppe zone of Western Siberia (zone I) is located in the northern forest-steppe of the Ob region. The soil of the experimental site is leached medium-thick medium loamy chernozem, the humus content in the 0–20 cm layer is about 6%. Selyaninov's hydrothermal coefficient is 1.0–1.2.

The steppe zone of the Northern Kulunda (II zone) is the Northern -Kulunda department of the Siberian Research Institute of Fodder Crops (SRIFC) of the Siberian Federal Scientific Center of Agrobiotechnology of the Russian Academy of Sciences. The soil of the experimental site is southern solonetzic chernozem, shallow, light loamy. The climate of the zone is sharply continental, with hot summers and cold winters. The hydrothermal coefficient for the zone is less than 0.5.

The forest-steppe zone of Eastern Siberia (III zone) is the East Siberian department of Siberian Research Institute of Fodder Crops. The soil of the experimental site is ordinary heavy loamy chernozem with a humus content in the arable horizon of 7.7–7.8%. The hydrothermal coefficient for May - August is 1.5, which corresponds to the indicators of good moisture.

The growing season of 2013, on average across the zones, was characterized by excessive moisture and lack of heat. The growing season in 2014 was unfavorable in terms of heat and moisture supply for grain fodder and leguminous crops. Agrometeorological conditions of the 2015 growing season in the steppe zone of Western Siberia were characterized by the absence of precipitation from late May to mid-July.

In the experiment, the following ratios of components in mixtures were used: barley (75%) + peas (field pea) (35%), oats (75%) + peas (field pea) (35%), wheat (70%) + peas (field pea) (40%), barley (30%) + peas (field pea) (50%) + oats (30%), barley (30%) + peas (field pea) (50%) + wheat (30%), oats (30%) + peas (field pea) (50%) + wheat (30%), barley (20%) + oats (20%) + wheat (20%) + peas (field pea) (50%).

RESULTS AND DISCUSSION

To solve the practical problem of the study, the production advantages of mixed crops by zones have been determined. For oats, in contrast to barley and wheat, conditions are favorable in all zones (the yield of grain fodder is from 10.4 to 37.0 c / ha, depending on the conditions of the growing season). For barley, conditions were more favorable in the forest-steppe zone of Western and Eastern Siberia, the yield was 29.4 and 42.1 c / ha, respectively (see Table 1). Peas (field pea) in single-species crops formed a yield almost 2 times less than that of cereals, legumes lodged badly and were affected by diseases. Compared with single-species crops, the mixtures were not inferior, and in some cases exceeded single-species crops of peas (field

pea) in grain collection. They are marked more plastic to meteorological conditions.

In all research areas, a two-component mixture of oats + peas provided a stable and high yield of 10.6–48.5 c / ha. These indicators are 10-13% higher than the data of single-species crops of cereals, and 1.5-2 times higher than those of single-species crops of peas. Traditional barley-pea mixtures, on average, provided an increase in grain yield in comparison with single-species pea crops by 1.8-14.9 c / ha. The introduction of the third component into the double mixture (especially wheat mixed with oats and peas) reduced the yield by 18-26%, which indicates the low competitiveness of this crop and its oppression by oats and peas.

One of the important indicators in the cultivation of mixtures is the proportion of the legume component in the grain yield. It varied on average from 3 to 32% and depended on the cultivation area. The minimum content of peas in the mixture (3–8%) was obtained in the steppe zone of Northern Kulunda, the maximum (24–32%) - in the forest-steppe zone of Western Siberia.

The mixtures formed a more stable yield over the years, compensating for the lack of yield of one component at the expense of another. For 3 years of research, the coefficient of variation in grain yield of cereal crops was 44%, while oats - 52%, wheat - 62, peas - 31%. Consequently, the total yield of mixed crops is less susceptible to the influence of meteorological conditions in individual years than crops in single-species crops.

To solve the problem of assessing the biological effectiveness of mixed crops, the following indicators were used: LER and CA [14]. Using the LER value, the calculation of the size of the land area required to obtain in single-species crops the same amount of production of each of the components, which was formed per unit area of the mixed crop. The higher the LER value, the higher the efficiency of land use when growing a mixture, if LER = 1, then mixed cultivation of crops is ineffective for obtaining products [15].

The analysis of experimental data showed that the biological efficiency of mixed crops depends on the meteorological conditions of the growing season, the cultivation zone, the ratio of the components in the mixture and the aggressiveness of the crop. For 3 years of research in the forest-steppe zone of Western Siberia, the LER index for all mixtures was registered above 1, which indicates the effec-

Табл. 1. Урожайность зерна зернофуражных культур в одновидовых и смешанных посевах в разных зонах возделывания, ц/га (среднее за 2013–2015 гг.)

Table 1. Grain yield of fodder crops in single-species and mixed crops in different zones of cultivation, centner/ha (average for 2013-2015)

Option	Cultivation area								
	I			II			III		
	Mixture	Cereals	Legumes	Mixture	Cereals	Legumes	Mixture	Cereals	Legumes
Wheat	29,2	29,2	–	7,4	7,4	–	27,9	27,9	–
Oat	30,8	30,8	–	10,4	10,4	–	37,0	37,0	–
Barley	29,4	29,4	–	7,7	7,7	–	42,1	42,1	–
Pea	14,0	–	14,0	8,7	–	8,7	24,3	–	–
Barley + pea	28,9	23,7	5,2	9,5	8,4	1,1	39,3	31,0	8,25
Oat + pea	26,5	22,2	4,2	10,6	9,7	0,9	48,5	37,8	10,6
Wheat + pea	22,6	15,4	7,2	9,9	8,9	0,1	32,5	25,0	7,5
Barley + pea + oat	27,0	19,7	7,3	9,3	8,5	0,83	42,9	35,0	7,9
Barley + pea + wheat	26,2	19,1	7,1	8,9	7,9	0,1	38,9	33,8	5,1
Oat + pea + wheat	25,6	19,7	5,9	9,5	8,7	0,8	36,2	26,0	10,2
Barley + pea + oat + wheat	26,0	19,7	6,2	9,1	8,2	0,9	42,0	32,7	9,3

tiveness of the cultivation of mixtures in this zone. The most effective in this zone were the binary mixtures of barley with peas (LER 1.17 units) and three-component mixtures containing barley with wheat (LER 1.16–1.17 units) (see Table 2). In three-way blends containing oats and wheat, the LER decreased to 1.07.

The cultivation of mixtures with wheat in the steppe zone is also less efficient. In the steppe zone of Northern Kulunda, the most productive binary mixtures of barley with field pea (LER 1.21 units) and wheat with field pea (LER 1.3 units). In three-component mixtures in dry conditions of the steppe zone, unfavorable conditions are formed for the legume component, its share in the grain yield is insignificant.

The forest-steppe zone of Eastern Siberia is characterized by sufficient moisture (HTC = 1.5), which contributes to obtaining good grain yields. In this area, it is most efficient to cultivate a two-component mixture of oats and peas (LER 1.45 units) with a high contribution of the legume component to the efficiency of the mixture (LER 0.43 units). The high value of the coefficient shows that to obtain the same amount of grain in single-species crops, 1.45 times more land area is required, i.e. the relative productivity of the two-component mixture is 45% higher. It can be unambiguously asserted that the obtained value of the "land equivalents ratio" shows the advantage of mixed crops.

The aggressiveness coefficient represents the competition of crops in a mixed sowing, which is determined by correlating the change in the yield of both components of the mixture to the expected indicators. This coefficient is calculated by the formula (2).

For culture B, the sign of the coefficient will be opposite to culture A. A coefficient value equal to zero means that both components of the mixture have the same competitive ability and are in the same conditions. Under other circumstances, crops will have the same CA numerical value. However, the more aggressive component of the mixture will have a positive sign, the less competitive - negative.

In the forest-steppe zone of Western Siberia, in mixed crops of cereals with peas, the CA of components varied from plus 0.01 to plus 0.53 over the years of research (see Fig. 1).

In mixtures of barley and peas, CA approached zero. This indicates that the crops had the same competitive ability and were in optimal growing conditions. Under the most favorable conditions for legumes (in a mixture with wheat), the CA of peas increased to plus 0.53, peas acted as a dominant and provided a greater contribution to the overall productivity of this agrocenosis. In mixtures with barley (when harvesting for grain), the CA of cereals was plus 0.12–0.24, determining the high value

Табл. 2. Биологическая эффективность смешанных злаково-бобовых агроценозов в различных зонах возделывания

Table 2. Biological efficiency of mixed cereal and legume agrocenosis in different cultivation zones

Option	Cultivation area								
	I			II			III		
	LER			LER			LER		
	cereals	pea	mixture	cereals	pea	mixture	cereals	pea	mixture
Barley + pea	0,8	0,37	1,17	1,09	0,12	1,21	0,73	0,33	1,06
Oat + pea	0,72	0,3	1,02	0,93	0,11	1,04	1,02	0,43	1,45
Wheat + pea	0,52	0,51	1,03	1,2	0,1	1,3	0,89	0,3	1,09
Barley + pea + oat	0,64	0,52	1,16	0,89	0,1	0,99	0,89	0,32	1,21
Barley + pea + wheat	0,65	0,51	1,17	0,89	0,1	0,99	0,96	0,22	1,18
Oat + pea + wheat	0,65	0,42	1,07	0,98	0,1	1,08	0,81	0,47	1,28
Barley + pea + oat + wheat	0,65	0,46	1,11	0,93	0,1	1,03	1,02	0,38	1,4

of this component in the total productivity of the mixture.

In the steppe zone of Northern Kulunda, with low moisture reserves in the soil during the development of seedlings of legumes, unfavorable conditions were created for the development of plants, and their competitiveness decreased. Under these conditions, the CA value of the legume component dropped to minus 1.58, and its share in the agrocenosis decreased as much as possible (see Fig. 2).

Under these conditions, the cereal component showed the maximum aggressiveness, the CA increased to plus 1.58. During the growing season, the developed plants of the cereal component of the mixture exerted a strong suppressive effect on the legume component of the mixture. The coefficient of aggressiveness of the legume component in the steppe zone did not exceed –0.95.

The conditions of the forest-steppe zone of Eastern Siberia are characterized by a slight suppression of legumes by the cereal component (see Fig. 3).

In mixtures of barley and oats with peas in this zone, CA approaches zero, which indicates favorable conditions for the growth of crops in binary crops. The introduction of the second and third cereal components into the mixture reduces the CA of peas to minus 1.21, which indicates a higher competitiveness of cereals in a complex mixture, as evidenced by the high proportion of cereals in the mixture yield.

CONCLUSION

1. In the forest-steppe zone of Western Siberia, when cultivating for grain fodder, two-component mixtures with a seeding rate of 60–75% cereal (barley or oats) and 35–50% leguminous components (peas) have an advantage. The yield is 23–29 centners of grain / ha with a digestible protein content of 106–110 g / c. units and the indicator "ratio of land equivalents" 1.17 units.

2. In the conditions of the steppe zone of Western Siberia, two-component mixtures of barley and wheat with field pea are most effective (60% of the cereal and 50% of the legume component). The productivity of these cenoses was noted at the control level, the nutritional value was 6–10% higher. The indicator "ratio of land equivalents" for the zone - 1.21-1.3 units.

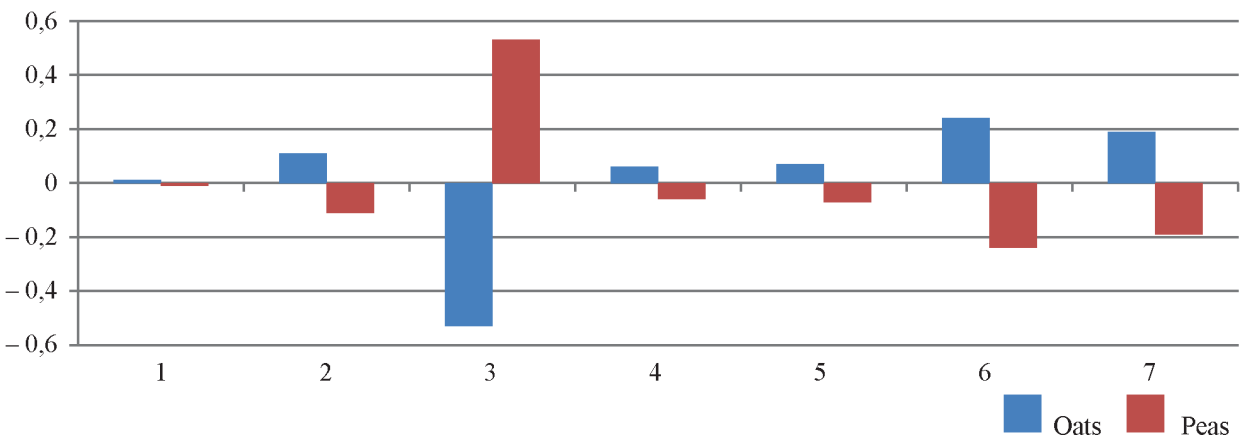

Рис. 1. Коэффициент агрессивности культур смешанных посевов в условиях лесостепной зоны Западной Сибири

Здесь и на рис. 2, 3 варианты посевов: 1. ячмень + горох, 2. овес + горох, 3. пшеница + горох, 4. ячмень + горох + овес, 5. ячмень + горох + пшеница, 6. овес + горох + пшеница, 7. ячмень + горох + овес + пшеница

Fig. 1. Coefficient of aggressiveness of mixed crops cultivated in the forest-steppe zone of Western Siberia

Here and in Fig. 2, 3 sowing options: 1. barley + peas, 2. oats + peas, 3. wheat + peas, 4. barley + peas + oats, 5. barley + peas + wheat, 6. oats + peas + wheat, 7. barley + peas + oats + wheat

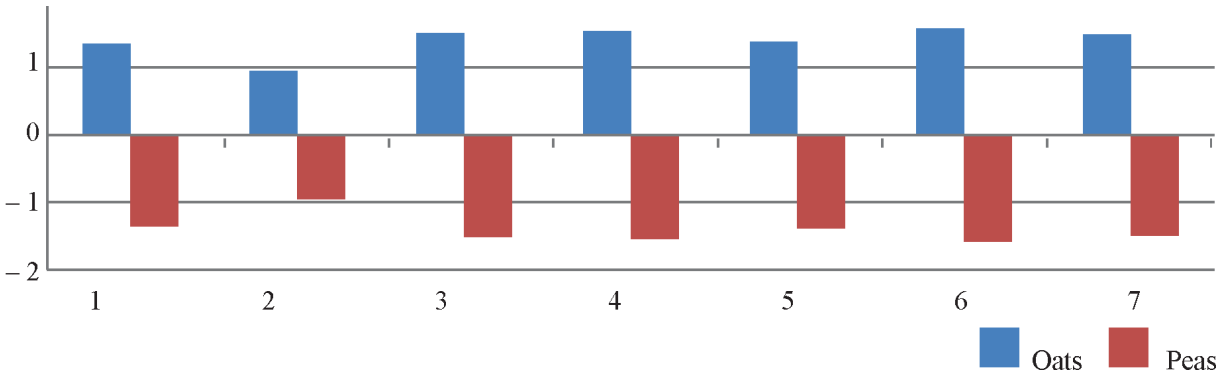

Рис. 2. Коэффициент агрессивности культур смешанных посевов в условиях степной зоны Северной Кулунды

Fig. 2. Coefficient of aggressiveness of mixed crops cultivated in the conditions of the Northern Kulunda steppe zone

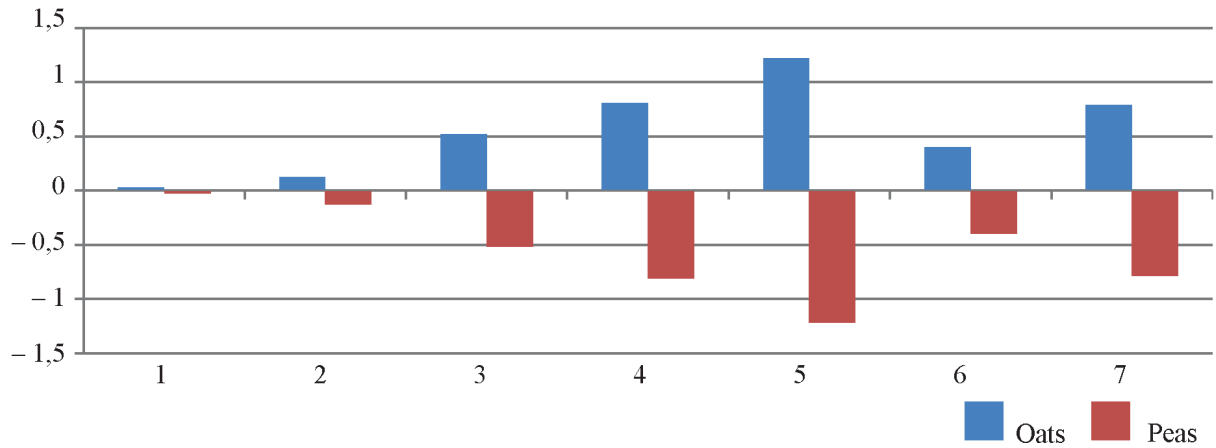

Рис. 3. Коэффициент агрессивности культур смешанных посевов в условиях лесостепной зоны Восточной Сибири

Fig. 3. Coefficient of aggressiveness of mixed crops cultivated in the forest-steppe zone of Eastern Siberia

3. In the forest-steppe zone of Eastern Siberia, the highest grain yield was provided by a mixture of oats with peas (4.85 c / ha) and oats 30% + peas 50% + barley 30% (42.9 c / ha) with the value of the "ratio of land equivalents" up to 1, 45 units.

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Дата поступления статьи 21.12.2020
Received by the editors 21.12.2020

https://doi.org/10.26898/0370-8799-2021-1-6
УДК: 631.52: 633.262
Тип статьи: оригинальная
Type of article: original

СКРИНИНГ КОЛЛЕКЦИОННЫХ ОБРАЗЦОВ КОСТРЕЦА БЕЗОСТОГО В ТАЕЖНОЙ ЗОНЕ ЗАПАДНОЙ СИБИРИ

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Представлены результаты изучения коллекционных образцов костреца безостого Федерального исследовательского центра Всероссийский институт генетических ресурсов растений им. Н.И. Вавилова (ВИР) для выявления доноров селекционно-ценных признаков. Исследования 2015–2018 гг. проведены в Томской области. Почвы опытных участков дерново-подзолистые, супесчаные по гранулометрическому составу, с содержанием гумуса в пахотном горизонте не более 2%. Учетная площадь делянки 0,5 м^2. Повторность двукратная. Закладка опытов, фенологические наблюдения, учет урожая и обработка данных проведены согласно методическим рекомендациям Всероссийского научно-исследовательского института кормов им. В.Р. Вильямса, ВИР и методике Государственного сортоиспытания. Годы исследования характеризовались неравномерным распределением тепла и влаги в течение вегетационного периода. Это позволило выявить наиболее адаптивные образцы для использования в селекции костреца безостого сенокосно-пастбищного направления в условиях таежной зоны. Выделен ценный исходный материал по высокорослости – сорта Хабаровский, Титан, Возвышенский, СибНИИСХоз 88, дикорастущие образцы Якутии (К-14215), Вологодской (К-14224), Омской (К-14228), Свердловской (К-14209) областей, местный образец Томской области (К-14226). Выявлены образцы, устойчивые к поражению грибными болезнями, – сорта Моршанский, Хабаровский, Эркээни, дикорастущие образцы Иркутской (К-14221, К-14227), Вологодской (К-14212, К-14224), Омской (К-14228) областей, местный образец Томской области (К-14226). Высокоурожайными по кормовой массе признаны дикорастущие формы Вологодской области (К-14212, К-14222) и местная популяция Томской области (К-14214); высокооблиственными – сорта Приморский 46, СибНИИСХоз 88, дикорастущие формы Коми (К-14208), Иркутской (К-14227), Вологодской (К-14212, К-14224) областей, местные образцы Томской области (К-14214, К-14226); с высокой семенной продуктивностью – сорта Дуэт, Приморский 46, Эркээни, дикорастущие формы Вологодской области (К-14212, К-14224), местный образец Томской области (К-14226). По комплексу основных хозяйственно важных признаков для посева в питомнике поликросса отобраны дикорастущие образцы Вологодской области (К-14212, К-14224), местные образцы Томской области (К-14214, К-14226).

Ключевые слова: кострец безостый, коллекционный питомник, урожайность, хозяйственно важные признаки, устойчивость

SCREENING OF AWNLESS BROMEGRASS COLLECTION SAMPLES IN THE TAIGA ZONE OF WESTERN SIBERIA

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The paper presents the results of the study of collection samples of awnless bromegrass from the Federal Research Center N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR) to identify donors of valuable breeding traits. The study was carried in 2015-2018 in Tomsk region. The soils of the experimental plots were sod-podzolic, sandy loam by granulometric composition, with a humus content in the arable layer of no more than 2%. The recorded area of the plot was 0.5 m^2. The trials were repeated two times. Procedures for trial establishment, phenological observations, harvest recording and data processing were performed in accordance with the methodological

recommendations of the All-Russian Williams Fodder Research Institute, VIR and the State Variety Testing Methodology. The years of the study were characterized by uneven distribution of heat and moisture during the growing season. This made it possible to identify the most adaptive samples for selective breeding of awnless bromegrass which can be used as a hay and pasture plant in the taiga zone. The following valuable source materials were selected for tall varieties: Khabarovsky, Titan, Vozvyshensky, SibNIISkhoz 88; samples of wild plants Yakutia (K-14215), Vologda (K-14224), Omsk (K-14228), Sverdlovsk (K-14209) regions, a local sample of Tomsk region (K-14226). The following samples resistant to fungal diseases were identified: Morshansky, Khabarovsky and Erkeeni varieties; samples of wild forms of Irkutsk (K-14221, K-14227), Vologda (K-14212, K-14224), Omsk (K-14228) regions, a local sample of Tomsk region (K-14226). The following high-yielding varieties in terms of fodder mass were recognized: wild forms of Vologda region (K-14212, K-14222) and a local population of Tomsk region (K-14214); highly leafy varieties: Primorsky 46, SibNIISKHoz 88, wild forms of Komi (K-14208), Irkutsk (K-14227), Vologda (K-14212, K-14224) regions, local samples of Tomsk region (K-14214, K-14226); varieties with high seed yield: Duet, Primorsky 46, Erkeeni, wild forms of Vologda region (K-14212, K-14224), a local sample of Tomsk region (K-14226). Based on the set of the main economically valuable traits for sowing in a polycross nursery, samples of wild plants from Vologda region (K-14212, K-14224), and local samples of Tomsk region (K-14214, K-14226) were selected.

Keywords: awnless bromegrass, collection nursery, yield, economically valuable traits, resistance

Для цитирования: *Уразова Л.Д., Литвинчук О.В., Сайнакова А.Б.* Скрининг коллекционных образцов костреца безостого в таежной зоне Западной Сибири // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 51–59. https://doi.org/10.26898/0370-8799-2021-1-6

For citation: Urazova L.D., Litvinchuk O.V., Saynakova A.B. Screening of awnless bromegrass collection samples in the taiga zone of Western Siberia. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1, pp. 51–59. https://doi.org/10.26898/0370-8799-2021-1-6

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

INTRODUCTION

Awnless bromegrass (Bromopsis inermis Leys.) is a perennial tall loosely-bunched rootstock grass. It is eaten by all species of animals and is used in the form of green mass, haylage, dehydrated fodder and is suitable for grazing; it is rated higher than that of many cereal grasses in terms of fodder merits (nutritional value, digestibility, and palatability) [1–3].

High yield of awnless bromegrass, its endurance in relation to lack of moisture and low temperatures, undemanding soil, ability to grow well after mowing and grazing, immunity against fungal diseases make it one of the most valuable fodder grains [4, 5].

Natural and climatic conditions of Siberia limit the species composition of cultivated forage crops and their productivity, and affect the quality of forage. The creation of varieties of fodder crops with high productivity and tolerance to the extreme conditions of Siberia is an urgent task of breeding perennial grasses [6–8].

Currently, the primary problem for all zones of cultivation of awnless bromegrass is the creation of productive varieties for fodder and seeds that have yield stability in space and time, resistant to unfavorable environmental factors, diseases, pests, combining high yield of green mass with good feed advantages [9-11].

The purpose of the research is to study and identify samples of awnless bromegrass with high productivity and resistance to diseases for use in the breeding process.

MATERIAL AND METHODS

Breeding studies were carried out in 2015–2018 in the fields of the Narym Department of Breeding and Seed Production of the Siberian Research Institute of Agriculture and Peat - a branch of the Siberian Federal Scientific Center

of Agrobiotechnology of the Russian Academy of Sciences (a branch of the SFSCA RAS) in Kolpashevo, Tomsk Region. The study area is characterized by extreme soil and climatic conditions[1,2] [12].

The research used collection samples of awnless bromegrass obtained from the Federal Research Center N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR). In the 2015 collection nursery 24 samples of domestic origin were studied for a complex of economically important traits and properties: breeding varieties (12), local varieties (2), wild forms from Western and Eastern Siberia, and the European part of Russia (10).

The technology of setting up the main breeding and seed-growing nurseries is generally accepted in the cultivation of perennial grasses in Western Siberia [13]. The area of the plots is 0.5 m^2 in duplicate with a row spacing of 50 cm. Crop care consisted of three or four weeding with simultaneous loosening of the row spacings. The study of the source material in the collection nurseries was carried out according to the methodological instructions of the All-Russian Williams Fodder Research Institute (FWRC FPA)[3]. The obtained data was processed according to B.A. Dospekhov[4] using the Snedecor[5] application package.

Phenological observations were carried out at all stages of the study which characterize the following features of development: growth rates, recovery ability, early maturity, and other signs. In the year of sowing the date of the emergence of the seedlings and the date of full germination, the date of the tillering start and full tillering, the state of the herbage before leaving for winter and the date of termination of the growing season were noted. In the second year of life and subsequent years tests of the grass stand the following data was noted: the beginning of the growing season; dates of the onset of development phases (beginning of earing, full earing, beginning of flowering, mass flowering, mass ripening of seeds); harvest dates (for hay - two mows or for seeds); the condition of the grass stand before leaving for the winter; the date of termination of the growing season. The general assessment took into account leafiness, bushiness, evenness, stand density and other indicators. Eye assessments were performed on a five-point scale (see footnote 3).

The density of the grass stand was noted in the first year of the study at full germination and before going into winter, in the second and subsequent years - during regrowth in spring, along mows and before going into winter. Winter hardiness was determined by counting overwintered and dead plants according to the method for determining the density of the herbage (see footnote 3). It was combined with the determination of the nature of damage, the causes of plant death. The measurement of plant height was carried out when used for green mass in the phase of mass earing, when counting for seeds - at the beginning of the seed ripening. Lodging resistance was determined at the beginning of flowering and seed ripening.

Record of performance of the herbage was carried out using double-cut mowing: the first - in the phase of complete ear formation, the second - as the mowing maturity was reached (the length of stand was above 50 cm). The foliage of the perennial grasses is an indicator of the quality of the green mass and hay and one of the important indicators of the nutritional value of the variety, since the leaves contain 2-3 times more crude protein than the stems [5]. To determine the foliage samples taken at the time of the yield registration to determine the hay yield were used.

Seed productivity of the selection material was determined by sowing samples in a pure form according to the optimal agricultural technology. The grass stand was mowed from the entire counting area with a sickle. Threshed

[1]Agroclimatic resources of the Tomsk region. L.: Gidrometeoizdat, 1975.147 p.
[2]Agroclimatic reference book on the Tomsk region. L.: Gidrometizdat, 1960.116 p.
[3]Guidelines for the selection of perennial cereal grasses. Moscow: VIK, 2012.51 p.
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seeds were brought to the standard for purity and germination.

When studying resistance to leaf infections, the counts were carried out during the period of maximum development of the disease according to the methodological instructions of the VIR (see footnote 6). To determine the degree of plant damage in the field, 20 leaves were collected from each plot, which were then compared with the tables of the Peterson Scale and other [14].

Determination of the content of protein and fiber in the dry mass was carried out in the Laboratory and Analytical Center of the Siberian Federal Scientific Center of Agrobiotechnology of the Russian Academy of Sciences - a branch of the SFNCA RAS in accordance with GOST 13496.4–93 and GOST R 52839–2007.

RESULTS AND DISCUSSION

Extreme weather conditions during the period of research made it possible to evaluate the breeding material for adaptability to stress factors of the environment. The samples tolerated well moderately cold winters 2015/16 - 2017/2018 with a high snow cover.

In the year of sowing of the collection nursery (2015), August and September were somewhat cooler (–0.5–2.6 ° C) and drier (–28.4; –24.8 mm) of mean annual values.

In 2016, the regrowth of awnless bromegrass was noted on April 18 (average air temperature 4.8 ° C, precipitation in the form of rain at the end of the third decade, deviation from the average long-term indicators minus 29 mm). The average monthly air temperature in May in 2016 was 7.8 ° C. Due to favorable weather conditions, the bromegrass samples grew well. The regrowth occurred in the spring of 2017 on April 20. The average air temperature during this period was 8.8 ° C, no precipitation was observed. The average monthly air temperature in May 2017 was recorded at 8.3 ° C, precipitation in a form of rain and snow was in the first decade, the beginning of the second and third decades (exceeding the norm by 39 mm). Dry and hot weather in the 1st decade of June 2017 (the air temperature reached 25 ° C in the absence of precipitation) accelerated the development of plants. Drought adversely affected the development of plants; in cereals, premature yellowing of the leaves of the lower layer was observed. After rains in the 2nd and 3rd decades of June, the condition of the plants improved slightly, but damage from drought significantly affected the seed yield.

Due to cold protracted spring of 2018, regrowth began in spring on May 8, 18 days later than in 2017.The average air temperature during this period was 12.0 ° C. In May, the average monthly air temperature was 3.7 ° C, precipitation in a form of rain and snow in the first decade, the beginning of the second and third decades (deviation from the norm plus 26 mm). Despite the unfavorable weather conditions in the spring period of 2018, perennial grasses grew well. Dry and hot weather in the 1st decade of June 2018 (air temperature reached 25 ° C) accelerated the development of grasses. Warm and dry weather in July - August promoted accelerated seed ripening.

Plant density of most of the studied issues for 2015–2018. was 4–5 points. Low density (1–2 points) was noted in SGP-7 from the Krasnoyarsk Territory and a wild specimen of the Irkutsk Region (K-14221). These estimates coincide with the state of the herbage of the samples before going into winter.

In terms of development rates, the studied varieties and wild populations of awnless bromegrass belong to mid-season species. In 2016, full heading was noted on June 14, mass flowering on June 29, and seed ripening on July 25. In 2017, full earing was recorded on June 19, mass flowering on June 28, and mass seed ripening on August 4. In 2018, full earing was noted on June 27, mass flowering - on July 6, mass ripening of seeds - on August 16. The flowering duration varied from 4 to 7 days. The termination of the growing season in 2016 fell on October 12, in 2017 - on October 22, in 2018 - on October 29. The duration of the growing season in 2016 was 99 days, in 2017 - 106, in 2018 - 101 days.

Winter hardiness of perennial grasses is determined by living conditions and agrotechnical methods of cultivation [15]. Due to the high

snow cover in 2015/16 - 2017/18, bromegrass samples overwintered well, winter hardiness was 100%. Plants left in the winter in a developed state, mowing and harvesting of crop residues was carried out a month before the onset of constant frosts, so no fallout on the crops was observed.

On average for 2016–2018 the height of plants varied in the phase of mass earing from 108 to 125 cm, during the flowering period - from 131 to 150 cm. According to the experiments, the cultivars Khabarovskiy, Titan, Vozvyshenskiy, SibNIISHoz 88, wild specimens of Yakutia (K-14215), Vologda (K-14224), Omsk (K-14228), Sverdlovsk (K-14209) regions, a local sample of the Tomsk region (K-14226) (see Table 1) belong to tall grass. At the same time, the bromegrass samples were characterized by high lodging resistance (4–5 points).

Fodder grasses are affected by a large number of fungal diseases. Leaf diseases are the most widespread; they have a noticeable effect on the quality and quantity of forage [12, 16]. In the conditions of the Tomsk region, awnless bromegrass is most often affected by helminthosporium (Helminthtosporium bromi Died.) and septoria (Septoria sp.). According to the research data, during seed ripening, leaves are affected by helminthosporiosis on average for 2016–2018. amounted to 19.2–59.3%, septoria - 0.5–11.3% (for the standard, respectively, 40.9 and 4.5%) (see Table 2). Varieties Morshanskiy, Khabarovskiy, Erkeeni, wild specimens of Irkutsk (K-14221, K-14227), Vologda (K-14212, K-14224), Omsk (K-14228) regions, local specimen of Tomsk region (K-14226) showed high resistance to these diseases. The infection with helminthosporiosis was 19.2–36.7%, with septoria - 0.5–1.8%.

In the case of haymaking use the productivity of the awnless bromegrass was recorded in the case of two-mowing use. The first cut - in the full ear formation phase on June 14 (2016), June 20 (2017), July 2 (2018). The second cut - June 26 (2016), August 2 (2017), August 17 (2018). On average for 2016–2018 the yield of the green mass of the studied samples was 19.7–43.3 t / ha, air-dry 6.1–13.5 t / ha. According to these characteristics, the wild-growing forms of the Vologda Oblast (K-14212, K-14222) and the local population of the Tomsk Oblast (K-14214) were distinguished. The excess over the standard variety Langepas was 10.3–11.0% in terms of the green mass yield, 5.8–12.5% of dry matter.

The leafiness of the studied numbers on average for three years changed in the first cut from 53.2% (wild specimen, Omsk region) to 66.3% (wild specimen, Komi). Varieties Primorsky 46, SibNIISKhoz 88, wild forms of Komi (K-

Табл. 1. Высота растений образцов костреца безостого в коллекционном питомнике посева 2015 г., см

Table 1. Plant height samples of awnless bromegrass in the collection nursery sown in 2015, cm

Variety, origin	2016	2017	2018	Average	± to the standard
Langepas, standard, Tyumen region	123	132	158	138	0
Titan, Omsk region	140	139	172	150	+12
Vozvyshensky, Kemerovo region	136	135	175	149	+11
SibNIISkhoz 88, Omsk region	129	153	159	147	+9
Khabarovsky, Khabarovsk region	131	144	162	146	+8
K-14215, wild form, Yakutia	129	135	170	145	+7
K-14224, wild form, Vologda region	124	151	161	145	+7
K-14226, local form, Tomsk region	123	140	168	144	+6
K-14228, wild form, Omsk region	130	129	174	144	+6
K-14209, wild form, Sverdlovsk region	128	136	166	143	+5
LSD_{05}	8,0	7,0	7,2		

Табл. 2. Оценка поражения болезнями коллекционных образцов костреца безостого посева 2015 г. (средние данные за 2016–2018 гг.), %

Table 2. Assessment of disease damage to collection samples of awnless bromegrass sown in 2015 (average data for 2016-2018), %

Variety, origin	Helminthosporiosis	Rust	Mildew	Septoria blight
Langepas, standard, Tyumen region	40,9	0	0	4,5
K-14221, wild form, Irkutsk region	19,2	0	0	4,8
Khabarovsky, Khabarovsk region	27,7	0	0	6,8
K-14212, wild form, Vologda region	32,6	1,0	0	11,3
Vozvyshensky, Kemerovo region	35,9	0	0	4,5
Morshansky 707, Tula region	36,7	0	0	0,5
SibNIISkhoz 88, Omsk region	36,9	0	0	5,3
K-14228, wild form, Omsk region	51,2	0	0	0,7
Erkeeni, Yakutia	59,3	0	0	1,0
K-14224, wild form, Vologda region	49,9	0	0	1,0
K-14227, wild form, Irkutsk region	45,8	0	0	1,0
Duet, Arkhangelsk region	45,3	0	0	1,6
K-14226, local form, Tomsk region	48,1	0	0	1,8
Pomor, Arkhangelsk region	49,2	0	0	2,4
K-14222, wild form, Vologda region	45,4	0	0	2,4
K-14216, wild form, Yakutia	53,3	0	0	2,8
K-14215, wild form, Yakutia	52,8	0	0	2,9
K-14209, wild form, Sverdlovsk region	41,2	7,0	0	3,0
Antei, Irkutsk region	45,0	0	0	4,0

14208), Irkutsk (K-14227), Vologda (K-14212, K-14224) regions, local samples of the Tomsk region (K-14214, K-14226).

The nutritional value of a culture can be judged by its protein and fiber content. The average protein content in the studied samples was 9.6%, fiber - 32.9%. According to these indicators, the Duet variety from the Arkhangelsk region (11.0% protein, 30.95% fiber) surpassed the standard Langepas variety (10.8% protein, 33.49% fiber). Wild samples from the Vologda Oblast K-14212 (30.4%) and K-14222 (30.69%) were also characterized by a low fiber content.

Under the research conditions, collection samples of awnless bromegrass for seeds were harvested in 2016 on July 26, 2017 - on August 4, and in 2018 - on August 16. On average, over three years, the seed productivity of the studied numbers was 0.16-0.59 t / ha. In terms of seed yield, the standard varieties Duet, Primorskiy 46, Erkeeni, wild forms of the Vologda region (K-14212, K-14224), and a local sample of the Tomsk region (K-14226) (see Table 3) significantly exceeded the standard.

According to the complex of the main economically important characters for sowing in the polycross nursery, wild-growing samples of the Vologda region (K-14212, K-14224), local samples of the Tomsk region (K-14214, K-14226) were selected.

Табл. 3. Характеристика лучших образцов костреца безостого в коллекционном питомнике посева 2015 г. при двуукосном использовании (средние данные за 2016–2018 гг.)

Table 3. Characteristics of the best samples of awnless bromegrass sown in the collection nursery in 2015 with double cutting (average data for 2016–2018)

Variety, origin	Yield									Foliage, cm
	green mass			dry matter			seeds			
	t/ha	% to the standard	± to the standard	t/ha	% to the standard	± to the standard	t/ha	% to the standard	± to the standard	
Langepas, standard, Tyumen region	39,0	100,0	0	12,0	100,0	0	0,41	100,0	0	61,1
K-14212, wild form, Vologda region	43,3	111,0	+4,3	13,5	112,5	+1,5	0,50	122,0	+0,09	61,4
K-14214, local form, Tomsk region	43,0	110,3	+4,0	12,7	105,8	+0,7	0,29	70,7	-0,12	65,5
K-14222, wild form, Vologda region	39,0	100,0	0	10,9	90,8	–1,1	0,32	78,0	–0,09	58,2
K-14224, wild form, Vologda region	39,0	100,0	0	11,2	93,3	–0,8	0,59	143,9	+0,18	62,2
Duet, Arkhangelsk region	38,0	97,4	–1,0	12,0	100,0	0	0,57	139,0	+0,16	58,5
Primorsky 46, Primorsky Krai	27,3	70,0	–11,7	7,8	65,0	–4,2	0,46	112,2	+0,05	63,2
Erkeeni, Yakutia	33,7	86,4	–5,3	10,0	83,3	–2,0	0,43	104,9	+0,02	58,7
K-14226, local form, Tomsk region	37,3	95,6	–1,7	11,3	94,2	–0,7	0,42	102,4	+0,01	63,0
LSD_{05}			3,8			0,5			0,07	

CONCLUSION

For selection of awnless hay-pasture bromegrass in the taiga zone of the Tomsk region, the following samples were selected:

– tall - varieties Khabarovsk, Titan, Vozvyshensky, SibNIISHoz 88, wild samples of Yakutia (K-14215), Vologda (K-14224), Omsk (K-14228), Sverdlovsk (K-14209) regions, local sample of Tomsk region (K- 14226);

– resistant to fungal diseases - varieties Morshanskiy, Khabarovskiy, Erkeeni, wild specimens of Irkutsk (K-14221, K-14227), Vologda (K-14212, K-14224), Omsk (K-14228) regions, local sample of Tomsk region (K-14226);

– characterized by a high yield of herbage, dry matter - wild forms of the Vologda region (K-14212, K-14222) and the local population of the Tomsk region (K-14214);

– highly leafy - varieties Primorskiy 46, SibNIISHoz 88, wild forms of Komi (K-14208), Irkutsk (K-14227), Vologda (K-14212, K-14224) regions, local samples of Tomsk region (K-14214, K-14226);

– with high seed productivity - varieties Duet, Primorsky 46, Erkeeni, wild forms of the Vologda region (K-14212, 14224), a local sample of the Tomsk region (K-14226).

According to the complex of the main economically important characters for sowing in the polycross nursery, wild-growing samples of the Vologda region (K-14212, K-14224), local samples of the Tomsk region (K-14214, K-14226) were selected.

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Дата поступления статьи 30.11.2020
Received by the editors 30.11.2020

https://doi.org/10.26898/0370-8799-2021-1-7
УДК: 633.13:631.52
Тип статьи: оригинальная
Type of article: original

УРОЖАЙНОСТЬ И КОРМОВЫЕ КАЧЕСТВА ТРИТИКАЛЕ В СМЕШАННЫХ ПОСЕВАХ С ВЫСОКОБЕЛКОВЫМИ КУЛЬТУРАМИ

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Представлены результаты полевых и лабораторных исследований по возделыванию тритикале в смешанных посевах с высокобелковыми культурами. Исследования выполнены в 2015–2017 гг. на лугово-черноземной мучнисто-карбонатной почве, по гранулометрическому составу – легкий суглинок, в лесостепной зоне Забайкалья. Дана оценка тритикале в одновидовых и смешанных посевах по адаптивности к условиям выращивания, урожайности, показаны хозяйственно ценные признаки данных посевов. Установлена возможность повышения урожайности и кормовых качеств агроценозов путем использования тритикале в смешанных посевах с высокобелковыми культурами. В среднем за годы исследований по урожайности и кормовым качествам смешанные посевы превосходили одновидовые агроценозы тритикале по зеленой массе в 1,6–1,9 раза, переваримому протеину в 2,6–3,7 раза. В смешанных посевах наилучшие результаты обеспечили тритикале с кормовыми бобами, урожайность зеленой массы составила 40,5 т/га, сухого вещества – 5,70 т/га, содержание кормовых единиц – 4,67 т/га, переваримого протеина – 785 кг/га, обменной энергии – 57,6 ГДж/га. Обеспеченность одной кормовой единицы переваримым протеином – 168 г. Смешанные посевы тритикале с кормовыми бобами увеличили продуктивность в сравнении с одновидовыми посевами по урожайности зеленой массы в 1,3–1,9 раза, сухого вещества в 1,4–1,9, по сбору кормовых единиц в 1,4–2,0, валовой энергии в 1,5–2,0 раза. Все культуры устойчивы по засухе и полеганию. Отмечено отсутствие пораженности тритикале вредителями и болезнями.

Ключевые слова: тритикале, редька масличная, рапс яровой, бобы, смешанные посевы, урожайность, качество, адаптивность

YIELD AND FEED QUALITIES OF TRITICALE MIXED WITH HIGH-PROTEIN CROPS

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The results of field and laboratory studies on the cultivation of triticale mixed with high-protein crops are presented. The study was carried out during the period of 2015-2017 on meadow chernozem mealy-carbonate soil, light loam by granulometric composition, in the forest-steppe zone of Trans-Baikal Territory. The assessment of triticale in single-species and mixed crops for adaptability to growing conditions and yield is given. Economically valuable traits of these crops are shown. The possibility of increasing the yield and feed qualities of agrocenoses by sowing triticale with high-protein crops was established. On average, over the years of research, mixed crops outperformed single-species triticale agrocenoses in terms of yield and feed quality, green mass by 1.6-1.9 times, digestible protein by 2.6-3.7 times. In mixed crops, triticale with fodder beans provided the best results, the yield of green mass was 40.5 t/ha, dry matter – 5.70 t/ha, feed units – 4.67 t/ha, digestible protein – 785 kg/ha, exchange energy – 57.6 GJ/ha, availability of digestible protein per one feed unit – 168 g. Triticale crops mixed with fodder beans increased productivity compared with single-species crops in terms of green mass yield by 1.3-1.9 times, dry matter by 1.4-1.9 times, feed units by 1.4-2.0 times, gross energy by 1.5-2.0 times. All crops are resistant to drought and lodging. The absence of pest and disease infestation in triticale was noted.

Keywords: triticale, oilseed radish, spring rapeseed, beans, mixed crops, yield, quality, adaptability

Для цитирования: *Андреева О.Т., Пилипенко Н.Г., Сидорова Л.П., Харченко Н.Ю.* Урожайность и кормовые качества тритикале в смешанных посевах с высокобелковыми культурами // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 60–66. https://doi.org/10.26898/0370-8799-2021-1-7

For citation: Andreeva O.T., Pilipenko N.G., Sidorova L.P., Kharchenko N.Yu. Yield and feed qualities of triticale mixed with high-protein crops. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1, pp. 60–66. https://doi.org/10.26898/0370-8799-2021-1-7

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

INTRODUCTION

The creation of a solid fodder base for full-value feeding of farm animals and an increase in their productivity requires an increase in the production of all types of fodder and an improvement in their quality[1,2] [1–13].

A significant role in the sustainable production of high-quality fodder is assigned to the creation of highly productive agrocenoses from bluegrass crops and their mixtures, adaptive to growing conditions. A properly selected set of crops in agrocenoses provides optimal density and density of the stand, formation of layering, the most even use of plant life factors (moisture, light, nutrients), allows to form high yields of vegetative mass and increase the nutritional value of feed.

Of the bluegrass crops cultivated in Transbaikalia, triticale, a new culture for the region, is of great importance. It has increased resistance to drought and shedding of grain, is an alloploid that combines the high productivity of wheat and the adaptive resistance of rye to adverse conditions and diseases. 100 kg of green mass contains 22–25 k. Units, 2.3–2.7 kg of digestible protein. Grain and bran are used for fodder as a high-protein and high-lyzin feed for livestock and poultry. Fodder varieties of triticale yield up to 500-600 centners of green mass / ha. Triticale is a promising crop the use of which can increase the production of feed and grain in Transbaikalia [8–9].

Mixed crops of cultivated plants have been widespread since ancient times; they make it possible to effectively use agroclimatic resources due to the formation of highly productive agrocenoses [14]. It has been proven that mixtures of triticale with annual high-protein crops provide the richest in protein and better eaten by animals [15, 16].

The listed nutritional qualities in combination with high yield in mixed crops determine the great importance of triticale for strengthening the fodder base in animal husbandry of the Trans-Baikal Territory [2, 8–10, 17].

The aim of the research is to evaluate the effectiveness of using triticale in mixed crops with high-protein crops to increase the productivity and nutritional value of fodder agrocenoses.

MATERIAL AND METHODS

The studies were carried out in 2015–2017. on the fields of the Research Institute of Veterinary Medicine of Eastern Siberia - a branch of the Siberian Federal Scientific Center of Agrobiotechnology of the Russian Academy of Sciences, located in the Ingodinsko-Chita forest-steppe of the Trans-Baikal Territory.

The climate of the zone is sharply continental with little snow, cold winters, hot summers and a lack of precipitation. The frost-free period lasts 90–110 days. The sum of positive temperatures above 10 ° C is 1500–1800 °. The annual amount of precipitation is 330-380 mm, their main amount (85-90%) falls in the warm period, the maximum - in July - August, the minimum - in May – June.

During the years of research, the weather conditions during the growing season were different. Growing seasons (April - September) 2015, 2016 are marked as typical of the forest-

[1]Pirjo A., Pentti A., Pekka H. et al. Dairy cow feeding. Vantaa: Union of centers "ProAgria", 2009. 127 p.

[2]Vasina N.V., Bordyugovskaya A.V. Fodder productivity of the culture of mixtures of early sowing at different levels of mineral nutrition // Advances in science to the agro-industrial complex. Samara, 2014. pp. 16-19.

steppe zone of Transbaikalia showing 270.2; 194.7 mm of precipitation with an average long-term norm of 276 mm. The average monthly air temperature for these periods was 11.2; 11.4 °C with an average long-term rate of 11.2 °C. Hydrothermal coefficients (HC) of the growing seasons were (0.9; 0.7, respectively). The distribution of precipitation over the months of the growing seasons was uneven; in some periods, high air and soil temperatures were recorded. The growing season of 2017 was characterized by increased moisture supply. Total precipitation was 317.6 mm from April to September. The deviation from the average long-term indicator (276.0 mm) was 41.6 mm, or 15.1%. The average daily air temperature during the growing season did not exceed 15.4 °C.

In general, the climatic conditions created during the years of research allowed the plants of the studied crops to realize their maximum productive potential and form a sufficiently high yield of fodder mass, which indicates their adaptability to the extreme conditions of the Trans-Baikal Territory.

The soil of the experimental site is meadow chernozem mealy-carbonate, the granulometric composition is light loam. The reaction of the soil solution of the arable horizon is weakly acidic, the subsoil one is neutral. The amount of organic matter in the 0–20 cm layer is 3.67%, total nitrogen 0.3%. The availability of mobile phosphorus is low, exchangeable potassium is average.

The area of the sowing plot is 100 m^2, accounting for forage purposes is 25 m^2, the replication is fourfold, the location of the plots is consistent.

The agrotechnology for the cultivation of fodder crops is common in the zone [18]. Mineral fertilizers under triticale and fodder beans were introduced under pre-sowing cultivation at the rate of $N_{60}P_{60}R_{60}$, under spring rapeseed and oil radish they were introduced fractionally - under pre-sowing cultivation $N_{60}P_{41}K_{60}$ and P_{19} during sowing. Sowing of fodder crops was carried out at the optimal recommended time (second half of May) in an ordinary way using a CH-16 seeder with a seeding rate: triticale 4.0-4.5 million germinating seeds / ha, spring rapeseed 3.0, oil radish 3.0, fodder beans 1.2 million germinating seeds / ha. The composition and seeding rate of crops in two-component mixtures: triticale - 70%, spring rapeseed, oil radish, forage beans - 50%. Seeding depth: triticale 5–8 cm, spring rape 2–4, oil radish 3–4, forage beans 6–8 cm. Sowing of fodder crops mixtures was carried out in one pass of the seeder. The recording of the green mass yield was determined by a continuous method from an area of 25 m^2.

The objects of research are zoned varieties of the studied crops: triticale Ukro, spring rapeseed Spar, oil radish Tambovchanka, Siberian fodder beans.

The experimental work was carried out in accordance with the guidelines for conducting field experiments with fodder crops, accompanied by laboratory field observations [3-6].

The crop data was statistically processed by analysis of variance according to R.A. Fischer as presented by B.A. Dospekhov (see footnote 4). The analysis of plant samples was carried out in the agrochemical laboratory of the Institute according to generally accepted methods.

RESULTS AND DISCUSSION

The research results showed that the studied crops reacted differently to the soil and climatic conditions of growth. The period from sowing to germination for the studied crops was 10–15 days. The period of germination - budding in cabbage crops is 26–37 days, for forage beans - 36 days. The period of shoots - tillering of triticale - 12 days, shoots - heading - 42; seedlings - flowering of triticale - 58, spring rapessed and oilseed radish - 37–46, fodder beans - 52 days (see Table 1).

[3]Methodology for conducting field experiments with fodder crops. M., 1983.197 p.

[4]Dospekhov B.A. Field experiment technique. M., 1985.351 p.

[5]Experimentation in field cultivation. Moscow: Rosselkhozizdat, 1982.190 p.

[6]Methodology for state variety testing of agricultural crops. Moscow: Kolos, 1985.267 p.

According to the assessment of the reaction to drought, provided for by the method, the main criterion of which is yellowing of the basal leaves and loss of turgor, all studied crops are drought-resistant, at the same time respond well to moisture supply.

The observations of the linear growth of the studied crops showed that the most intensively developed crops during the growing season were triticale and spring rapeseed plants, in which the height to mowing maturity was 120 cm. Samples of oilseed radish and fodder beans had a height of 114– 116 cm. Insignificant mutual suppression and decrease in plant height by 2–18 cm in comparison with single-species crops was observed in multi-species crops. (see Table 2).

The determination of plant foliage in triticale showed that plant foliage in mixed crops was 2–4% inferior to single species. The largest leafiness - 53–57% in single-species and mixed crops was obtained for triticale and fodder beans, the smallest - 43–46% for spring rapeseed and oil radish.

In the course of research, it was found that the productivity of triticale, spring rapeseed, oil radish and fodder beans in single-species and mixed crops is different (see Table 3).

The studies have shown various patterns of growth, development, formation of yield and nutritional value of the studied crops in agrocenoses depending on the type of crops and the method of sowing.

Favorable conditions of heat and moisture supply and nutritional regime during the years of research had a positive effect on the passage of physiological processes in plants and contributed to the formation of elements of the structure of the yield and yield according to the variants of the experiment (see Tables 2, 3). The maximum yield of green and dry mass was obtained in the variant of triticale + fodder beans (40.5 and 5.7 t / ha). This variant exceeded the mixture of triticale with spring rapeseed and oilseed radish by 5.4–7.2 and 1.45–1.50 t / ha. The lowest yield of green mass (20.8 t / ha) and dry matter (3.0 t / ha) was obtained when sowing triticale in single-species sowing. One-species sowing was inferior in terms of these indicators to mixed sowings of triticale with high-protein crops, respectively, by 12.5–19.7 and 1.20–2.70 t /ha. So, in the mixed sowing of triticale + fodder beans, a higher yield of fodder units of 4.67 t / ha, of digestible protein - 785 kg / ha, gross energy -

Табл. 1. Продолжительность межфазных периодов, дни (среднее за 2015–2017 гг.)

Table 1. Duration of interphase periods, days (on average for 2015-2017)

Option	Period				
	sowing – germination	germination – budding	germination – tillering	germination – heading	germination – flowering
Triticale	15	–	12	42	58
Spring rapeseed	11	37	–	–	46
Oilseed radish	10	36	–	–	37
Fodder beans	15	36	–	–	52
Triticale + spring rapeseed	15 11	– 37	12 –	42 –	58 46
Triticale + oilseed radish	15 10	– 26	12 –	42 –	58 37
Triticale + fodder beans	15 15	– 36	12 –	42 –	58 52

Табл. 2. Высота и облиственность растений в агроценозах (в среднем за 2015–2017 гг.)

Table 2. Height and leaf formation of plants in agrocenoses (on average for 2015–2017)

Culture	Stem height, cm	Leaf formation, %
Triticale	120	57
Spring rapeseed	120	45
Oilseed radish	116	46
Fodder beans	114	56
Triticale + spring rapeseed	107 102	53 43
Triticale + oilseed radish	110 114	54 44
Triticale + fodder beans	115 110	53 54

Табл. 3. Продуктивность и питательная ценность тритикале в смешанных посевах с высокобелковыми культурами (среднее за 2015–2017 гг.)

Table 3. Productivity and nutritional value of triticale mixed with high-protein crops (average for 2015–2017)

Culture	Green mass, t/ha	Dry matter, t/ha	Fodder units, t/ha	Digestible protein, kg/ha	The amount of digestible protein for 1 f. u., g	Gross energy, GJ/ha
Triticale	20,8	3,00	2,30	212	92	29,1
Spring rapeseed	28,9	3,60	3,30	627	190	38,2
Oilseed radish	30,2	3,62	2,82	558	198	35,5
Fodder beans	30,0	4,05	3,12	702	225	39,7
Triticale + spring rapeseed	33,3	4,20	3,60	572	159	43,3
Triticale + oilseed radish	35,1	4,25	3,36	541	161	42,1
Triticale + fodder beans	40,5	5,70	4,67	785	168	57,6
LSD_{05}	2,8	0,15	0,13			

Note. The ratio of components in mixed crops was as follows: triticale - 25% + spring rapeseed - 75%; triticale - 25% + oilseed radish - 75%; triticale - 40% + fodder beans - 60%.

57.6 GJ / ha was obtained with the provision of one fodder unit with digestible protein of 168 g.

CONCLUSIONS

1. In the forest-steppe zone of the Trans-Baikal Territory, the maximum fodder productivity is formed by agrocenoses of mixed crops of triticale with fodder beans. As a result of the research, the following indicators were achieved: the yield of green mass 40.5 t / ha, the collection of feed units 4.67 t / ha, the amount of digestible protein 785 kg / ha, gross energy content 57.6 GJ / ha with provision of digestible protein 168 g / ha. to. units.

2. Mixed crops of triticale with fodder beans increased productivity in comparison with single-species crops of triticale in terms of collection of feed units by 2.0 times, digestible protein by 3.7 times, and gross energy by 2.0 times.

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Дата поступления статьи 30.12.2020
Received by the editors 30.12.2020

https://doi.org/10.26898/0370-8799-2021-1-8
УДК: 632.763.79:632.951:635.21
Тип статьи: оригинальная
Type of article: original

ЗАЩИТА КАРТОФЕЛЯ ОТ КАРТОФЕЛЬНОЙ КОРОВКИ *HENOSEPILACHNA VIGINTIOCTOMACULATA* MOTSCH. (COLEOPTERA, COCCINELLIDAE)

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Представлены результаты применения экологически безопасных методов борьбы с вредителями картофеля. Проведены сравнительные полевые испытания инсектоакарицидов и микробиологических препаратов на посадках картофеля районированного сорта Янтарь в Приморском крае в 2018, 2019 гг. Объект исследований – личинки и жуки картофельной коровки *Henosepilachna vigintioctomaculata*. Посадку клубней проводили в оптимальные для региона сроки – конец апреля – начало мая. В исследованиях использованы препараты Фитоверм на основе аверсектина С (50 г/л), Акарин на основе авертина N (2 г/л), Бацикол на основе штамма *Bacillus thuringiensis* var. *darmstadiensis* (BtH_{10}), Битоксибациллин на основе штамма *Bacillus thuringiensis* var. *thuringiensis* (BtH_1). Препараты изучены в отдельных опытах и в совместных с инсектицидом Корадо. Растения картофеля опрыскивали препаратами однократно. Учеты численности вредителя проводили до обработки и после обработки на 5, 10, 15-е сутки на 10 растениях картофеля в трех повторностях в соответствии с утвержденными методиками. Высокую эффективность 90,5–94,0% показал биоинсектицид Фитоверм в норме применения 0,16 л/га. Однократное применение биоинсектицидов на протяжении 15 сут сдерживало интенсивность развития вредителя ниже порогового уровня. Совместное использование биоинсектицидов и инсектицида против картофельной коровки обеспечивало снижение численности фитофага на 90,8–99,8% по сравнению с контрольным вариантом (без применения средств защиты растений). Включение препаратов биологического происхождения Фитоверм, Акарин, Бацикол, Битоксибациллин в технологии возделывания картофеля позволит ограничить численность картофельной коровки и решить проблему экологизации защиты растений на юге Дальнего Востока.

Ключевые слова: картофель, вредитель, картофельная коровка, инсектоакарицид, биоинсектицид, инсектицид, биологическая эффективность, урожайность

POTATO PROTECTOIN AGAINST THE POTATO LADYBIRD *HENOSEPILACHNA VIGINTIOCTOMACULATA* MOTSCH. (COLEOPTERA, COCCINELLIDAE)

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The results of the application of environmentally friendly methods of potato pest control are presented. Comparative field trials of insectoacaricides and microbiological preparations were carried out on potatoes of the recognized variety Yantar in the Primorsky Territory in 2018 and 2019. The object of research was the larvae and beetles of the potato ladybird *Henosepilachna vigintioctomaculata*. The tubers were planted at the optimal time for the region, late April – early May. The study used Fitoverm preparations based on aversectin C (50 g/l), Akarin based

on avertin N (2 g/l), Batsikol based on the strain of *Bacillus thuringiensis* var. *darmstadiensis* (BtH_{10}), Bitoxybacillin based on the strain of *Bacillus thuringiensis* var. *thuringiensis* (BtH_1). The preparations were studied independently and with Corado insecticide. Potato plants were sprayed with the preparations once. Pest counts were carried out before treatment and after treatment on the 5th, 10th, 15th day on 10 potato plants in three replications in accordance with the approved methods. Bioinsecticide Fitoverm showed a high efficiency of 90.5–94.0% at the application rate of 0.16 l/ha. A single application of bioinsecticides for 15 days restrained the intensity of the pest development below the threshold level. The combined use of bioinsecticides and an insecticide against the potato ladybird provided a decrease in the phytophage population by 90.8–99.8% compared to the control variant (without the use of plant protection products). The inclusion of preparations of biological origin Fitoverm, Akarin, Batsikol, Bitoxybacillin in potato cultivation technology will allow to limit the number of potato ladybird and solve the problem of plant protection in an environmentally-friendly way in the south of the Far East.

Keywords: potatoes, pest, potato ladybird, insectoacaricide, bioinsecticide, insecticide, biological efficiency

Для цитирования: *Коваленко Т.К., Пронюшкина А.С.* Защита картофеля от картофельной коровки *Henosepilachna vigintioctomaculata* Motsch. (Coleoptera, Coccinellidae) // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 67–73. https://doi.org/10.26898/0370-8799-2021-1-8

For citation: Kovalenko T.K., Pronyushkina A.S. Potato protection against potato ladybird *Henosepilachna vigintioctomaculata* Motsch. (Coleoptera, Coccinellidae). *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1, pp. 67–73. https://doi.org/10.26898/0370-8799-2021-1-8

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

INTRODUCTION

The 28-spotted potato ladybird Henosepilachna vigintioctomaculata Motsch., 1853 (Coleoptera, Coccinellidae) causes significant damage to potato plantings in the south of the Far East. When protecting crops, insecticides belonging to different chemical classes are used. The systematic use of chemicals leads to the formation of resistant populations of the pest, which is a factor in the deterioration of the ecological situation. One of the methods of reducing the negative impact of pesticides on the environment is the treatment of planting material with combined preparations with insecticidal and fungicidal properties [1, 2]. The studies carried out indicate that the pre-planting treatment of tubers with Prestige, SC is promising for the control of potato pests in the Primorsky Territory [3].

Currently, manufacturers prefer environmentally friendly biological plant protection systems. The use of biological products contributes to the conservation of environmental biodiversity [4, 5]. In the conditions of Primorsky Territory, work was carried out to study and evaluate the effectiveness of microbiological preparations against the potato ladybird but the range of biological preparations has been significantly updated recently. Insectoacaricidal preparations based on avermectins synthesized by the actinomycete Streptomices avermitilis are used to protect crops from harmful organisms [6–9].

Of greatest interest are preparations based on the entomopathogenic bacteria Bacillus thuringiensis Berliner, which have a selective effect and are safe for humans, warm-blooded animals and the environment. Due to the presence of crystals of endotoxin, exotoxin, phospholipase C, and spores, B. thuringiensis exhibits entomotoxic, entomopathogenic, and metatoxic effects [10, 11]. The All-Russian Research Institute of Agricultural Microbiology (ARRIAM, St. Petersburg - Pushkin) has developed entomopathogenic biological products Batsikol and Bitoxibacillin. Batsikol is based on the Bacillus thuringiensis var. darmstadiensis (BtH_{10}), which has a specific effect on coleoptera. The basis of Bitoxibacillin is the bacterium Bacillus thuringiensis var. thuringiensis (BtH_1). The

preparations are designed to combat a wide range of mass phytophagous pests of agricultural crops [12–14]. The study of new bioinsecticides is important for improving the range of biological agents for controlling the potato ladybird in the Primorsky Territory.

The purpose of the research is to evaluate the biological and economic efficiency of preparations of biological origin against the potato ladybird in the soil and climatic conditions of the southern Far East.

MATERIAL AND METHODS

Studies to assess the biological effectiveness of drugs were carried out in 2018, 2019. Field experiments were carried out in the village of Dubovy Klyuch of the Ussuriysk district of the Primorsky Territory on the planting of potatoes of the zoned Yantar variety. The object of research is the larvae and beetles of the potato ladybird. The tubers were planted at the optimal time for the region (late April - early May). The plot area was 16.8 m^2. In each variant of the experiment three replications were carried out. The placement of plots in replicates is randomized. To regulate the number of potato ladybirds Fitoverm, EC preparations (a.i. aversectin C, 50 g / l) were used at application rates of 0.07 and 0.16 l / ha (LLC NBTs "Farmbiomed"), Akarin, EC (a.i. avertin N, 2 g / l) - 1.2 and 1.6 l / ha, Batsikol, F (Bacillus thuringiensis, strain BtH_{10}) - 15 l / ha and Bitoxibacillin, F (Bacillus thuringiensis, strain BtH_1) - 15 l / ha (ARRIAM). The preparations were used separately and together with the insecticide Corado, SC (a.i. imidacloprid, 200 g / l) - 0.1 l / ha. Potato plants were sprayed with the preparations once. Pest counts were carried out before treatment and after treatment on the 5th, 10th, 15th day on 10 potato plants of each replication in accordance with the approved methods[1]. The biological effectiveness of the preparations was determined by the reduction in the number of the pest adjusted for control and was calculated using the Henderson and Tilton formula (see footnote 1). Statistical data processing was carried out according to B.A. Dospekhov[2].

RESULTS AND DISCUSSION

In 2018, the number of potato ladybird larvae before protective measures ranged from 6.9 to 15.0 ind./plant with a population of 69.3% of plants. Larvae of the first - third instars were present on the plants. In 2019, at the time of treatment, young larvae prevailed on the plants with numbers from 5.9 to 8.5 ind./plant with a population of 78.7% of plants.

Avermectin-based preparations showed high biological effectiveness against the potato ladybird. A significant initial effect was shown by the bioinsecticide Fitoverm at the rate of application of 0.16 l / ha, ensuring the death of 93.3% of the larvae of the pest on the 5th day after treatment. The effectiveness of the protective action of the drug remained at the level of 90.5–94.0% for 15 days. In the norm of application of 0.07 l / ha the effectiveness of bioinsecticide in the years of research was significantly lower and amounted to 79.7-84.7% on the 5-15th day (see Table 1).

A rather high efficiency of 74.0–81.6% against the larvae of the potato ladybird was shown by another preparation based on avermectins, Akarin. There was no significant difference in biological effectiveness between the variants with different application rates (1.2 and 1.6 l / ha).

Throughout the entire reference period, the bioinsecticide kept the number of potato ladybird below the economic threshold of harmfulness. In the course of the research, it was found that Fitoverm, in the norm of application of 0.07 l / ha, showed almost the same effectiveness with the drug Akarin in regulating the number of potato ladybirds, but in the norm of application of 0.16 l / ha the efficiency was significantly higher. Fitoverm at this consumption rate showed insecticidal activity at the level of the chemical preparation Corado.

The effectiveness of microbiological preparations based on Bacillus thuringiensis on the

[1]Methodical guidelines for registration tests of insecticides, acaricides, molluscicides and rodenticides in agriculture. SPb.: ARRIBPP, 2009. 321 p.

[2]Dospekhov B.A. Field experiment technique. M: Kolos, 1985.336 p.

Табл. 1. Эффективность биоинсектицидов против картофельной коровки (среднее за 2018, 2019 гг.)
Table 1. Effectiveness of bioinsecticides against potato ladybird (average for 2018, 2019)

Option	Preparation rate of application, l/ha	Average number of larvae, number. (on average per one plant)				Decrease in the number of pests relative to the original, adjusted for control after treatment by day of registration, %		
		before treatment	after treatment by day of registration					
			5	10	15	5	10	15
Control	–	7,2	8,4	8,2	5,9	–	–	–
Fitoverm, EC	0,07	9,2	2,2	1,4	1,4	81,7	84,7	79,7
Fitoverm, EC	0,16	6,7	0,7	0,9	0,4	93,3	90,5	94,0
Akarin, EC	1,2	6,8	2,2	2,0	1,7	74,0	75,3	74,2
Akarin, EC	1,6	8,6	3,0	2,3	1,8	74,4	80,5	81,6
Batsikol, Fl.	15	8,0	3,7	2,2	0,7	63,8	80,5	87,7
Bitoxibacillin, Fl.	15	8,7	3,1	2,0	1,5	69,2	84,7	84,5
Corado, SC	0,1	9,7	0,2	0,05	0,01	97,7	99,6	99,8
Fitoverm, EC + Corado, SC	0,03 + 0,03	7,5	0,3	0,08	0,2	96,8	99,3	97,0
Akarin, EC + Corado, SC	0,6 + 0,03	8,0	0,6	0,1	0,01	92,0	97,7	99,8
Batsikol, Fl + Corado, SC	7,5 + 0,03	6,8	0,4	0,05	0,01	94,2	99,2	99,7
Bitoxibacillin, Fl + Corado, SC	7,5 + 0,03	7,8	0,9	0,08	0,2	90,8	99,2	97,7
LSD_{05}	–	–	–	–	–	8,3	5,5	6,0

5th day after treatment was marked significantly lower. These preparations showed a low efficiency of 56.6–61.0% in 2018. In the same year, at the time of treatment, in addition to the larvae of the first and second instars larvae of the third instar were observed on the plants (in 2019, only young larvae were present on the plants). Weather conditions (frequent heavy rains during the growing season) did not allow the treatment to be carried out in time and subsequently influenced the effectiveness of the preparations. By the 10th day, in the variants with the use of Batsikol and Bitoxibacillin, an increase in the toxic effect was observed, the decrease in the number of the pest was 80.5–84.7%. The effectiveness of the protective action remained at the level of 84.5–87.7% and on the 15th day after treatment. By this time, significant differences were noted in the biological effectiveness of Batsikol with the preparations Fitoverm (0.07 l / ha) and Akarin (1.2 l / ha).

The use of tank mixtures of chemical plant protection products with biological products helps to reduce the pesticide load. When using preparations based on actinomycetes (Fitoverm and Akarin), Bacillus thuringiensis (Batsikol and Bitoxibacillin) and Corado (0.03 l / ha), the number of pests on the 5th day after treatment decreased by 90.8–96.8%. On the 10-15th day, almost complete death was noted (97.0-99.8%). Tank mixtures of preparations showed efficiency at the level of an insecticide at a consumption rate of 0.1 l / ha.

The use of chemical and biological preparations had an effect on the yield of potatoes, the increase in the yield of potato tubers averaged over 2 years from 2.3 to 4.6 t / ha, while the control indicator was 26.0 t / ha (see Table 2). The largest yield increase of 3.8-4.6 t / ha was obtained when Fitoverm was used at a consumption rate of 0.16 l / ha and the combined use of biological preparations with an insecticide.

CONCLUSION

The studies carried out confirm the prospects of using preparations based on actinomycetes (Fitoverm and Akarin) and Bacillus thuringiensis (Batsikol and Bitoxibacillin) in regulating

Табл. 2. Урожайность картофеля при применении препаратов (среднее за 2018, 2019 гг.)
Table 2. Productivity of potatoes with the application of preparations (average for 2018, 2019)

Experiment option	Preparation rate of application, l/ha	Average yield, t/ha	Yield gain	
			t/ha	%
Control	–	26,0	–	–
Fitoverm, EC	0,07	29,0	3,0	11,5
Fitoverm, EC	0,16	29,8	3,8	14,6
Akarin, EC	1,2	28,3	2,3	8,8
Akarin, EC	1,6	28,8	2,8	10,8
Batsikol, Fl.	15	28,6	2,6	10,0
Bitoxibacillin, Fl.	15	28,3	2,3	8,8
Corado, SC	0,1	30,2	4,2	16,2
Fitoverm, EC + Corado, SC	0,03 + 0,03	30,0	4,0	15,4
Akarin, EC + Corado, SC	0,6 + 0,03	29,9	3,9	15,0
Batsikol, Fl + Corado, SC	7,5 + 0,03	30,3	4,3	16,5
Bitoxibacillin, Fl + Corado, SC	7,5 + 0,03	30,6	4,6	17,7
LSD_{05}		3,0		

the number of potato cows in Primorsky Krai. A single application of bioinsecticides ensured a decrease in the number of pests by 63.8–94.0% and had an impact on the formation of the yield.

A high level of effectiveness of biological products Fitoverm, Batsikol, Bitoxibacillin, Akarin was observed when used together with the insecticide Corado. In these variants, a significant protective result (97.0–99.8%) was noted on the 15th day after application. The addition of biological products to the insecticide allows reducing the pesticide consumption rate by 3 times without reducing the overall biological effectiveness of the mixture, increasing the yield by 15.0-17.7% and reducing the chemical load on the agrobiocenosis.

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Дата поступления статьи 14.12.2020
Received by the editors 14.12.2020

https://doi.org/10.26898/0370-8799-2021-1-9
УДК: 619:615.1
Тип статьи: оригинальная
Type of article: original

СПОСОБЫ ПОВЫШЕНИЯ ИММУНОГЕННОСТИ ИНАКТИВИРОВАННЫХ ВАКЦИН ПРОТИВ МЫТА ЛОШАДЕЙ

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Представлены результаты исследований по специфической профилактике инфекционных болезней лошадей. Разработаны способы повышения иммуногенности экологически безопасных вакцин против мыта, который вызывается мытным стрептококком – *Sreptococcus equi*. Работа проведена в лабораторных условиях и коневодческих хозяйствах Республики Саха (Якутия). Токсичность и иммуногенность вакцины определяли общепринятыми методами на молодняке лошадей. На основании изучения иммунобиологической реактивности молодняка лошадей обосновано использование иммуномодуляторов при разработке инактивированных вакцинных препаратов. Вакцины с иммуномодуляторами испытывали и регистрировали согласно утвержденным методикам исследования лекарственных средств для ветеринарного применения. В качестве иммуномодулятора в составе вакцин использованы полирибонат (поливедрим) и культуральная жидкость (фугат) из штамма бактерий *Bacillus subtilis* ТНП-3. Для приготовления вакцины против мыта использовали штаммы бактерий *Streptococcus equi* Н-34 и *Streptococcus equi* «Н-5/1», которые депонированы во Всероссийской государственной коллекции штаммов микроорганизмов Всероссийского государственного Центра качества и стандартизации лекарственных средств для животных и кормов, используемых в ветеринарии и животноводстве. После иммунизации инактивированными вакцинами с иммуномодуляторами эффективность вакцин повышается на 20% и достигает 90%. Вакцины повышают иммунобиологическую реактивность организма. Наиболее эффективными отмечены вакцина «Табын» и вакцина из штамма *Streptococcus equi* «Н-5/1» с фугатом, штамма бактерий *Bacillus subtilis* ТНП-3. Вакцина с полирибонатом утверждена в России (2000 г.), вакцина «Табын» применяется в Казахстане (2018 г.). Данные вакцинные препараты, обеспечивающие высокую противоэпизоотическую эффективность, экологически безвредны, так как не содержат токсичные вещества и антибиотики.

Ключевые слова: штамм бактерий, вакцина, иммуномодулятор, иммунобиологическая реактивность, иммуногенность

WAYS TO INCREASE THE IMMUNOGENICITY OF INACTIVATED VACCINES AGAINST STRANGLES

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The results of the study on the specific prevention of infectious diseases in horses are presented. Methods have been developed to increase the immunogenicity of environmentally friendly vaccines against strangles, caused by the beta-hemolytic streptococcus – *Sreptococcus equi*. The work was carried out in laboratory conditions and horse breeding farms of the Republic of Sakha (Yakutia). The toxicity and immunogenicity of the vaccine was determined by conventional methods on young horses. Based on the study of the immunobiological reactivity of young horses, the use of immunomodulators in the development of inactivated vaccine preparations has been substantiated. Vaccines with immunomodulators were tested and registered in accordance with approved research methods for medicinal products for veterinary use. Polyribonate (polyvedrim) and culture liquid (fugate) from the bacterial strain Bacillus subtilis TNP-3 were used in the composition of vaccines as an immunomodulator. To prepare a vaccine against strangles, strains of bacteria Streptococcus equi H-34 and Streptococcus equi "H-5/1" were used, which were deposited in the Russian State Collection of Microorganism Strains of the Russian State Center for Animal Feed and Drug Standardization and Quality. After immunization with inactivated vaccines containing immunomodulators, the effectiveness of vaccines increases by 20% and reaches 90%. Vaccines increase the body's immunobiological reactivity. The most effective were the “Tabyn” vaccine and the vaccine from the Streptococcus equi strain H-5/1 with fugate, the Bacillus subtilis strain TNP-3. The polyribonate vaccine was approved in Russia (2000), the “Tabyn” vaccine is used in Kazakhstan (2018). These vaccine preparations, which ensure high antiepizootic efficacy, are environmentally friendly, since they do not contain toxic substances and antibiotics.

Keywords: bacterial strain, vaccine, immunomodulator, immunobiological reactivity, immunogenicity

Для цитирования: *Неустроев М.П., Донченко А.С.* Способы повышения иммуногенности инактивированных вакцин против мыта лошадей // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 74–81. https://doi.org/10.26898/0370-8799-2021-1-9

For citation: Neustroev M.P., Donchenko A.S. Ways to increase the immunogenicity of inactivated vaccines against strangles. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1, pp. 74–81. https://doi.org/10.26898/0370-8799-2021-1-9

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

Благодарность
Авторы благодарят сотрудников лаборатории по разработке микробных препаратов и лаборатории ветеринарной биотехнологии Якутского НИИ сельского хозяйства им. М.Г. Сафронова за помощь при проведении исследований.
Acknowledgments
The authors are grateful to the staff of the laboratory for the development of microbial preparations and the laboratory of veterinary biotechnology of M.G. Safronov Yakut Scientific Research Institute of Agriculture for the help with the research.

INTRODUCTION

The growth in the livestock and productivity of herd horse breeding is constrained by a number of factors, among which infectious diseases occupy a significant place. The most common, especially among young horses, is strangles which is caused by the mythosis streptococcus - Sreptococcus equi [1, 2]. It is believed that the pathogen of strangles has not changed for 700 years, although there are zonal features of its strains [3].

Horse strangles is most common in Novosibirsk, Irkutsk regions, Krasnoyarsk and Altai territories [4], the republics of Tyva[1], Khakassia and Sakha (Yakutia) [5] of the Russian Federation, as well as in Kazakhstan[2], Mongolia [6], Kyrgyzstan [7]. Cases of the disease were noted

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in the Netherlands[3], the Arab Republic of Egypt [8], Korea [9], Brazil [10].

In the Republic of Sakha (Yakutia), the incidence of strangles in young horses is 57.8–62.7% of the total population; mortality, depending on the development of the epizootic process, is 4.0–22.0% [5]. In Mongolia and the Republic of Sakha (Yakutia), the spread of infection and an increase in the incidence of strangles are associated with a decrease in the immunobiological reactivity of animals in extreme climatic conditions, with the historically established features of the traditional industry and the lack of planned preventive measures [5, 6].

Strangles currently remains a serious problem due to the lack of specific means of preventing this disease. In the modern world, different types of vaccines are tested, manufactured and used: inactivated, attenuated, live. In the Netherlands, a live vaccine against horse strangles has been developed from the Streptococcus equi strain TW 928 (see footnote 3), but it is not registered in Russia. In the USA, a live vaccine from an attenuated strain, which induces the production of antibodies in blood serum after 7–10 days, and a modified intranasal vaccine Pinnacle IN, two-time use, have been developed and are being used. These vaccines are not used in Russia; they require two and three doses at intervals of several weeks, which is inconvenient for the use [11].

In Kazakhstan, an inactivated subunit vaccine from the Sreptococcus equi YUS-15 strain, the KazNIVI vaccine[4] and the Akyntai vaccine[5] have been developed. However, these vaccines contain antibiotics and cannot be used for organic production.

Currently, an effective method of fighting strangles is generally recognized - specific prophylaxis with vaccines, but in veterinary practice there are no ecologically harmless anti-epizootic vaccines. The problem of prevention of strangles acquires special significance in the period of market relations, when the value of breeding animals increases, sales of horse breeding products and the production of organic products are expanding.

The purpose of the study is to develop ways to increase the immunogenicity of ecologically safe vaccines against horse washing by using immunomodulators.

MATERIAL AND METHODS

The work was carried out in the laboratory of veterinary biotechnology of the Yakut Scientific Research Institute of Agriculture (YSRIA), SPC Khotu-Bakt LLC and in horse breeding farms in the Republic of Sakha (Yakutia).

To prepare a vaccine against strangles we used strains of bacteria Streptococcus equi H-34 and Streptococcus equi "H-5/1" which were deposited in the All-Russian State Collection of Microorganism Strains of the Russian State Center for Animal Feed and Drug Standardization and Quality (FSFI "VGNKI") used in veterinary and animal husbandry.

To accumulate the bacterial mass for the manufacture of the vaccine, we used meat-peptone broth (MPB) with 1% glucose and with the addition of horse blood serum. The prepared bacterial base was inactivated with 0.04% formalin solution. Aluminum hydroxide was used as an adjuvant.

The vaccine from the Streptococcus equi H-34 strain as an immunomodulator was supplemented with polyribonate (polyvedrim), developed by the Scientific Research, Design and Technology Institute of Biologically Active Substances SPA Vector and the Institute of Experimental Veterinary Medicine of Siberia and the Far East. Polyribonate was added to the vaccine at the rate of 0.5 mg / kg of live weight. An immunomodulator was added to the vaccine from the Streptococcus equi strain "H-5/1" - a culture liquid (fugate) from the bacterial strain Bacillus subtilis TNP-3 (registration number RCAM04759, certificate of deposit dated December 27, 2017). The strain was cultivated for 5 days in meat-peptone broth at 37 ° C. The

[4]Patent No. 36813 Republic of Kazakhstan. Vaccine against horse strangles/ A.B. Bizhanov, A.R. Sansyzbaev. 1999. Bul. No. 10.

[5]Patent No. 31032 Republic of Kazakhstan. Vaccine against horse strangles "Akyntai" / B.Sh. Karataev, N.A. Myrzakhmetuly, A.B. Bizhanov. 2016. Bul. No. 4.

bacterial mass containing 1 billion microbial cells was centrifuged at 7000 rpm for 15 min to separate the culture liquid (CL). It was filtered through membrane filters into sterile vials heated in a water bath at 95 ° C for 15 min. Fugate was added to the finished vaccine in a 2: 1 ratio.

The toxicity and immunogenicity of the vaccine were determined by conventional methods on young horses. The vaccine with the immunomodulator polyribonate was tested and recorded according to the approved rule[6]. The study of the vaccine with the fugate of the bacterial strain Bacillus subtilis TNP-3 was carried out according to the method[7].

The tests of the vaccine from the Streptococcus equi H-34 strain with the fugate of the Bacillus subtilis TNP-3 bacterial strain and the execution of scientific and technical documentation were carried out in accordance with the rules[8].

To assess the immunogenic properties of the horse strangles vaccine, the lethal dose of the industrial strains (LD_{50}) was preliminarily determined. The effectiveness of immunization was determined by the number of mice resistant in morbidity and mortality to infection in comparison with animals of the control group. Production trials of vaccines were carried out in the strangles dysfunctional farms of the Republic of Sakha (Yakutia).

RESULTS AND DISCUSSION

The immunobiological reactivity of the body of young horses has age and seasonal characteristics and is interrelated with the dynamics of the content of protein, mineral and vitamin components in the blood. The most critical periods in the development of foals in immunological and physiological terms, caused by the action of stress factors (weaning, abrupt type change and inadequate feeding, severe cold and infestation with helminths), are 2 months of age, as well as winter, especially the first two months after weaning. In this regard, the use of immunomodulators in the development of vaccine preparations is justified.

The inactivated vaccine made from the Sreptococcus equi H-34 strain with the immunomodulator polyribonate is harmless and nonreactive. When the drug is administered twice with an interval of 14 days, high-intensity immunity is induced in at least 90-100% of immunized laboratory mice and horses. Immunization causes an increase in the phagocytic ability of leukocytes, lysozyme and bactericidal activity of serum, induces the synthesis of precipitating antibodies and an increase in the concentration of immunoglobulins Ig G and Ig M. This indicates the stimulation of cellular and humoral factors of immunity providing its intensity.

In the study of target animals, it was proved that the addition of polyribonate to the vaccine against strangles increases its immunogenicity by 20%. Production tests for 1265 heads of young horses have shown that the vaccine with polyribonate protects up to 97.2% of immunized foals from strangles disease.

Based on the analysis of literature data and research results, polyribonate was chosen as an immunomodulator among possible immunostimulating agents. It has immunoregulatory, anti-stress properties that enhance the body's nonspecific resistance. The works of A.S. Donchenko et al. [12] established the ability of polyribonate to increase the immunogenic properties of the BCG[9] vaccine. The vaccine with polyribonate was approved in 2000 by the Veterinary Department of the Ministry of Agriculture of the Russian Federation and was widely used in the constituent entities of Russia. However, due to the high cost of polyribonate, the termination of its production and the expira-

[6]Regulation on the procedure for examination, testing and registration of veterinary drugs in the Russian Federation, approved on October 3, 1995 by the Veterinary Department of the Ministry of Agriculture and Food of the Russian Federation.

[7]The order of the Ministry of Agriculture of the Russian Federation No. 101 of March 6, 2018 "On Approval of the Rules for Conducting a Preclinical Study of a Medicinal Product for Veterinary Use, a Clinical Study of a Medicinal Product for Veterinary Use, and a Study of the Bioequivalence of a Medicinal Product for Veterinary Use."

[8]Rules for conducting state registration (re-registration) and maintaining the State register of veterinary drugs in the Republic of Kazakhstan, approved by the order of the Minister of Agriculture of the Republic of Kazakhstan dated October 31, 2002, No. 349.

tion of the registration period, this vaccine has been discontinued.

The new inactivated vaccine against horse strangles from the Streptococcus equi strain "H-5/1" contains a culture liquid (fugate) from the Bacillus subtilis TNP-3 bacterial strain as an immunomodulator.

The safety of the vaccine has been established in laboratory animals. The immunogenicity of the vaccine against strangles in laboratory white mice was 90%. Clinical trials carried out on 117 heads of young horses, showed a high efficiency of vaccine prevention (up to 100%). Currently, scientific and technical documentation has been prepared for approval by the Rosselkhoznadzor.

A vaccine "Tabyn" has been developed from the bacterial strain Sreptococcus equi H-34 with the culture liquid of the bacterial strain Bacillus subtilis TNP-3 for the use in the Republic of Kazakhstan. The immunizing ability of the Tabyn vaccine was compared with the previously developed vaccine against strangles with the polyribonate immunomodulator. 20 white mice were taken for each vaccine. Then the animals were inoculated with a daily culture of the pathogenic strain of strangles streptococcus at a dose of $5LD_{50}$. During 10 days of observation, animals from the first group of mice fell ill and 2 animals died, from the second group – 2 animals and in the control group - 17 animals. Immunization with the Tabyn vaccine protects up to 90% of white mice from experimental infection with a pathogenic strain of strangles streptococcus. The experience of challenging vaccinated foals with a pathogenic strain confirmed the high immunogenicity of the inactivated vaccine.

After immunization with the Tabyn vaccine on the 24th day, an increase in the parameters of the immunobiological reactivity of the organism (bactericidal and lysozyme activity of blood serum) was noted in the blood serum. By the end of the observation, an increase in the number of leukocytes with a noticeable increase in their phagocytic activity was recorded in foals immunized with the Tabyn vaccine.

On day 30, the blood of foals immunized with the Tabyn vaccine showed the highest titer of precipitating antibodies (1: 35), which is higher than that of young animals vaccinated with the polyribonate vaccine (1: 20).

The possibility of using the culture liquid of the bacterial strain Bacillus subtilis TNP-3 as a component of the inactivated vaccine against strangles was established. The antiepizootic efficacy of the Tabyn vaccine (vaccine from the Streptococcus equi H-34 strain + culture liquid of the Bacillus subtilis bacterial strain) is not inferior to the strangles vaccine inactivated with the immunomodulator polyribonate. The economic efficiency of the Tabyn vaccine is 2–3 times higher than its analogue.

This method of specific prophylaxis of strangles with the "Tabyn" vaccine of horses is ecologically, economically and epizootologically justified. Based on the research results, scientific and technical documentation was developed, which was approved by the Committee for Veterinary Control and Supervision of the Republic of Kazakhstan. The registration certificate was received (RK-VP-1-3750-18 dated November 27, 2018).

The high efficiency of inactivated vaccines with fugate of the Bacillus subtilis TNP-3 bacterial strain can be explained by the antigenic activity of the vaccine strains and the immunomodulatory component - the culture liquid (fugate) of the Bacillus subtilis TNP-3 bacterial strain. According to the research results, the bacterial strain Bacillus subtilis TNP-3 can induce the synthesis of interferon and stimulate the immunobiological reactivity of the organism, enhance the immunogenicity of inactivated bacterial and viral vaccines [13, 14]. The developed vaccine is not inferior in immunogenicity and even surpasses (up to 90%) the preparations developed in the Netherlands (see footnote 3), the USA [11], Kazakhstan (see footnotes 4, 5), and surpasses in terms of envi-

[9]Donchenko A.S., Alikin Yu.S., Donchenko V.N. Application of biologically active substances as immunomodulators in veterinary medicine and medicine. Literature review / AUAAS. Sib. Br. IEVMSiFE. Novosibirsk, 1989.

ronmental friendliness and harmlessness, since does not contain antibiotics.

The absence of toxicity of the vaccine with the culture liquid from the Bacillus subtilis TNP-3 bacterial strain is consistent with the previously obtained results, which showed the harmlessness of the Sakhabactisubtil preparation, consisting of the Bacillus subtilis TNP-3 and Bacillus subtilis TNP-5 bacterial strains in linear rats and mice in the development of a drug probiotic [15, 16].

CONCLUSION

Methods have been developed to increase the immunogenicity of ecologically safe vaccines against horse strangles. New inactivated vaccines with immunomodulators polyribonate and fugate of the bacterial strain Bacillus subtilis TNP-3 are presented. High immunogenicity of inactivated vaccines (up to 90%) has been established. The most effective are the vaccine "Tabyn" and the drug from the Streptococcus equi strain "H-5/1" with the fugate of the bacterial strain Bacillus subtilis TNP-3, which can be successfully used in Russia and in the countries of Eurasia.

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Дата поступления статьи 24.12.2020
Received by the editors 24.12.2020

https://doi.org/10.26898/0370-8799-2021-1-10
УДК: 636.271
Тип статьи: оригинальная
Type of article: original

ОЦЕНКА ГЕНЕАЛОГИЧЕСКИХ ЛИНИЙ КРУПНОГО РОГАТОГО СКОТА КАЗАХСКОЙ БЕЛОГОЛОВОЙ ПОРОДЫ

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Проведена оценка хозяйственно полезных признаков и экстерьера основных генеалогических линий коров казахской белоголовой породы в двух племенных хозяйствах Алтайского края. Для анализа использованы показатели хозяйственно полезных признаков и экстерьера первотелок и полновозрастных коров казахской белоголовой породы: живая масса, промеры, общий балл за экстерьер, молочность. Установлено, что первотелки линии Замка 3035 превосходят сверстниц по обхвату груди, Задорного 1325 и Короля 13682 – по косой длине туловища. Животные линии Пиона 29 по живой массе уступают сверстницам. Лучшие показатели по живой массе отмечены у полновозрастных коров линии Задорного 1325, по молочности – у линии Короля 13682. В целом достоверных межлинейных отличий по большинству признаков у животных оцениваемых линий не отмечено. Анализ полновозрастных коров, принадлежащих к линиям Замка 3035, Короля 13682, Задорного 1325, свидетельствует о превосходстве сверстниц по живой массе, линии Короля 13682 – по молочности. Изучение коэффициентов наследуемости показало низкий уровень влияния генотипа на изменчивость основных признаков. Данный факт может свидетельствовать о высокой степени консолидации казахской белоголовой породы. В племенной работе с данной породой необходимо шире использовать производителей, принадлежащих линиям Задорного 1325, Замка 3035. Особое внимание необходимо уделить ротации генеалогических групп. Рекомендуется для повышения генетической изменчивости признаков в стадах использовать новых неродственных животных из других регионов. Для этого следует проводить отбор согласно требованиям по бонитировке и параметрам отбора, рассчитанным для конкретного хозяйства.

Ключевые слова: крупный рогатый скот, казахская белоголовая порода, генеалогическая структура, линия, тип, живая масса, молочность

ESTIMATION OF GENEALOGICAL LINES OF CATTLE OF THE KAZAKH WHITE-HEADED BREED

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An assessment of economically useful traits and external conformation of the Kazakh white-headed cows of the main genealogical lines, bred in the farms of the Altai Territory, was carried out. For the analysis, indicators of economically useful traits and conformation of first-calf heifers and full-aged cows of the Kazakh white-headed breed were used: live weight, measurements, total score for conformation, milk production. It was established that first-calf heifers of Zamok 3035 line surpass their herdmates in chest girth, and heifers of Zadorny 1325 and Korol 13682 lines are superior in oblique body length. Cows of Peon 29 line are inferior to their peers in live weight. The best indicators in live weight were noted in full-aged cows of Zadorny 1325 line, in milk yield – in Korol 13682 line. In general, there were no significant differences in most animal traits between the lines assessed. Analysis of full-aged cows belonging to the lines of Zamok 3035, Korol 13682, Zadorny 1325 showed that they surpass their herdmates in live weight, the lines of Korol 13682 – in milk yield. The study of the coefficients of heritability showed a low level of influence of the

genotype on the variability of the main traits. This fact may indicate a high degree of consolidation of the Kazakh white-headed breed. In the breeding work with this breed, it is necessary to make wider use of sires belonging to the lines of Zadorny 1325, Zamok 3035. Particular attention should be paid to the rotation of genealogical groups. It is recommended to use new unrelated animals from other regions to increase the genetic variability of traits in herds. In order to do this, selection should be carried out in accordance with the grading requirements and selection parameters calculated for a particular farm.

Keywords: cattle, Kazakh white-headed breed, genealogical structure, line, type, live weight, milk yield

Для цитирования: *Солошенко В.А., Плешаков В.А., Инербаев Б.О., Дуров А.С., Храмцова И.А.* Оценка генеалогических линий крупного рогатого скота казахской белоголовой породы // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 82–89. https://doi.org/10.26898/0370-8799-2021-1-10

For citation: Soloshenko V.A., Pleshakov V.A., Inerbaev B.O., Durov A.S., Khramtsova I.A. Estimation of genealogical lines of cattle of the Kazakh white-headed breed. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1, pp. 82–89. https://doi.org/10.26898/0370-8799-2021-1-10

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

INTRODUCTION

In the practice of breeding cattle of the Kazakh white-headed breed, a balance has been formed between the use of bulls of existing lines and producers belonging to the lines, the formation of which has reached the final stage [1].

A significant role in this breed is played by animals belonging to the Shaman 1161, Peon 61184, Graf 8489, Marshal and Akbas-Bai lines, which are currently actively used to create highly productive herds of animals [2].

The structure of the Zorky 3433 line is represented by highly productive offspring that have undergone targeted selection in a number of generations and are distinguished by breeding and productive qualities characteristic of the line. This ancestor is a descendant of the bull-producer Zadorny 1325 of the intra-breed hornless type "Zavolzhsky" created in the Volgograd region [3].

Crossing of lines gives a variety of animals in terms of productivity in each combination of parental pairs. At the same time, the influence of linear bulls on the indicators of productive and breeding qualities of animals is not the same [4].

Rational use of genotypic factors, as well as their interaction, provide a real opportunity to improve the productive qualities of animals using a heterogeneous selection. Only in the conditions of the Saratov region is it possible to use the potential of nine animal lines for different variants of selection [5, 6].

Working with lines in intensive technology conditions is of particular importance. So, in the conditions of the Tambov region, bull calves belonging to the Landysh 9878 line have the largest live weight, whereas in the leading farms of the Republic of Kazakhstan the lines of Veteran 7880, Korol 13682 are the largest [7–10].

The use of target zootechnical and genetic parameters of the breeding value in the process of selection and breeding work with the Kazakh white-headed cattle breed contributes to the creation and improvement of highly productive lines in animal populations [11–13].

Breeders of the Kazakh white-headed breed of most of the lines have good reproductive qualities. Rational use of the best linear animals in herd reproduction will make it possible to predict the future reproductive capacity of cows at an earlier age [14, 15].

A two-stage assessment of bulls makes it possible to conduct breeding work aimed at creating large, intensively developing animals with good meat qualities. It is necessary to have a system of control and testing stations where work with animals is carried out for an objec-

tive assessment of breeding bulls and working with lines [16–20]. The aim of the study is to assess the productive qualities and conformation of cows of the Kazakh white-headed breed of various genealogical lines in the conditions of the Altai Territory.

MATERIAL AND METHODS

The research was carried out in the breeding farms of the LLC "Farm" and LLC "Kolos" of the Altai Territory, engaged in breeding and selection of cattle of the Kazakh white-headed breed.

Indicators of economically useful traits and conformation of first-calf heifers and full-aged cows of the Kazakh white-headed breed were used for the analysis: live weight, measurements, total score for conformation, milk production.

The assessment of genealogical lines of full-aged cows of the Kazakh white-headed breed was carried out. Comparison of lines was carried out in relation to the average by the herd and the breed standard. Interline differences were identified in the on-farm aspect.

The reliability of the difference was determined between the animals of the evaluated line and the rest of the population. The research results were processed by the method of variation statistics according to the generally accepted methods[1],[2].

RESULTS AND DISCUSSION

The assessment of the population of first-calf heifers of the Kazakh white-headed breed in the LLC "Farm" shows that they are relatively homogeneous in terms of measurements (see Table 1). Noteworthy is the superiority over the peers of the first-calf heifers of the Zamok 3035 line in terms of chest girth, which is advisable to use when ordering mating. The females of Zadorny 1325 and Korol 13682 lines are distinguished by the oblique length of the body. The milk production of animals of all lines ex-

Табл. 1. Характеристика линий первотелок казахской белоголовой породы ООО «Фарм»
Table 1. Characteristics of the lines of first-calf heifers of the Kazakh white-headed breed in LLC "Farm"

Trait	Line				By sample (n = 67)
	Korol 13682 (n = 34)	Zadorny 1325 (n = 16)	Zamok 3035 (n = 10)	Peon 29 (n = 7)	
Live weight, kg	455,0 ± 9,01	450,9 ± 13,04	447,7 ± 16,23	418,1 ± 11,73*	449,1 ± 6,30
Height at the withers, cm	122,9 ± 0,65	122,9 ± 1,29	122,6 ± 1,76	119,9 ± 1,33	122,5 ± 0,55
Height at hips, cm	126,2 ± 0,66	126,3 ± 1,20	127,4 ± 1,37	123,6 ± 1,41	126,1 ± 0,52
Chest width behind shoulder blades, cm	44,2 ± 0,51	44,3 ± 0,65	46,6 ± 1,04	44,4 ± 0,75	44,6 ± 0,36
Width in hips, cm	51,7 ± 0,41	51,1 ± 0,62	49,8 ± 0,44	50,3 ± 0,56	51,1 ± 0,28
Width of loin, cm	29,3 ± 0,52	28,3 ± 0,86	29,7 ± 0,58	27,4 ± 0,80	28,9 ± 0,37
Oblique body length, см	152,7 ± 1,16	153,9 ± 1,95	149,5 ± 2,38	150,1 ± 2,76	152,3 ± 0,90
Oblique rear length, cm	51,3 ± 0,38	51,6 ± 0,96	51,4 ± 0,29	51,7 ± 1,83	51,4 ± 0,36
Chest girth behind shoulder blades, cm	182,2 ± 4,67	180,6 ± 6,23	191,5 ± 2,84*	162,4 ± 13,46	181,2 ± 3,28
Milk yield, kg	216,9 ± 4,00	221,0 ± 5,87	225,9 ± 8,70	216,7 ± 8,71	219,0 ± 2,77

[1]Plokhinsky N.A. A guide to biometrics for zootechnicians. Moscow: Kolos, 1969.255 p.
[2]Stalh W., Rasch D., Šiler R., Vahal J. Populationsgenetik für tierzüchter. Berlin – Praga, 1969. 439 s

ceeds the requirements of the breed standard. The live weight of first-calf heifers on average in the sample belongs to the elite-record class, while animals belonging to the Peon 29 line are inferior to their peers in this trait ($p \geq 0.95$).

The best indicators in terms of live weight were noted in full-aged cows of the Zadorny 1325 line, in terms of milk production - in the Korol 13682 line. Individuals belonging to the Peon 29 line are significantly inferior to their peers in milk production. In general, there were no significant interline differences in most traits in animals of the evaluated lines of the LLC Pharm (see Table 2).

Analysis of productive traits in the population of cows 5 years old and older of the Kazakh white-headed breed in the LLC "Kolos" showed that the animals meet the requirements of the elite class in terms of live weight, and the breed standard in terms of milk production (see Table 3).

Animals belonging to the lines of Zamok 3035, Korol 13682, Zadorny 1325 correspond to the elite-record class in terms of live weight. No significant differences have been established in terms of milk production and height in the sacrum, while the tallest and most milk production are the animal lines of the Korol 13682.

Табл. 2. Характеристики линий полновозрастных коров казахской белоголовой породы в ООО «Фарм»

Table 2. Characteristics of the lines of full-aged cows of the Kazakh white-headed breed in LLC "Farm"

Trait	Line			By sample (n = 77)
	Korol 13682 (n = 42)	Zadorny 1325 (n = 32)	Peon 29 (n = 3)	
Live weight, kg	540,4 ± 8,23	545,9 ± 9,18	506,7 ± 23,21	541,4 ± 6,02
Height at the withers, cm	122,9 ± 0,47	123,4 ± 0,64	123,7 ± 1,52	123,2 ± 0,38
Height at hips, cm	127,1 ± 0,55	126,9 ± 0,65	127,0 ± 1,41	127,0 ± 0,41
Depth of chest, cm	85,6 ± 0,58	86,1 ± 0,67	82,3 ± 2,13	85,7 ± 0,44
Width of chest, cm	46,3 ± 0,45	45,9 ± 0,60	44,7 ± 0,98	46,1 ± 0,35
Oblique body length, см	159,4 ± 1,57	155,6 ± 4,19	155,0 ± 2,94	157,7 ± 1,96
Oblique rear length, cm	52,0 ± 0,36	53,4 ± 0,44	52,3 ± 1,44	52,6 ± 0,29
Chest girth, cm	199,4 ± 2,80	200,4 ± 3,14	196,0 ± 3,09	199,7 ± 2,02
Pastern girth, cm	21,1 ± 0,16	21,1 ± 0,15	20,3 ± 0,27	21,1 ± 0,11
Milk yield, kg	243,6 ± 3,82	235,0 ± 5,79	207,3 ± 15,04*	238,6 ± 3,23

Табл. 3. Характеристики линий полновозрастных коров казахской белоголовой породы в ООО «Колос»

Table 3. Characteristics of the lines of full-aged cows of the Kazakh white-headed breed in LLC "Kolos"

Line	Trait		
	Live weight, kg	Height at hips, cm	Milk yield, kg
Other lines (n = 93)	559,1 ± 5,88	129,36 ± 0,51	214,8 ± 2,55
Peon 29 (n = 68)	555,0 ± 8,77	129,9 ± 0,70	218,5 ± 3,70
Zamok 3035 (n = 22)	579,3 ± 11,15	129,6 ± 1,09	216,5 ± 4,29
Korol 13682 (n = 43)	560,3 ± 8,59	131,1 ± 0,64	219,1 ± 3,68
Zadorny 1325 (n = 21)	575,2 ± 9,29	129,9 ± 0,50	214,4 ± 4,75
By sample (n = 339)	564,9 ± 3,24	130,1 ± 0,26	216,4 ± 1,40

Assessment of the coefficients of heritability showed a low level of influence of the genotype on the manifestation and variability of the main characters. This fact may indicate a high degree of consolidation according to the characteristics of the estimated populations (see Table 4).

In LLC "Pharm" it is necessary to carry out custom pairing of parental forms in order to achieve the goal of improving the following indicators: live weight, chest depth, oblique body length. Better performances can be achieved by using the best lines of sire bulls.

In LLC "Kolos" it is necessary to conduct animal breeding for the maximum increase in milk production of cows.

In the estimated population of the Kazakh white-headed breed, a low coefficient of heritability of traits was noted. The less genetic variability of traits in a particular herd, the lower the selection effect in the first generation. It is recommended to use new unrelated animals from other regions to increase the genetic variability of traits in herds. For this, selection should be carried out in accordance with the grading requirements and selection parameters calculated for a particular farm.

CONCLUSION

Kazakh white-headed cattle, in contrast to aboriginal analogues, like any cultural breed, needs constant maintenance and improvement of breeding and productive qualities. To improve the productive qualities of animals, it is necessary to make wider use of producers belonging to the lines of Zadorny 1325, Zamok 3035. For the rest of the genealogical structures, it is necessary to identify effective successors. When drawing up breeding programs and improving herds, special attention should be paid to the rotation of genealogical groups. In this case, the quick receipt of improved breeding qualities of animals is guaranteed.

Табл. 4. Коэффициент наследуемости признаков у коров 5 лет и старше

Table 4. The coefficient of trait heritability in cows of 5 years old and older

Trait	Farm	
	LLC «Farm»	LLC «Kolos»
Live weight	0,05	0,03
Height at the withers	0,17	–
Height at hips	0,20	0,01
Depth of chest	0,06	–
Width in hips	0,23	–
Oblique body length	0,11	–
Chest girth	0,19	–
Pastern girth	0,02	–
Milk yield	0,34	0,07

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Дата поступления статьи 18.10.2020
Received by the editors 18.10.2020

https://doi.org/10.26898/0370-8799-2021-1-11
УДК: 636.4: 577. 118. (571.1)
Тип статьи: оригинальная
Type of article: original

ОСОБЕННОСТИ АККУМУЛЯЦИИ МЕДИ В ЩЕТИНЕ СВИНЕЙ РАЗЛИЧНЫХ ПОРОД

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Приведены результаты оценки содержания меди в щетине свиней ландрасской, кемеровской и скороспелой мясной пород. Исследования выполнены на клинически здоровых шестимесячных животных в хозяйствах Новосибирской, Кемеровской областей и Алтайского края. Условия содержания животных стандартные с типовым кормлением. Элементный анализ проб щетины свиней выполнен методом атомно-эмиссионной спектрометрии с индуктивно-связанной плазмой. Обработку данных проводили с применением Microsoft Office Excel и Statistica 8 (StatSoft Inc., USA), в том числе используя непараметрические методы. Установлен убывающий ранжированный ряд по уровню меди в волосе свиней для пород: ландрасская → кемеровская → скороспелая мясная. В виде отношения он представлен как 5,1 : 4,5 : 1. Показатели меди в щетине свиней ландрасской, кемеровской и скороспелой мясной пород составили 44,0; 39,0 и 8,7 мг/кг соответственно. Аккумуляция меди в щетине свиней ландрасской и кемеровской пород зафиксирована в 5,6 и 4,5 раза больше, чем в скороспелой мясной ($p < 0,001$). Однородностью показателей отмечены скороспелая мясная и кемеровская породы, у них зарегистрирован наименьший межквартильный размах и отношение крайних вариант. Исследованиями с использованием критерия Краскела-Уоллиса установлено, что порода влияет на аккумуляцию меди в щетине свиней. Различия зарегистрированы в парах: скороспелая мясная – кемеровская и скороспелая мясная – ландрасская породы ($p < 0,001$). Наиболее сходные результаты изучения животных на основании кластерного анализа выявлены между кемеровской и ландрасской породами. Скороспелая мясная порода отличается относительной устойчивостью к аккумуляции меди в щетине. Полученные данные можно предварительно принять в качестве физиологической нормы концентрации меди в щетине свиней различных пород, районированных в Западной Сибири.

Ключевые слова: медь, щетина, свиньи, влияние пород

PECULIARITIES OF COPPER ACCUMULATION IN THE BRISTLES OF PIGS OF DIFFERENT BREEDS

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The results of assessing the copper content in the bristles of pigs of Landrace, Kemerovo and Early maturing meat breeds are presented. The study was carried out on clinically healthy six-month-old animals in the farms of Novosibirsk and Kemerovo regions and Altai Territory. The conditions for keeping animals were standard with typical feeding. Elemental analysis of pig bristle samples was carried out by inductively coupled plasma atomic emission spectrometry. The data was processed using Microsoft Office Excel and Statistica 8 (StatSoft Inc., USA), including nonparametric methods. A decreasing ranged series was established according to the level of copper in the hair of pigs for Landrace → Kemerovo → Early maturing meat breeds. As a ratio, it is represented as 5.1 : 4.5 : 1. Copper in the bristles of Landrace, Kemerovo and Early maturing meat breeds amounted to 44.0, 39.0 and 8.7 mg/kg, respectively. The accumulation of copper recorded in the bristles of Landrace and Kemerovo pig breeds was 5.6 and 4.5 times higher than that of Early maturing meat breed ($p < 0.001$). The Early maturing meat and Kemerovo breeds were characterized with the homogeneity of indicators; they had the smallest interquartile range and the ratio of the extreme variants. The study using Kruskal-Wallis criterion established that the breed affects the accumulation of copper in the bristles of pigs. Differences were registered in pairs: Early maturing meat – Kemerovo and Early

maturing meat – Landrace breeds ($p < 0.001$). The most similar results of studying animals based on cluster analysis were found between Kemerovo and Landrace breeds. Early maturing meat breed is relatively resistant to copper accumulation in the bristles. The data obtained can be tentatively taken as a physiological norm for the accumulation of copper in the bristles of pigs of various breeds zoned in Western Siberia.

Keywords: copper, bristles, pigs, influence of breeds

Для цитирования: *Зайко О.А., Назаренко А.В., Королева И.А., Романенко М.А., Магер С.Н.* Особенности аккумуляции меди в щетине свиней различных пород // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 90–98. https://doi.org/10.26898/0370-8799-2021-1-11

For citation: Zaiko O.A., Nazarenko A.V., Koroleva I.A., Romanenko M.A., Mager S.N. Peculiarities of copper accumulation in the bristles of pigs of different breeds. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1, pp. 90–98. https://doi.org/10.26898/0370-8799-2021-1-11

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

INTRODUCTION

The stability of the chemical composition in the body is one of the most important living conditions for humans and animals, changes in which lead to a wide range of diseases [1]. In this regard, the amount of accumulation of chemical elements in the tissues and organs, the relationship between them and the biochemical components of the body at different levels are being studied. Topical issues are related to the individual mineral status and health of animals, the impact on a person who consumes food of animal origin[1–3] [2].

Copper is one of the important chemical elements for realizing the genetic potential of mammals, in particular pigs, by influencing gene expression. It serves as a mineral component and a cofactor for many enzymes in the body [3]. Copper has prooxidant and antioxidant effects necessary for the full provision of biological processes and the development of diseases [4]. For example, copper is a component of superoxide dismutase and glutathione peroxidase, a decrease in the activity of which leads to impaired antioxidant protection. But excessive intake of supplements containing copper can induce systemic lipid peroxidation and oxidative stress [5]. Pigs, according to studies, rarely need additional introduction of copper, provided a balanced diet, which is based on grain feed [6].

Evaluation of the mineral status of animals by the concentration of certain chemical elements in skin derivatives is of interest to many scientists [7, 8]. Copper belongs to the group of elements with a high enrichment coefficient, which indicates an insignificant susceptibility to exogenous contamination, the concentration in skin derivatives is mainly due to endogenous factors [9].

The assessment of the ecological safety of objects of inanimate and wildlife is carried out in various constituent entities of the Russian Federation, including the Siberian regions [10–12]. Assessment of the interior of agricultural animals includes studies of the content of chemical elements in organs and tissues, hematological and immune biochemical parameters of blood. It is necessary for assessing the state of animal health and monitoring the environmental background, which affects the safety and quality of agricultural products[4] [13]. Interpretation of the results of these studies is difficult due to the lack of reference intervals

[1]Zayko O.A. Variability and correlation of chemical elements in organs and tissues of pigs of early maturing meat breed SM-1: dis. abs. of PhD in Biology. Novosibirsk, 2014.183 p.

[2]Narozhnykh K.N. Variability, correlations and the level of heavy metals in organs and tissues of Hereford cattle in the conditions of Western Siberia: dis. abs. of PhD in Biology. Novosibirsk, 2019. 163 p.

[3]Strizhkova M.V. Content, variability and correlation of macronutrients in organs and tissues of black-and-white cattle: dis. abs. of PhD in Biology. Novosibirsk, 2018. 126 p.

characterizing the permissible content of various chemical elements in organs and tissues of animals [14].

The purpose of the research is to establish the interbreed features of the accumulation of copper in the hairline of pigs of various breeds, zoned in Western Siberia.

MATERIAL AND METHODS

The study was conducted in 2016–2020. on groups of clinically healthy pigs of three breeds: Early maturing meat (EM-1), Kemerovo and Landrace, raised on the farms of the Novosibirsk, Kemerovo regions and the Altai Territory. The animals were kept in standard conditions for this species using meat battening[5]. The pigs were vaccinated in accordance with the plans of veterinary preventive measures. Specialists systematically performed elements of a general study, conducted a study of habitus, skin, skin derivatives, mucous membranes and a special study. The animals were provided with standard feeding with a complete feed, depending on the live weight of the animals. The diets are balanced in terms of nutrients, minerals and vitamins. In particular, the amount of copper, depending on the change in the live weight of animals, was in all groups from 19 to 38 mg per head per day. Control of compound feeds according to the range of guaranteed and additional indicators was carried out in accordance with the established procedure[6, 7]. The animals were watered from their own sources of domestic drinking water supply, while the water quality corresponded to the second class of GOST[8].

Water, soil and feed were studied for the content of heavy metals, including copper in the areas of pig breeding by the Center for Collective Use of Scientific Equipment for Multielement and Isotope Research of the Siberian Branch of the Russian Academy of Sciences (SB RAS) of the Institute of Geology and Mineralogy.V.S. Sobolev and the Institute of Inorganic Chemistry. A.V. Nikolaev of the Siberian Branch of the Russian Academy of Sciences[9] [15].

The subject of this research is pig bristles. Samples were obtained from the dorsal neck using ethanol-cleaned stainless-steel scissors. They are represented by the guard hair. The total number of samples was 65. A sample of bristles was taken, it was cleaned from contamination and further sample preparation in accordance with the relevant GOSTs. Elemental analysis was performed directly by inductively coupled plasma atomic emission spectrometry using an iCAP-6500 spectrometer from Thermo Scientific (USA) [16].

The data obtained was processed with Microsoft Office Excel and Statistica 8 software (StatSoft Inc., USA). The Shapiro-Wilk and Kolmogorov-Smirnov test were used to assess the nature of the distribution. The following indicators were assessed: arithmetic mean, error of arithmetic mean, median, standard deviation, interquartile range, maximum and minimum values of copper content in bristles. As an alternative to univariate analysis of variance, the nonparametric Kruskal-Wallis test was used to establish the differences in copper accumulation between the breeds. Cluster analysis was carried out to combine the breeds with homogeneous characteristics using the Ward's method. Manhattan distance was used as a distance metric.

[4]Sebezhko O.I., Korotkevich O.S., Konovalova T.V., Biryulya I.K., Petukhov V.L., Kamaldinov E.V., Narozhnykh K.N., Osadchuk L.V. Biochemical, hematological and mineral parameters in pigs of two breeds reared in large industrial complexes of Western Siberia // 3 rd International Symposium for Agriculture and Food. Ohrid: Faculty of agriculture and food, 2017. P. 100.

[5]GOST 28839-2017. Agricultural animals. Pigs. Zootechnical requirements for the content of fattening. Instead of GOST 28839-90; intro. 2018-07-01. M.: Standartinform, 2017.4 p.

[6]GOST R 51550-2000. Compound feed concentrates for pigs. General technical conditions. - Introduced for the first time; intro. 2001-01-01. M.: PPC Publishing house of standards, 2002. - 10 p.

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[9]Syso A.I. Heavy metals in the environment as a threat to plants, animals and humans // Agrochemistry in the XXI century. Materials of the All-Russian Scientific Conference with International Participation, dedicated to the memory of Academician V.G. Mineeva. Edited by V.A. Romanenkov. 2018. pp. 30–33.

RESULTS AND DISCUSSION

As a result of a number of tests, it was found that the quantitative characteristic of the level of copper in the bristles of pigs from Kemerovo and early maturing meat breeds is characterized by a normal distribution. In the Shapiro-Wilk test, it was found that the W-criterion is 0.97 ($p > 0.05$). The hypothesis about the normal distribution of the same trait in Landrace pigs was rejected.

Table 1 presents data on the level of copper in the hair of pigs of the considered breeds. Ranking the breeds according to the studied trait, it was found that the decreasing series looks as follows: Landrace breed → Kemerovo breed → early maturing meat breed, as relative indicators, taking into account the median: 5.1: 4.5: 1. Significant differences were established among animals of the Landrace breed by the ability to accumulate copper in the bristle, which is expressed by a significant ratio of extreme options. There is no information in the scientific literature on the differences in the accumulation of chemical elements in the body of pigs of different breeds. But it is known about the essential features of the exchange of copper in the body in different breeds of sheep and its physiological consequences for animals[10].

The concentration of copper in the bristles of pigs of the Kemerovo and Landrace breeds is 4.5 and 5.6 times higher, respectively, than this indicator of the early maturing meat breed ($p < 0.001$).

No differences were found in the content of copper in the derivative of the skin in pigs of the Landrace and Kemerovo breeds. It should be noted that on the territory of Western Siberia there is no heavy metal pollution outside the sanitary and hygienic zones [17].

The level of accumulation of chemical elements in the hairline of animals makes it possible to determine the individual mineral status, which is important for farm animals kept in a group way. At the same time, the data obtained can serve as standard indicators for animal breeds zoned in a certain territory, since information on this issue in the literature is scattered. According to the researchers, there are levels of copper accumulation in pig hair of 3–7 and 8–15 mg / kg, both deficient and normal, respectively[11]. In comparison with these values, an excess of descriptive statistics was recorded in animals of the Landrace and Kemerovo breeds.

The study of the content of chemical elements in organs, tissues, skin derivatives of various breeds and types is relevant for solving the question of the presence or absence of hereditary factors [18]. In this study, the EM-1 breed turned out to be more homogeneous in terms of the copper content in the bristles, the smallest interquartile range and the ratio of the extreme variants were recorded (see Fig. 1). Animals of the Kemerovo breed were distinguished by similar characteristics.

After calculating the Kruskal-Wallis criterion, it was found that the breed factor affects the amount of copper deposition in the bristle of pigs ($p < 0.001$), if we evaluate the three breeds together. There are significant differ-

Содержание меди в щетине свиней некоторых пород, районированных в Западной Сибири, мг/кг
The content of copper in the bristles of some pig breeds zoned in Western Siberia, mg / kg

Breed	*n*	$\bar{X} \pm Sx$	*Me*	σ	IQR	lim	Extreme variant ratio
Kemerovo	26	39,4 ± 1,6	39,0	7,9	12,2	25 – 56	1 : 2,2
EM -1	18	8,72 ± 0,2	8,7	1,0	1,7	7,2 – 10,9	1 : 1,5
Landrace	21	49,2 ± 8,0	44,0	36,7	68	7,7 – 110	1 : 14,3

Note. Me - median, σ - standard deviation, IQR - interquartile range.

[10]Radostits O.M., Gay C.C., Hinchcliff K.W., Constable P.D. Veterinary medicine: a textbook of the diseases of cattle, sheep, pigs, goats and horses // Toronto: Saunders Elsevier, 2007. 2180 p.

ences in the pairs SM-1 - Kemerovo breed and SM-1 - Landrace breed ($p < 0.001$). Analysis of the data obtained indicates interbreed differentiation in the concentration of the studied chemical element in the bristles, which is a factor confirming the role of heredity in the predisposition and resistance to copper accumulation in the bristles of pigs.

In fig. 2 shows the similarity between the considered breeds of pigs in terms of the copper content in the bristles. It was found that the Kemerovo and Landrace breeds are more similar in comparison with animals of the early maturing meat breed.

Studies have established the hereditary determinism of the accumulation of chemical elements in organs, tissues and derivatives of the skin of farm animals [15, 19].

CONCLUSION

Interbreed differences in the accumulation of heavy metals in derivatives of the skin of pigs of breeds zoned in Western Siberia have been established. Indicators of the presence of copper in the bristles of pigs of early maturing meat, Kemerovo and Landrace breeds were 8.7; 39.0 and 44.0 mg / kg, respectively. The influence of the rock on the metal accumulation process was established ($p < 0.001$). Indicators on the content of copper in the bristles of pigs of various breeds, zoned in the territory of Western Siberia, can be preliminarily used as a physiological norm.

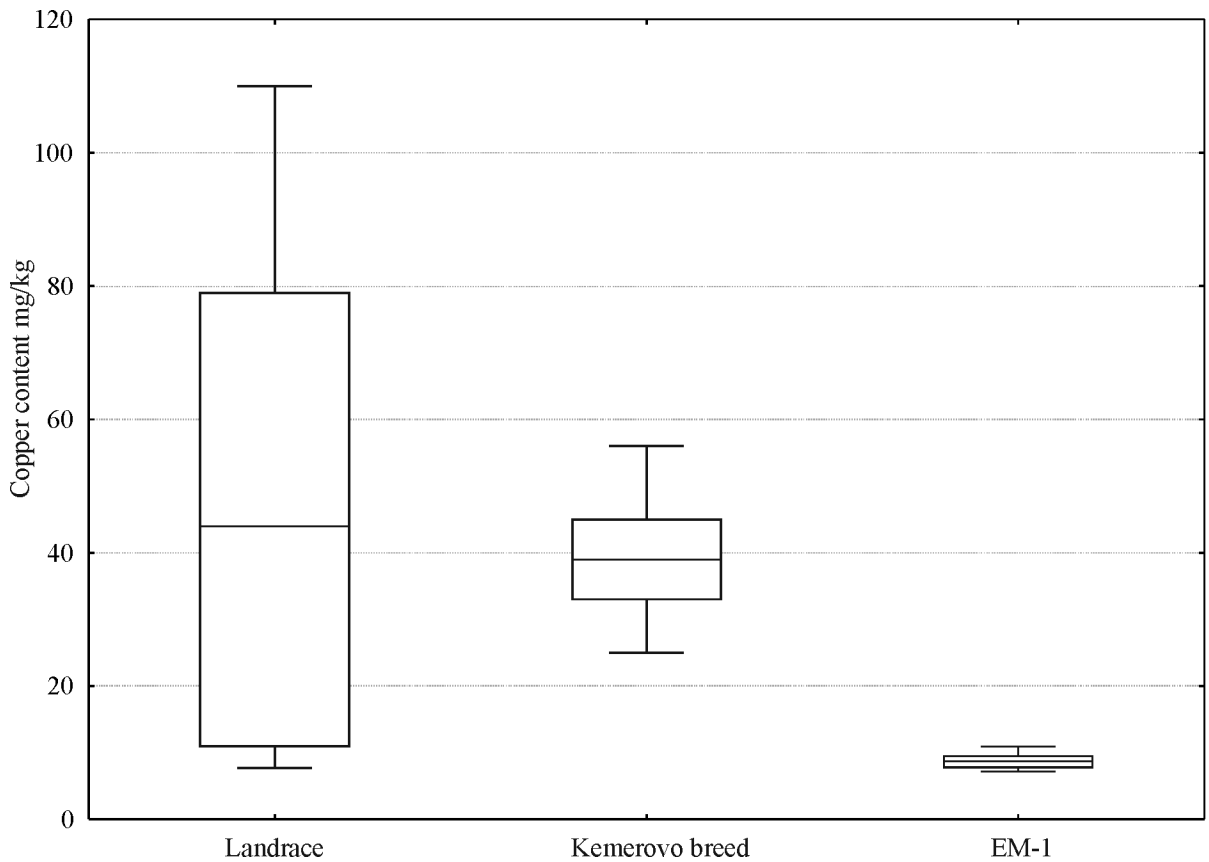

Рис. 1. Диаграммы размаха содержания меди в щетине свиней некоторых пород

Fig. 1. Diagrams of copper content range in the bristles of some pig breeds

[11]Puls R. Mineral levels in animal health: diagnostic data. Canada: Trinity Western University Press, 1988. 240 p.

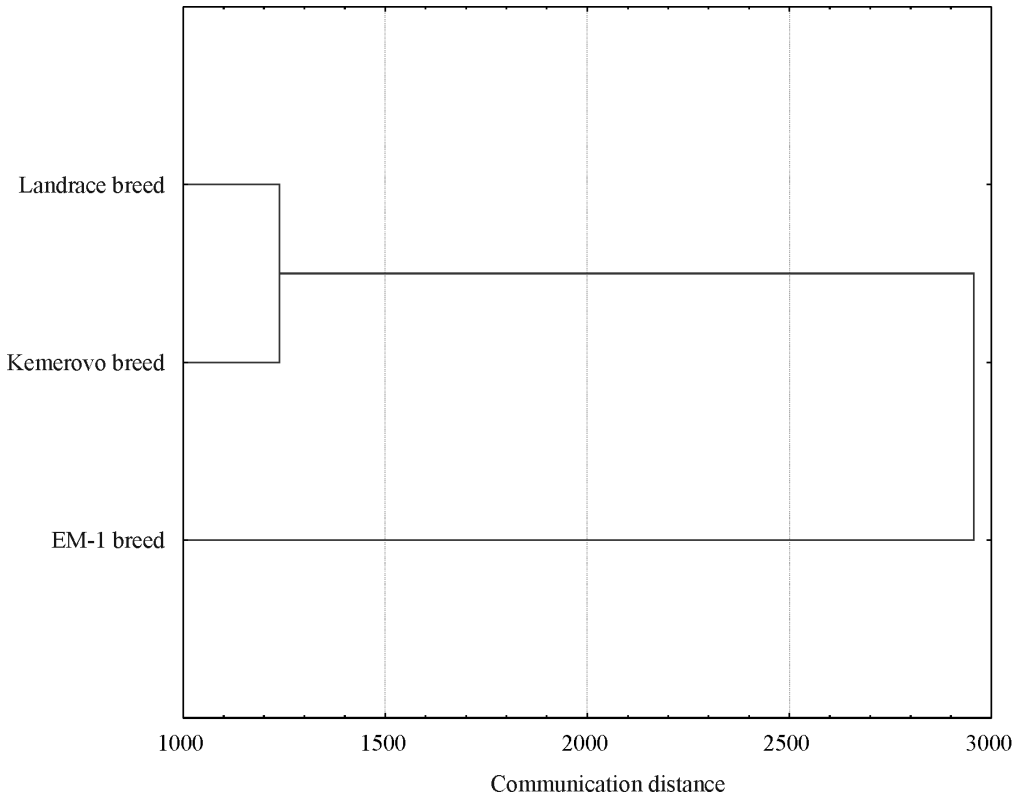

Рис. 2. Дендрограмма межпородного сходства содержания меди в щетине свиней
Fig. 2. Dendrogram of interbreed similarity of copper content in pig bristles

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Дата поступления статьи 21.12.2020
Received by the editors 21.12.2020

https://doi.org/10.26898/0370-8799-2021-1-12
УДК: 631.1:004.04
Тип статьи: обзорная
Type of article: review

К СОЗДАНИЮ МЕТРИЧЕСКОГО ПРОСТРАНСТВА ОБРАЗА СЕЛЬСКОХОЗЯЙСТВЕННОГО ОБЪЕКТА

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Представлен анализ различных подходов к прогнозированию сложных многофакторных систем в условиях неопределенности внешних условий. Данные подходы необходимо развивать с целью создания адекватных моделей сельскохозяйственной деятельности для целей ее эффективного планирования и управления. Отличительная особенность сельскохозяйственного производства – критическая зависимость от факторов внешней среды, которые не поддаются точному прогнозированию. Используемые для решения данной задачи в настоящее время регрессионное моделирование и анализ временных рядов в сложных случаях не дают адекватный прогноз динамики сельскохозяйственного объекта. В качестве подхода предлагается использовать построение «образа» системы. Данный подход относится к «природоподобным», так как моделирует способ принятия решения специалистом на основе накопленного опыта и интуиции. Ключевым параметром этого построения будет корректный выбор метрики (системы координат). Данный подход проиллюстрирован примером создания образа двухмерного явления в одномерной системе координат. В результате под образом понимается изображение реальности в векторном пространстве определенной размерности. Образ в представлении авторов – отображение реальности в искусственно созданной метрике, более доступное пониманию и анализу, но сохраняющее основные (важные) черты и функции исходного объекта. Методы искусственного интеллекта можно рассматривать в качестве инструментов для создания и анализа образов. Важной характеристикой образа является его прогностическая сила, т.е. возможность для использования образа с целью прогнозирования состояния реального объекта в будущем периоде. Образ сохраняет свою прогностическую силу, если прогноз, полученный с использованием данного образа, соответствует данным, полученным при наблюдении за реальным объектом. Образ формируется в подходящей метрике для решения конкретной задачи. Ключевым метрическим параметром образа сельскохозяйственной деятельности, пригодного для целей прогнозирования, является минимальная размерность используемого векторного пространства, при котором сохраняется прогностическая сила образа для решения поставленной задачи.

Ключевые слова: образ системы, моделирование процессов, прогнозирование, искусственный интеллект, размерность метрического пространства

CREATION OF THE SPATIAL METRIC FOR THE IMAGE OF AN AGRICULTURAL OBJECT

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The analysis of various approaches to forecasting complex multifactorial systems in conditions of uncertainty of external conditions is presented. It is necessary to develop these approaches in order

to create adequate models of agricultural activities for their effective planning and management. A distinctive feature of agricultural production is a critical dependence on environmental factors, which cannot be accurately predicted. Regression modeling and analysis of time series used at present to solve this problem in difficult cases do not result in an adequate forecast of the dynamics of an agricultural object. As an approach, it is proposed to use the construction of the "image" of the system. This approach is classified as "nature-like", as it simulates a way of decision-making by a specialist on the basis of accumulated experience and intuition. The key parameter of this construction will be the correct choice of the metric (coordinate system). This approach is illustrated by an example of creating an image of a two-dimensional phenomenon in a one-dimensional coordinate system. As a result, an image is understood as an image of reality in a vector space of a certain dimension. The image in the authors' view is a reflection of reality in an artificially created metric, more suitable for understanding and analysis, but retaining the main (important) features and functions of the original object. Artificial intelligence techniques can be seen as tools for image creation and analysis. An important characteristic of an image is its predictive power, i.e. the ability to use the image in order to predict the state of a real object in the future period. An image retains its predictive power if the forecast obtained using this image corresponds to the data obtained when observing a real object. The image is formed in a suitable metric for solving a specific problem. The key metric parameter of the image of agricultural activity, suitable for forecasting purposes, is the minimum dimension of the vector space used, at which the predictive power of the image is retained to solve the problem.

Keywords: system image, process modeling, forecasting, artificial intelligence, spatial metric dimension

Для цитирования: *Куценогий П.К., Каличкин В.К.* К созданию метрического пространства образа сельскохозяйственного объекта // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 99–109. https://doi.org/10.26898/0370-8799-2021-1-12

For citation: Kutsenogii P.K., Kalichkin V.K. Creation of the spatial metric for the image of an agricultural object. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2021, vol. 51, no. 1, pp. 99–109. https://doi.org/10.26898/0370-8799-2021-1-12

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

The creation of an image of an object, process or phenomenon in science is associated primarily with two disciplines - modeling and forecasting. It is believed that all cognition is modeling [1, 2]. A model is an artificially created system that reflects the similarity of structure and function to the original system, but which always simplifies and distorts the original. At the same time, simplification is necessary due to a great complexity of the agricultural system and the accumulated knowledge about its functioning. The adequacy of models of agricultural systems is limited by the complexity of the mathematical description and their nonstationarity, which manifests itself in their evolution in time. Consequently, model and modeling, regardless of methods (approaches), are of limited value and diffusion. To this it should be added that modeling is developed in the academic environment and is poorly used by production specialists. Mathematical modeling of agricultural processes and objects (for example, the management of the production process of plants) is, in fact, a “thing in itself”.

In turn, computer modeling is currently developing towards the processing of big data and their visualization (creation of images), since it is this process of data transformation that is most easily perceived by a person [3]. Within this paradigm, virtual reality (VR) and augmented reality (AR) technologies are most promising in simplifying the process of per-

ception and understanding of data, as well as decision support processes [4]. At the same time, according to N.N. Shabrov[1], the solution of extraordinary problems cannot be provided with a set of previously developed multipurpose models due to their inadequacy or ineffective scaling of computations. Solving such problems requires the development of unique models and equations of state of the object, as well as the development of numerical solution schemes. In this regard, simulation is carried out using supercomputers. Simulation on supercomputers generates ultra-large-scale amounts of data, the analysis and interactive visualization of which in virtual environment systems in real time, in turn, also requires the use of supercomputer computing. The amounts of data on the petabyte level (10^{15} bytes) are created in the process of simulation with computing systems performance on the level of petaflops (10^{15} operations per second). At the same time, to visualize volumes of data of the Petabyte level, both new technologies for analysis and visualization of results are required, as well as new software and hardware visualization tools[2].

In Russia, a national technological platform is currently being formed for the creation and development of supercomputer technologies, even of the exoflop class [3]. However, it is worth assuming that in the near future the solution of agricultural problems (note that they are extraordinary) is hardly possible on this technological platform. Business and the state are interested in it, but at present there are no researchers in Russia capable of solving this problem at a high professional level (agricultural science and education have not prepared such researchers).

The creation of forecasting methods is one of the main problems of science, and perhaps the most difficult of them. The most common forecasting in agriculture is based on the use of a factorial regression model [5–7]. However, it is impossible to include all the factors influencing the studied indicator, for example, the yield of crops in any regression model. Firstly, some of the factors are generally unknown, since our knowledge does not have the status of absolute truth. Secondly, some of the factors are theoretically known, but in practice there is no sufficiently reliable information on them. Thirdly, if the number of well-known factors is large, then all of them cannot be included in the regression equation based on mathematical constraints (excess of the number of factors over the sample size, multicollinearity [8, 9], heteroscedasticity) [10, 11].

Another common method is time series analysis, in which forecasting is carried out according to the trend [12-14]. This method also has disadvantages, namely: the implicitness of the dynamics factors hidden behind the "period number" deprives the researcher of the opportunity to take into account the expected leap in the development of a particular factor. It is not possible to simulate different forecast options for different combinations of factor values, which is usually done when doing the forecasting using a regression model with controlled factors. The outlook for the trend has the traits of fatalism, as it were.

Consequently, regression modeling and analysis of time series in difficult cases do not provide an adequate forecast of the dynamics of an agricultural object. Nevertheless, a person makes decisions and most often they turn out to be successful. Something faintly perceptible, intuitive, not subject to strict formalization prompts a person to make the right decision. In our opinion, this intuitive, created by the subjective experience of a person, appears in his head as a certain image of the result of an action, and the action itself appears as an image.

[1]Shabrov N.N., Kiev V.A., Kuzin A.K. Virtual environment systems - key technologies for analyzing the results of supercomputer modeling // Supercomputer days in Russia: conference materials, 2015. pp. 428–435.

[2]Shabrov N.N., Orlov S.G., Kuzin A.K., Suetov A.E. Parallel computer technologies in virtual environment systems. Goals and objectives // Supercomputer technologies in science, education and industry: materials of the conf. M.: Publishing house of Moscow State University, 2011. P. 669–671.

The axiom of understanding the image in modern philosophy and psychology has been the definition of the image given by G.V. Hegel[3], "... reveals to our eyes not an abstract essence, but its concrete reality ...". In cognitive science, an image is understood as "a representation in the mind of a non-present object or event" [15]. The main task of the image is to preserve the events and phenomena of reality in the memory in the form of some kind of "picture in the head", "projection of the scenes from the real world".

From the point of view of using an image as a publicly available tool, and not just a "picture in the head" of an individual subject, the definition "projection of a scene from the real world" is more appropriate. This projection is always carried out in some metric. For example, cinematography of the last century (not 3D) is a projection of a visual image onto a flat screen, i.e. a two-dimensional image of a three-dimensional world. The same applies to the art of painting. If an image is a "picture" corresponding to some original, then the dimension of the space of the picture and the dimension of the space of the original do not necessarily coincide at all. Nevertheless, the image that is required and has practical significance should allow one to get an adequate idea of the original and have a predictive power. In other words, an adequate image reflects the characteristics of the original necessary for forecasting, or in another way: it is possible to accurately (with acceptable accuracy) identify the original on the basis of the image. So, from a photograph, you can identify a person with almost 100% probability by the signs of their appearance, although a photograph is a two-dimensional image, and a person's appearance is a function of three-dimensional space. Moreover, identification can be made close to 100% from black and white photography, although a person's face has the entire color spectrum. This example shows that for the "identification" function, it is sufficient to create an image of an object in space, the dimension of which is much less than the possible dimension of the space required for an accurate description of the object.

The same should be applied to the description of agricultural activities. For an accurate and full-scale description of such processes, a multiparameter (multidimensional) description is required. There is a huge variety of interacting factors that ultimately lead to the final result of the activity. Taking into account all possible factors, much less, their accurate forecasting, is an unsolvable task. However, is it really necessary to create the most detailed possible image in the most complex and complete metric to adequately describe the situation and predict the result?

The purpose of the study is to determine the image of an agricultural object as a tool for adequate forecasting, to consider the concepts of the required and possible detailing of the image based on the specifics of the problem being solved and to determine the key metric space of the created image.

In psychology, the image is understood as a reflection of reality in the form of an integral structure, which becomes the content of the human psyche. This nature-like and anthropocentric approach can be developed by modeling images of real objects as it happens in artificial neural networks. However, there is also a slightly different approach. An object model is created in order to predict events associated with a given object that have never actually occurred, based on previous similar or analogous experiences. It should be emphasized that if an exact repetition of the conditions of an experiment is possible, as postulated in physics, then it is possible to accurately predict the result of a given experiment solely on the basis of experience. If the repetition of the experimental conditions is impossible or these conditions are initially underdetermined, then in any case it is necessary to build a model with a number of assumptions and predict the result based on this model. Thus, another definition of an object's image is a model that allows one to predict the state of a given object with an acceptable degree of accuracy (reliability).

[3]Gegel G.V. Aesthetics. T. 1.M.: Art, 1968.311 p.

The second (physical) definition of "image" intersects with the first in the part in which the image, which is a reflection of reality in the human psyche, as well as the numerical model, is subject to "improvement" as knowledge about the object is accumulated. Simple examples are appropriate here. One person's first impression of another person is an image that predicts behavior. What can you expect from this particular person in a given situation? As the experience of interacting with a person in various situations is accumulated, the first impression may turn out to be erroneous, and a more perfect model of prediction (the image of another person's personality) appears, which offers more accurate options for behavior in certain situations. The example with human behavior is quite typical, since it describes a very complex object with a large number of factors affecting the final result.

The image or "predictive model" of agricultural activity unambiguously refers to the activity that occurs under the influence of a large number of factors that have a critical impact on the final results of the ongoing processes, while a number of factors are subject to strong variability, others are generally undefined. Agricultural activity is associated with the life cycles of biological objects: plants and animals. The development and death of these biological objects depends both on the properties of the objects themselves, encoded in the genome, and on external conditions. One of the most significant external conditions that determine the development of plants is the weather in the form of a set of meteorological indicators: temperature, illumination, precipitation, wind speed, etc. It is important to realize that the concept of "weather" hides a very wide range of parameters of the state of the atmosphere, hydrosphere and soil at the point of measurement and at the point in time when measurements are taken. Often, when trying to create a predictive model of agricultural activity, they try to find a way to predict the weather for the period for which it is necessary to obtain a forecast of crop yields. Long-term weather forecasts are always values obtained with some degree of probability. Another factor to take into account: the current weather conditions at the time of observation (current experiment) will never be exactly the same. From the point of view of physical modeling, this means that it is impossible to reproduce the conditions of the experiment in order to verify the truth of the observations made at the current stage. It is not just the fact of the presence of difficultly predictable conditions that is important, but the fact of the underdetermination of these conditions that is important, since the only thing that is known for sure is that these conditions (especially in the time base) will never be repeated.

Any end result that we want to achieve can be represented in the form of an image. In fact, depending on the "completeness", the image allows simulating the result in the process of a mental (for a person) or numerical experiment in the case of creating a numerical virtual image. The image is placed in the boundary conditions that meet the expectations and produces a predictive result. Just like a person who can navigate in an environment that is not entirely familiar to them, relying on accumulated experience and the corresponding logical constructions, researchers expect the result that most closely matches the observed reality in the presence of incomplete or underdetermined boundary conditions from a qualitatively constructed image. The more "complete" the image being created, the less requirements it will impose on the number and accuracy of the input parameters used. From the point of view of human activity, this is what is called "experience."

An image is an artificially created reality that we should strive for (or should we predict?). Or is it a model with predictive power? By the concept of an image we mean the existing picture, which, being supplemented by conditions (assumed), gives the expected result. A correctly created image should be minimally sensitive to the accuracy of determining conditions in the future periods. How do we define the "quality" of an image? After an event occurs, reality can be correlated with a forecast. The conditions are no longer modeled or predicted, but have occurred in fact. In this situation, the observer

has the actual value of the projection and can compare it with the prediction based on the prebuilt image. The better the match, the better the image will be created. If the match does not fit into the specified range, the image will be corrected. There is an accumulation of experience, in accordance with which the image is corrected. Ideally, the image tends to a certain limiting case, when further accumulation of experience no longer leads to a more accurate description. The accuracy of predictions no longer increases with the number of tests performed and the number of adjustments made. This may also be due to the underdetermination of the conditions in which physical reality exists, the image of which is created by the researcher. In this case, the image must be accepted as adequate to reality to an achievable extent, and it is to this image that the researcher (observer) strives.

This approach is similar to the one used to "train" neural networks in machine learning. In this case, a neural network can be considered as a model capable of predicting the result of interest to the researcher after a certain setting or training. Within the model, certain degrees of freedom remain, namely: the weighting coefficients of signals transmitted from one layer of the network to the next in order to activate the functions of virtual neurons of the next layer. Given a sufficient number of training examples, i.e. sets of conditions and known results corresponding to these conditions, training takes place, which is the selection of weight coefficients so that the model adequately reproduces the entire array of training examples. We will dwell on the degree of adequacy below. Now let's consider the case when the training fails to complete successfully. There may be several reasons for this:

– insufficient number of training examples. It is not difficult to test this hypothesis if there is a possibility of further accumulation of experience. If it is possible to continue experiments in new conditions and as experience is gained, the accuracy of subsequent predictions increases, then the model (image) is adequate, but initially there was not enough data. As data accumulates, the image (model) is refined, but up to a certain limit inherent in the very structure of the image or model. Further data accumulation becomes redundant;

– inadequacy of the very structure of the image or model to the task at hand. If the accuracy of the predictions does not increase with the accumulation of data, it is necessary to modify the model itself. Probably, initially there are not enough degrees of freedom in it or they are inadequately defined;

– it is possible that the problem, in principle, cannot be solved with the help of some kind of modeling, or there is no adequate image describing the reality in the conditions essential for the process. This result arose, most likely, due to the initially high expectations of the researcher from the created image and an incorrectly formulated problem.

Let's consider this problem in more detail. The key question is the following: how detailed should and can be the image that we strive to create to simulate real physical or biological processes? The paradox, but in this case, "better" can be "worse". The predictive power of an overly detailed image may be obviously worse than that of an image with a lot of assumptions and generalizations. In the field of artificial intelligence and machine learning, this paradox is described in terms of "overfitting model". Let's explain the essence of the problem with an example.

Let's imagine that it is necessary to determine the personality of a person from a photograph. You can have a very clear, detailed digitized photograph and build upon it. Based on this photograph, we create a detailed digital image of this person, taking into account all the details of the existing photograph. Then, to identify a person, it will be necessary to take exactly the same photo, in the same angle and resolution. Most likely, it will not be possible to accurately reproduce the picture, and the machine algorithm will assert that any of the photographs presented does not correspond to the original, including photographs in which a person is captured from the original photograph used as the original image or model. This

very accurate model has a predictive power of zero, since it will give a negative answer with a 100% probability when identifying any person (including the correct one).

Now let's try to "rough" the image, using not all the data of the digitized photograph. We will develop a system of ratios describing the main features of the face: the ratio of the length of the nose to the distance between the tip of the nose and the chin, the ratio of the width and height of the forehead, the ratio of the length of the mouth and the distance between the eyes, etc. Having identified, for example, 100 such parameters that can be determined from photographs of a person, in fact, we will create a new metric in which the photograph can be transformed. Once the snapshot is encoded in the new metric, the amount of data used and stored is drastically reduced. To create an image of a person's face in the new metric, it is better to use not one accurate high-resolution image, but many images, albeit of poor quality. The use of multiple images will allow you to take into account the features of the facial expressions of each individual person when photographing. The dimension of the metric can be 100, and it can be more or less. The larger the dimension, the more accurately we will cut off incorrect images. However, we can immediately say that even a very rough model or image gives a nonzero probability of obtaining the correct result: with some finite probability, such an image will correspond to the real sought-for person. Since the probability of finding the correct person in the case of an overtrained model is immediately estimated by us as equal to zero, any finite probability of getting the correct answer is infinitely better in terms of the predictive power of the image or model. In the given example, it can be seen that a rough image can be significantly better than an attempt to create an accurate image as applied to a specific task.

It follows from the above that the image we are striving for is not an idealized description that is as close as possible to the picture of the world we represent, but the model that, when adequate boundary conditions are imposed on it, will give the predicted value of the quantity of interest with the maximum possible (permissible) accuracy. From this point of view, the determination of the limits of the minimum permissible limits of the spread of predicted values in relation to a specific problem is the most important issue to be solved when constructing predictive images or models.

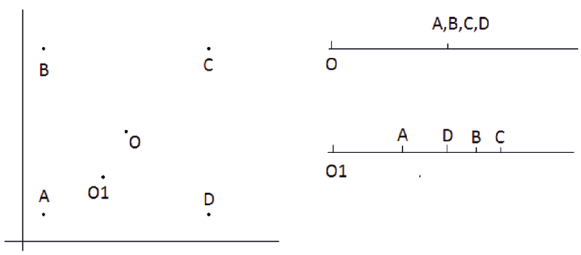
The process of “coarsening” an image for the purposes of its practical use can be represented in the form of a formal mathematical problem of finding the minimum possible dimension of the space for representation. Some authors [16] describe as a way of visualizing an object from n-dimensional space, its projection into a space of a lower dimension. In fact, this is the only practically working approach. So, when we talk about "visualization", we mean that the image can be presented in a graphical representation that is convenient for perception. However, a person is able to visually perceive objects in the form of two- and three-dimensional images. It is quite difficult, even with a highly developed imagination, to imagine a four-dimensional object. The next visualization task when choosing a projection into two- or three-dimensional space is the choice of a metric in which the observer can adequately assess a real (multidimensional) object, seeing only its “image” or projection into a space of a lower dimension. In the cited work [16], the measure of adequacy is assessed by such a criterion as the ability of the operator of a complex technical system, described by many parameters, to correctly assess its technical condition and retell, if necessary, the occurrence of an emergency situation. In this case, we have a specific application of the predictive power of the image. The system is generally described in n-dimensional space: the number of parameters, each of which can be measured in a wide range of values, is quite large. The system operator is able to quickly perceive only the two-dimensional image displayed on the display. The correct choice of the axes (two-dimensional metric) of the image will allow the operator to distinguish in this picture a situation that predicts the possible emergency behavior of the system.

The criticality of the choice of the metric for the purpose of using the image in the fu-

ture for solving practical problems can be illustrated by an elementary (naive) example. The figure shows 4 points (objects) A, B, C, D in the original two-dimensional space. It is proposed to choose a metric for one-dimensional representation of objects. Let us choose as a metric the distance of each of the points to some center O. If, as a reference point, we select a point O in the center of the square formed by the points ABCD, then in the new one-dimensional space it will be seen that all objects are equidistant from O. Therefore, in the original (true) space, you can arrange objects on a circle. However, information about the equidistance of points along the circle will be lost, which is an example of the cost of reducing the dimension of the image in comparison with the original representation. This fact indicates that the choice of a metric for creating an adequate image also depends on the formulation of the problem for the solution of which the image is created.

Let's consider this elementary example from the point of view of incorrect choice of metric for creating an image in n – 1-dimensional space. If you choose not point O, but point O1 as the starting point of the new metric, the display of objects in the new space will look like a strange distribution, in which it is difficult to see the system and draw any conclusions about the objects in the original representation.

The described example is not an image of the future of the system, but an image of its present state, which makes it possible to reflect



Пример создания одномерного образа расположения четырех объектов в двухмерном пространстве

An example of creating a one-dimensional image of the location of four objects in two-dimensional space

the main features associated with the development of the situation, or with the dynamics of the development of the system in a certain time perspective. It is this approach that makes it possible to move on to predicting the behavior of complex systems in the future.

As noted above, a complete forecast in the initial metric (reference coordinates of the description) becomes impossible due to the abundance of factors, some of which cannot be taken into account. Simplification of the metric while preserving the possibility of identifying the image is the ability to take into account precisely important and significant factors, including those that critically affect the behavior of the system. By simplifying the picture, it is possible to preserve the predictive power of the created image.

The image is formed on the basis of knowledge about the potential capabilities of the object, immersed in conditions. In general, the forecasting problem can be formulated as obtaining an image of a finite system for a time point T, having a certain set of data about the system at times preceding time T. The concept of an “image” is inextricably linked with the concept of an “observer”. When it comes to forecasting, very specific parameters of the image of interest to the observer are important. If we are talking about a picture, he is interested in portrait similarity with the desired object or subject, about agricultural activity - for example, the possible expected yield of specific crops and the necessary actions to obtain it. We are talking about an image in a specific "metric" or coordinate system. This is where the “observer” arises, since the image is created in accordance with the technical assignment of the observer and includes parameters that are important to him. The observer is interested in a specific forecast for specific parameters of the system. The choice of the optimal metric occurs precisely for the purpose of solving the problem posed by the observer. If the task is to create an image suitable for predicting the state of the system, it is necessary to take into account how many and what parameters of the system must be described, as well as on which external conditions the dependence is critical and which external conditions can and

which cannot be adequately predicted in the time perspective of interest.

For example, the task is to obtain a forecast of agricultural activity in the future. The critical parameters influencing the result are the weather conditions of the future period, the weather conditions of the previous period and the set of agricultural technologies used for the cultivation of the studied crop. The most unpredictable parameters are the weather parameters of the future period. Accordingly, an adequate predictive model should be built in the form of an image of the future period in such a metric in order to have minimal sensitivity to changes in parameters describing the current weather.

The dimension of the image space can be limited by the dimension of the available array of source data, on the basis of which this image is supposed to be created. The problem of finding the optimal dimension, or the optimal "metric" of the image, in itself is undoubtedly important.

Almost all artificial intelligence or machine learning methods (in a narrower sense) are reduced to representing the original data array in space with a constructed metric in such a way as to reveal hidden patterns encoded in the data itself, but not obvious in the original metric. The main advantage of such approaches is that the system itself selects the metric in which the presentation looks in the most obvious way. The choice of this metric is the key task of building an image, which is illustrated in the figure.

Any final result, including the result of agricultural activity, described in the future forecast period, can be represented in the form of an image. An image is a display of reality in an artificially created metric, more accessible to understanding and analysis, but retaining the main (important) features and functions of the original object.

An image is the state of an object in the future, which is supposed to be used for prognostic purposes based on knowledge about the potential capabilities of an object immersed in conditions (for example, a separate agrometeorological resource, yield, etc.). By image we mean the existing objective reality modeled using a set of vectors. Artificial intelligence methods can be considered as tools for creating and analyzing the generated images.

When creating an image of an agricultural object (activity), there are a number of objective restrictions on the maximum permissible detailing associated with the underdetermination of the conditions in which the activity will be reproduced. The underestimation of the details (information) available to the researcher when creating the image leads to a decrease in the accuracy of the forecast based on it. An attempt to create an image with more detail than the object of research allows leads to unstable behavior of the image, inadequate conclusions based on it and an unnecessary waste of computational resources. The key metric parameter of the image of an agricultural object (activity) suitable for forecasting purposes is the minimum dimension of the space of the created image, which retains its predictive power for solving the problem.

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Дата поступления статьи 03.10.2020
Received by the editors 03.10.2020

https://doi.org/10.26898/0370-8799-2021-1-13
УДК: 631.3
Тип статьи: обзорная
Type of article: review

ТЕНДЕНЦИИ ОБЕСПЕЧЕННОСТИ ТЕХНИКОЙ АПК ОМСКОЙ ОБЛАСТИ

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Представлены результаты анализа технической оснащенности производителей сельскохозяйственной продукции мобильными энергетическими средствами и технологическими машинами в зависимости от площадей возделываемых культур. Изучены данные 2008–2020 гг. государственной статистики Министерства сельского хозяйства и продовольствия Омской области. Общие посевные площади региона составляют 2881,2 тыс. га. Отмечено незначительное сокращение площади под зерновыми культурами на 2,9 тыс. га, под кормовыми культурами на 75,2 тыс. га, или 0,14 и 13,2%, соответственно. Показано значительное изменение количественного состава машинно-тракторного парка. Отмечено ежегодное сокращение количества тракторов, кормозаготовительных и зерноуборочных комбайнов. Количество тракторов уменьшилось на 2811 ед., или 26,6%. По состоянию на декабрь 2020 г. эксплуатация 30,6% зерноуборочных и 56,7% кормозаготовительных самоходных комбайнов не превышает 10 лет. Уменьшение количества сельскохозяйственных тракторов связано с использованием минимальной технологии обработки почвы, сокращением энергетических затрат и средств для проведения агротехнических операций по сравнению с традиционной технологией. Сокращение количества тракторов и комбайнов приводит к возрастанию средней нагрузки на машину. Данная тенденция определяет увеличение сроков проведения основных агротехнических операций, что сказывается на количестве и качестве конечной продукции. Определение оптимального состава тракторного парка должно проводиться для каждого конкретного хозяйства с учетом местных условий, структуры хозяйственной деятельности и его специализации.

Ключевые слова: техника, обеспеченность, тракторы, комбайны, посевные площади

TRENDS IN MACHINERY AVAILABILITY IN AGRO-INDUSTRIAL COMPLEX OF OMSK REGION

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The results of the analysis on the assessment of technical equipment of agricultural producers with mobile power facilities and technological machines depending on the area of cultivated crops in the Omsk region are presented. The state statistics data of the Ministry of Agriculture and Food of Omsk Region were studied for the period of 2008-2020. The total cultivation area of the region is 2881.2 thousand hectares. There was a slight decrease in the area under grain crops by 2.9 thousand hectares, under fodder crops by 75.2 thousand hectares, or by 0.14 and 13.2%, respectively. A significant change in the quantitative composition of the machine and tractor fleet is shown. An annual reduction in the number of tractors, forage harvesters and grain harvesters was noted. The number of tractors decreased by 2811 units, or by 26.6%. As of December 2020, the operation of 30.6% of grain harvesters and 56.7% of self-propelled forage harvesters does not exceed 10 years. A decrease in the number of agricultural tractors is connected with the use of a minimum tillage technology, a reduction in energy costs and funds for carrying out agrotechnical operations in comparison with traditional technology. Reducing the number of tractors and combines leads to an increase in the average load on the machine. This tendency leads to increasing the terms of the main agrotechnical operations, which affects the quantity and quality of the final product. The determination of the optimal composition of the tractor fleet should be carried out for each specific farm, taking into account local conditions, the structure of economic activity and its specialization.

Keywords: machinery, equipment, tractors, combine harvesters, cultivation areas

Для цитирования: *Чекусов М.С., Кем А.А., Михальцов Е.М., Шмидт А.Н.* Тенденции обеспеченности техникой АПК Омской области // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 1. С. 110–117. https://doi.org/10.26898/0370-8799-2021-1-13

For citation: Chekusov M.S., Kem A.A., Mikhal'tsov E.M., Shmidt A.N. Trends in machinery availability in Agro-Industrial Complex of Omsk region. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2021, vol. 51, no. 1, pp. 110–117. https://doi.org/10.26898/0370-8799-2021-1-13

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

The current state of the Russian agro-industrial complex is characterized by an outdated production and technical base, lack of investment attractiveness and competition. The regional agro-industrial complex influences the economic, political and social situation in the regions; agro-industrial enterprises produce more than 70% of consumer goods for the population and one third of the gross product[1,2] [1-3].

The level of development of the agro-industrial complex is largely determined by its technical equipment, which depends on the availability and volume of purchase of agricultural machinery and energy resources, as well as on their quality. Currently, there has been a significant reduction in the number of agricultural machinery and equipment supplied to agricultural production[3] [4–6].

In the course of reforming the economy of the country and the agro-industrial complex, there was an absolute and relative reduction in the number of machine and tractor fleet (MTF), its moral and physical aging, deterioration of the technical condition, deviation of the structure of the fleet of equipment from the optimal parameters. Optimization of the quantitative and qualitative composition of MTF is the initial condition for carrying out all the necessary agrotechnical operations on the areas available on the farm within optimal agrotechnical terms with minimum costs and maximum production profitability [7–9].

For the agricultural industry, the provision of tractors and other self-propelled machines is relevant, since most of the mechanized work is carried out in crop production with mobile energy resources [10–12]. The main reason for the deterioration in the state of technical provision of agriculture is the lack of funds for the purchase of machinery and equipment, and the reduction in investment in the industry.

The provision of agricultural organizations of the Omsk region with tractors and self-propelled agricultural combines is decreasing, but the number of total sown areas remains at the same level. As a result of the low rates of renewal of MTF, the load on morally and physically obsolete means of mechanization increases. This leads to an increase in the timing of agrotechnical operations for the cultivation of crops and a decrease in the quality of products. In modern conditions, it becomes relevant to search for ways to acquire and modernize the technical provision of agriculture [13].

As of 2020, there are more than 300 agricultural organizations, 2.3 thousand peasant farms and more than 333 thousand personal subsidiary plots in the Omsk region[4]. The process of consolidation of agricultural enterprises is gradually underway. Dynamics of changes in sown areas of agricultural crops in 2008–2020. is shown in Fig. 1.

The analysis of the presented material indicates that the cultivated areas during the period under review have changed insignificantly. In

[1]Draft strategy for innovative development of the agro-industrial complex of the Russian Federation for the period up to 2020 by the Ministry of Agriculture of the Russian Federation dated 13.09.2011.

[2]State program for the development of agriculture and regulation of agricultural products, raw materials and food for 2013–2020, approved by the Decree No. 747 of the Government of the Russian Federation of July 14, 2012.

[3]Forecast of scientific and technological development of the agro-industrial complex of the Russian Federation for the period up to 2030 by the Ministry of Agriculture of the Russian Federation dated December 13, 2016.

2020, they occupied 2,881.2 thousand hectares. Areas under grain crops in 2008–2020 decreased by 2.9 thousand hectares, under fodder crops - by 75.2 thousand hectares, or 0.14 and 13.2%, respectively.

Despite small changes in the volume of cultivated areas, the quantitative composition of the Omsk Region's commercial and industrial sectors has significantly decreased over the specified period[5]. The decrease in the availability of tractors in the agro-industrial complex is due to the reduction in the livestock section. The number of wheeled tractors in operation in the agricultural sector has decreased by 2,811 units over 12 years, or 26.6% (see Fig. 2). Changes in the number of tracked tractors are not considered in this article, since in the Omsk region this type of tractors is currently practically not used, mainly due to unreliability.

The reduction in the number of equipment is also associated with its re-registration as the property of individuals. After the change of ownership, machines for the most part no longer participate in the commercial production of agricultural products. Changes in the qualitative composition of the machine and tractor fleet in most farms, as a rule, do not occur due to the financial instability of most farms and their lack of the opportunity to purchase new energy-packed, highly efficient machines to replace old ones.

A decrease in the number of agricultural tractors is associated with the transition from soil cultivation technology with soil overturning to minimal cultivation, which requires less energy consumption and the composition of energy resources for carrying out all the necessary agrotechnical operations included in the technology [14].

The machine and tractor fleet of the Omsk region is characterized by long service life of equipment and significant worn-out state. The data on the service life of various types of mobile agricultural machinery in the Omsk region are given in the table.

The greatest worn-out state is characteristic of the fleet of tractors and combine harvesters - 88.0 and 68.8%, respectively (see table).

Intensive renewal of such universal technical means as self-propelled mowers was noted.

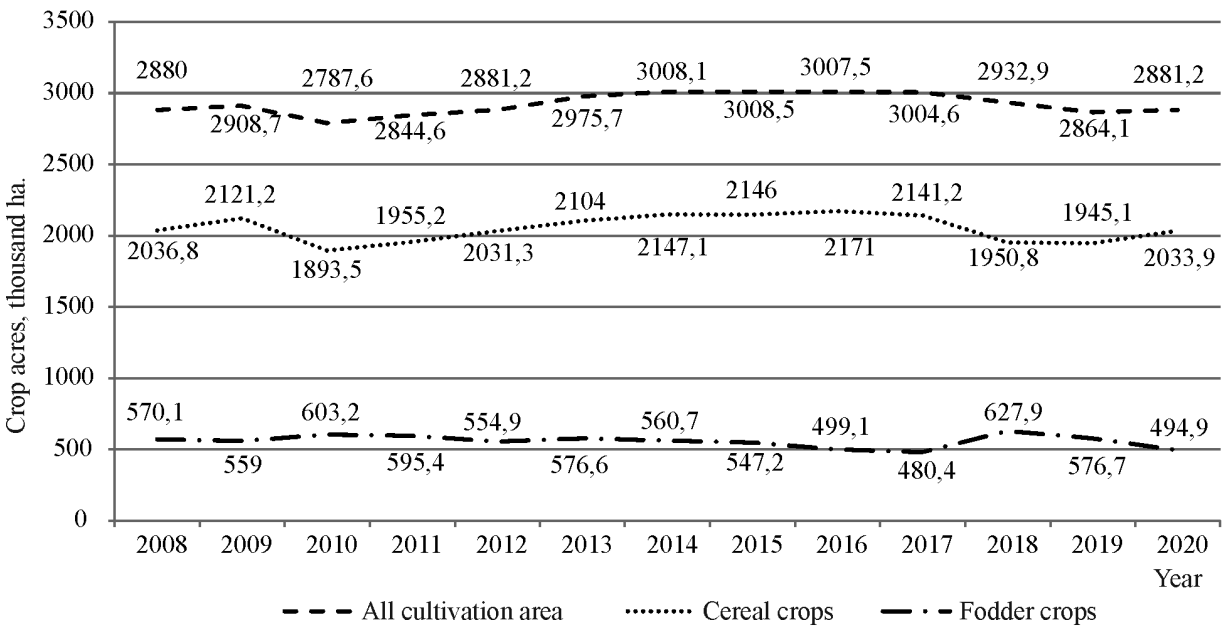

Рис. 1. Изменение посевных площадей в Омской области

Fig. 1. Changes in the cultivated areas in Omsk region

[4]Agriculture, hunting and forestry. URL: https://omsk.gks.ru/agriculture

[5]Availability of tractors, agricultural machines and energy capacities in agricultural organizations of the Omsk region as of January 1, 2019 Omsk: Omskstat, 2020.27 p.

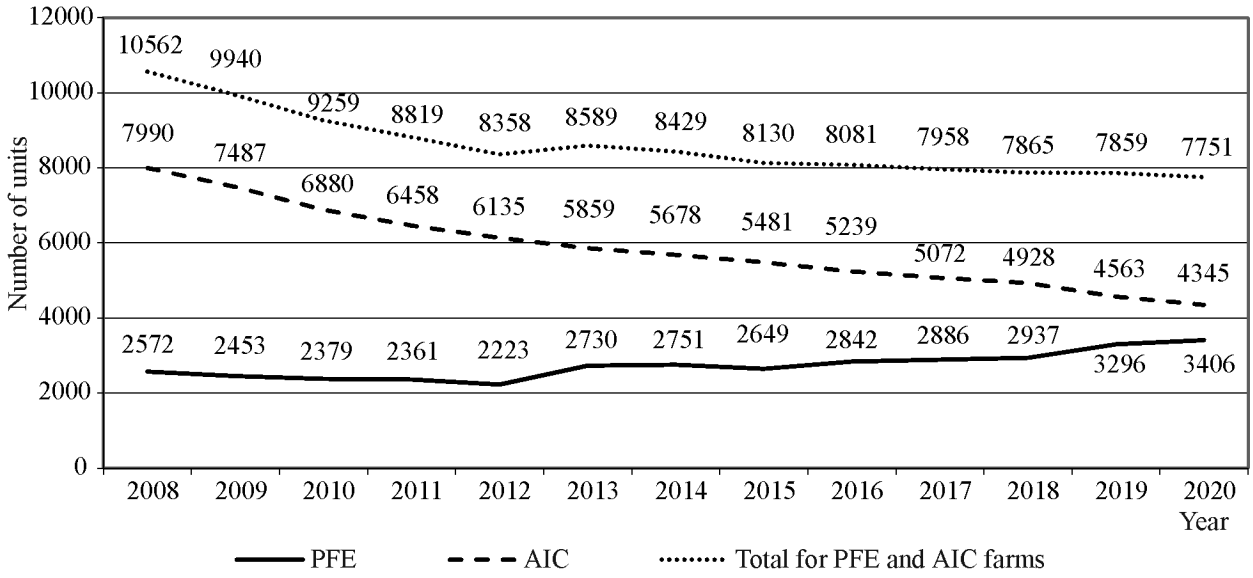

Рис. 2. Изменение количества колесных тракторов, зарегистрированных в собственности сельскохозяйственных товаропроизводителей, ед.

Fig. 2. Change in the number of wheeled tractors registered in the ownership of agricultural producers, units

Currently, there are 285 mowers in the region's farms, of which 65.1% have been in operation for up to 3 years.

With the introduction of intensive technologies into production, 126 units of high-performance self-propelled sprayers work in the farms of the Omsk region.

For tillage and sowing in the fields of the Omsk region, more than 15,000 units of agricultural machinery are used annually. (see Fig. 3).

The park of self-propelled agricultural harvesters in the Omsk region is in a more favorable condition in comparison with the fleet of tractors (see Fig. 4.).

Currently, a significant part of both physically and morally obsolete cleaning machines has been replaced. As of December 2020, 30.6% of grain harvesters and 56.7% of self-propelled forage harvesters have terms not exceeding 10 years. In this case, we can talk about a qualitative leap in the provision of farmers with mod-

Обеспеченность хозяйств Омской области мобильной сельскохозяйственной техникой (2020 г.)
Provision of farms of the Omsk region with mobile agricultural machinery (2020)

Name title	Mashinery, units.	Equipment that has served its depreciation period, units. (% to the availability)
Tractors	26229	24183 (88)
Self-propelled mowers	285	84 (29,5)
Self-propelled spraying machines	126	20 (15,9)
Self-propelled cutters	301	36 (12,0)
Combine harvesters	4788	3296 (68,8)
Including foreign production	974	318 (32,6)
Forage harvesters	274	157 (57,3)
Including foreign production	93	32 (34,4)

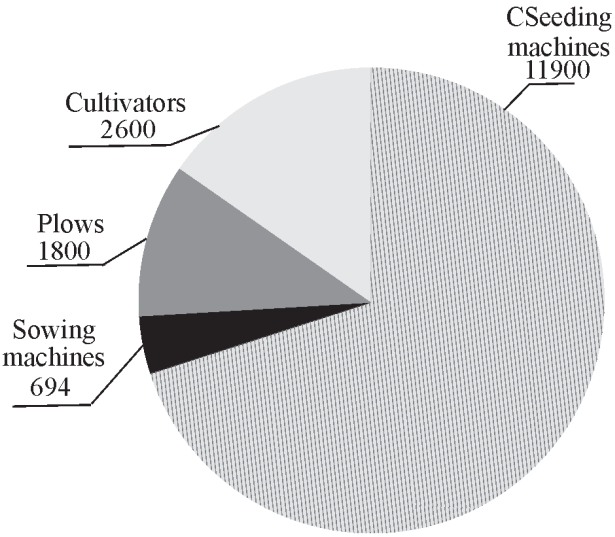

Рис. 3. Почвообрабатывающие и посевные орудия в Омской области, ед. (2020 г.)

Fig. 3. Tillage and sowing tools in Omsk region, units (2020)

ern high-performance equipment. Along with foreign equipment, domestic equipment (primarily produced by Rostselmash OJSC) [15] is also used in the fields. These machines are financially available mainly to farms located in the south of the Omsk region and specializing in grain cultivation.

Based on the analysis of data on the availability of combines among manufacturers of various forms of ownership, the load on one combine in the Omsk region in 2008–2020 is given. (see fig. 5).

The load on the combine harvester has increased from 402 to 543 hectares, while the load on forage machines has changed insignificantly (see Fig. 5).

To determine the number of mobile equipment in Western Siberia, the main criterion is the area that must be processed by one machine in the optimal agrotechnical period.

$$N = \frac{S_{\text{об.р}} \times k_{\text{т.г}}}{H_{\text{год}}},$$

The required number of agricultural machines to perform technological operations in crop production is calculated by the formula $N = S_{a.w} \times k_{t.r} H_{year}$, where $S_{a.w.}$ is the amount of work that needs to be carried out during the year, hectares; $k_{t.r}$ - coefficient of technical readiness (average values based on the results of technical inspection of the last 10 years for combine harvesters $k_{t.r} = 0.8$, for tractors $k_{t.r} = 0.7$); H_{year} - standard annual operating time for one machine or tool, ha.

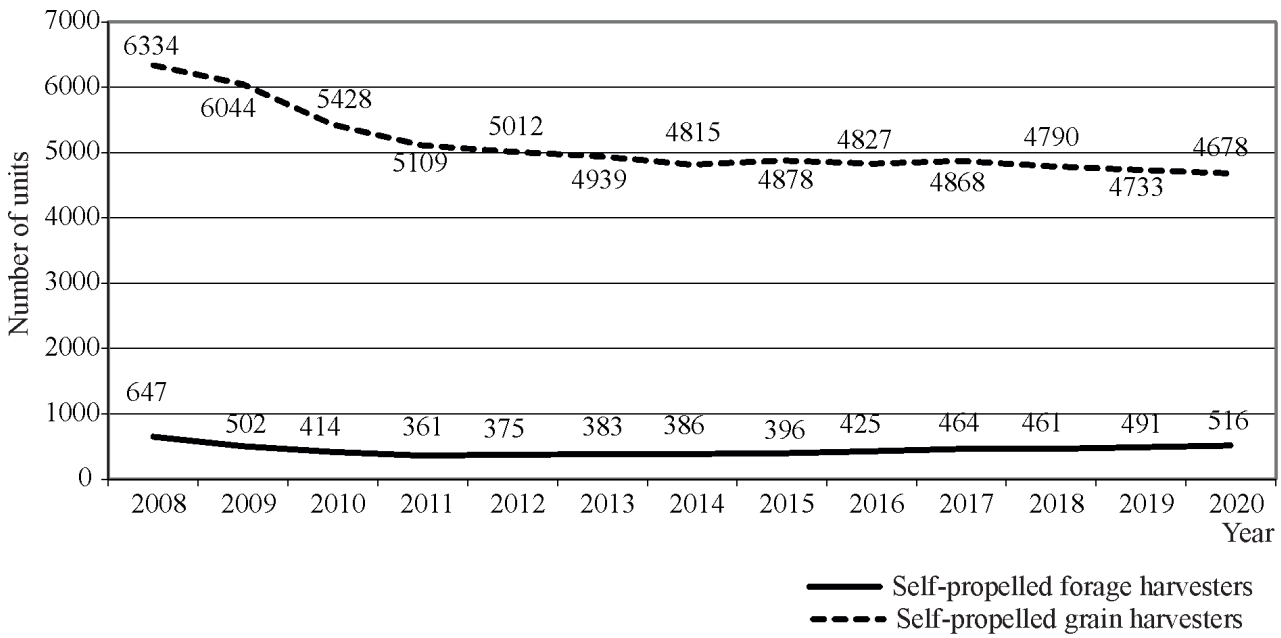

Рис. 4. Динамика изменения количества самоходных комбайнов

Fig. 4. Dynamics of changes in the number of self-propelled combines

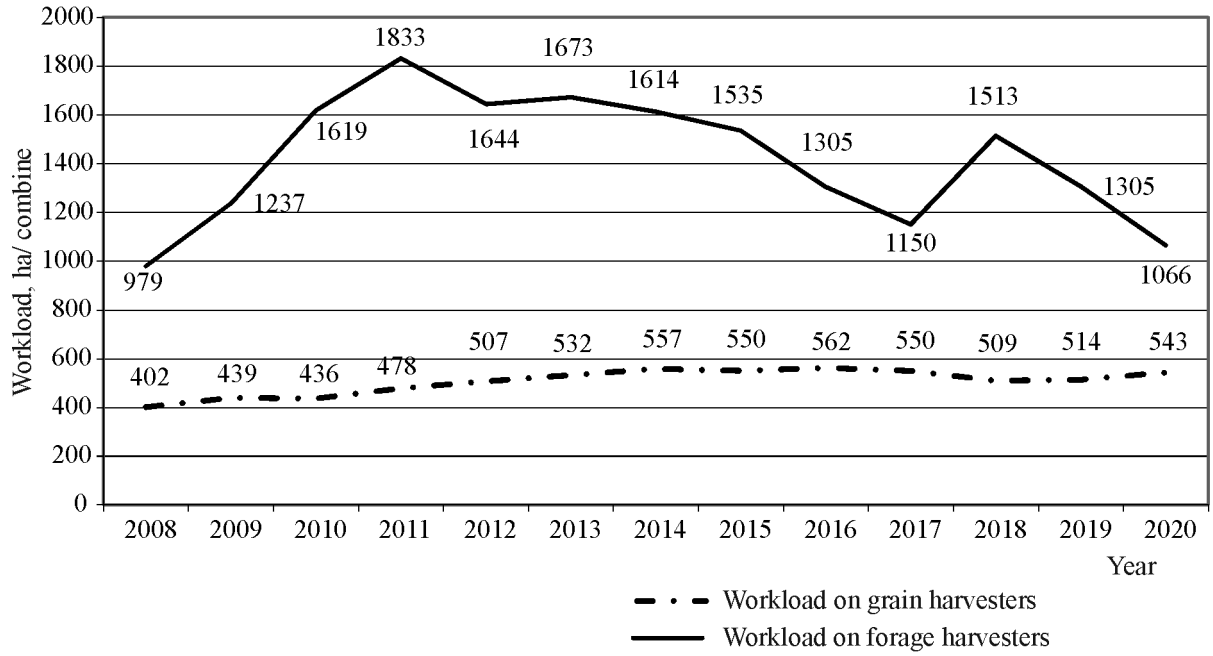

Рис. 5. Изменение средней нагрузки на самоходный комбайн

Fig. 5. Change in the average load on a self-propelled combine

On the whole, the quantity and quality of agricultural products produced, the costs of the corresponding resources and, ultimately, the economic well-being of the economy directly depend on the efficiency of using machine-tractor units. High technical equipment of the farm is the most important condition for minimizing costs, which ensures a high level of farming culture and accurate performance of technological operations in optimal terms.

CONCLUSION

There was a tendency to reduce the machine and tractor fleet in the Omsk region for 2008–2020 with a slight change in the volume of sown areas and their structure. The number of tractors used in agriculture in 2020 was 7751 units, grain harvesters - 4678 units, forage harvesters - 516 units. The reduction in the number of tractors and combines during the period under study led to an increase in the average annual load on a tractor by 99 hectares, or 36%, on a combine harvester - by 141 hectares, or 35%. This affects the timing of the main agrotechnical operations, the quantity and quality of the final product. The determination of the optimal composition of the tractor and combine harvester fleet should be carried out for each specific farm, taking into account local conditions and the structure of economic activity.

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Дата поступления статьи 21.12.2020
Received by the editors 21.12.2020