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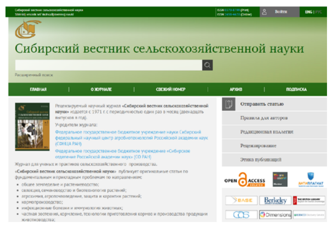

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СИБИРСКОЕ РЕГИОНАЛЬНОЕ ОТДЕЛЕНИЕ РОССЕЛЬХОЗАКАДЕМИИ НА СТРАЖЕ АГРОПРОМЫШЛЕННОГО КОМПЛЕКСА СИБИРИ (1969–2015 гг.)

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Представлена краткая историческая справка о деятельности в 1969–2015 гг. Сибирского регионального отделения Россельхозакадемии как центра научного обеспечения агропромышленного комплекса Сибири: ведущие ученые, структура отделения, территориальные научные центры, результаты работы и достижения научных учреждений, находившихся в ведении отделения, в области экономики, земледелия, растениеводства, животноводства, ветеринарной медицины, автоматизации, механизации и электрификации сельского хозяйства, переработки сельскохозяйственной продукции. Показана система подготовки научных кадров, главным звеном которой является Малая сельскохозяйственная академия. Перечислены основные направления интеграции деятельности отделения с научно-исследовательскими учреждениями Сибирского отделения Российской академии наук и вузами региона, а также направления международного сотрудничества. Рассказано о книгоиздательской деятельности отделения, научном журнале «Сибирский вестник сельскохозяйственной науки» и газете «Колос Сибири».

Ключевые слова: Сибирское отделение Россельхозакадемии, научный центр, научное обеспечение АПК, координация, ведущие ученые, разработки, патенты, авторские свидетельства, сорта, породы, технологии, интеграция

THE SIBERIAN REGIONAL BRANCH OF THE RUSSIAN ACADEMY OF AGRICULTURAL SCIENCES IS ON GUARD OF THE AGRO-INDUSTRIAL COMPLEX OF SIBERIA (1969–2015)

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A brief historical background on the activities of the Siberian Branch of the Russian Academy of Agricultural Sciences in 1969–2015 as a center of scientific support of the agro-industrial complex of Siberia is presented: the leading scientists, the structure of the branch, territorial scientific centers, the results of work and achievements of the scientific institutions under the jurisdiction of the branch in the field of economics, farming, crop production, animal husbandry, veterinary medicine, automation, mechanization and electrification of agriculture, processing of agricultural products. The system of scientific personnel training is shown, the main link of which is the Small Agricultural Academy. The main directions of integration of the branch's activities with the research institutions of the Siberian Branch of the Russian Academy of Sciences and universities of the region, as well as the directions of international cooperation are listed. The book-publishing activities of the branch, the scientific journal "Siberian Herald of Agricultural Science" and the newspaper "Kolos Sibiri" are described.

Keywords: Siberian branch of the Russian Academy of Agricultural Sciences, scientific center, scientific support for the agro-industrial complex, coordination, leading scientists, developments, patents, copyright certificates, varieties, breeds, technologies, integration

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Conflict of interest
The authors declare no conflict of interest.

The Siberian Branch of the Russian Agricultural Academy of Sciences ("VASKhNIL") was established in accordance with the Decree of the Council of Ministers of the USSR No. 867 of November 14, 1969. VASKhNIL academicians I.I. Sinyagin (Chairman), A.P. Kalashnikov, academician of the USSR Academy of Sciences D.K. Belyaev (Director of the Institute of Cytology and Genetics SB AS USSR), A.I. Selivanov, M.I. Tikhomirov, Prof. I.I. Gudilin (Rector of the Novosibirsk State Agricultural Institute) were members of the first Presidium of the Siberian Branch of the VASKhNIL.

As of January 1, 2014, the Siberian Regional Branch of the Russian Agricultural Academy had 15 full members (academicians) – A.N. Vlasenko, G.P. Gamzikov, P.L. Goncharov, V.G. Guglya, A.S. Donchenko, V.A. Zykin, I.P. Kalinina, N.I. Kashevarov, V.A. Moroz, P.I. M. Pershukovich, V.A. Soloshenko, N.A. Surin, S.N. Khabarov, I.F. Khramtsov, V.Z. Yamov; 12 corresponding members – V.V. Alt, N.G. Vlasenko, A.V. Goncharova, N.P. Goncharov, V.A. Domrachev, L.I. Inisheva, K.Y. Motovilov, Yu.A. Novoselov, R.I. Rutz, N.V. Tsuglenok, G.E. Chepurin, V.G. Shelepov; 187 doctors and 533 candidates of sciences.

The first Chairman of the Presidium of the Siberian Branch of the VASKhNIL was Academician Irakli Ivanovich Sinyagin (1970-1978). From 1978 to 1979, this position was held by Academician Alexander Nikolayevich Kashtanov. For a long time (from 1979 to 2004) the Siberian Branch of the Russian Agricultural Academy was headed by Academician Pyotr Lazarevich Goncharov. From November 2004 to 2015, the Chairman of the Department was RAS Academician Alexander Semenovich Donchenko [1].

As of the end of 2015, the Siberian Regional Branch of the Russian Agricultural Academy was a large scientific-organizational, methodological and coordinating implementation center. The branch included 31 scientific institutions, including the Siberian Scientific Agricultural Library, 7 breeding centers, and 22 federal state unitary enterprises. There were 2105 real estate objects and 616 items of movable property on the balance sheets of the institutions and organizations of the Siberian Regional Branch of the Russian Agricultural Academy, and 782,727.6 hectares of land use.

The Department participated in the scientific support of the agro-industrial complex (AIC) of 13 subjects of the Russian Federation in the Far North, Western and Eastern Siberia: Altai Republic, Buryatia, Tyva, Khakassia, Altai, Krasnoyarsk and Transbaikal Territories, Irkutsk, Kemerovo, Novosibirsk, Omsk, Tomsk and Tyumen Regions. Due to the wide variety of soil-climatic and economic conditions of the Siberian Federal District and the need for practical implementation of scientific developments in the field of agro-industrial production, seven territorial research centers were formed and successfully functioned: Tyumen, Omsk, North-Eastern, Novosibirsk, Altai, East Siberian, and Transbaikal.

During the period of activity of the Siberian Branch of the Russian Agricultural Academy 2324 certificates of authorship and patents for inventions, breeding achievements, utility models, industrial designs, 83 certificates for software products (databases and computer programs) have been obtained. The State Register of Breeding Achievements of the Russian Federation allowed for use includes 1124 plant varieties, 41 breeds and types of animals; the State Register of Protected Breeding Achievements includes 470 plant varieties, 17 breeds and types of animals, 1380 scientific developments in veterinary medicine.

In the economic sphere, concepts for the development of Siberia's agro-industrial complex and programs for the socio-economic development of the agro-industrial complex in the Republic of Buryatia, Tomsk, Chita, Kemerovo and Novosibirsk Regions have been created. Agricultural management systems were prepared and put into production both in the Novosibirsk region as a whole and in peasant (farmer) and private subsidiary farms in particular. Recommendations on the formation of rational management models in the organizations of the agro-industrial complex, including the Federal State Unitary Enterprise of the branch, the introduction of which allowed to increase the efficiency of production by 1.5–2.0 times, have been developed. Within the framework of the agro-industrial complex of Siberia the proposals and developments on regulation of price relations in agriculture, improvement of management of production and processing of agricultural products in local rural areas have been presented. Academicians M.I. Tikhomirov, V.A. Tikhonov, V.R. Boev, A.A. Vershinin, I.V. Kurtsev, P.M. Pershukevich; corresponding Member Yu.A. Novoselov; Doctors of Science V.R. Dabrasov, A.L. Balashev, E.A. Borisov, M.I.Bulychev, V.M. Gabov, M.P.Gritsenko, G.M. Gritsenko, B.S. Koshelev, I.A. Matveev, A.K. Mikhalchenko, G.A. Oraevskaya, E.A. Osipov, V.S. Potayev, Yu. G. Polulyakh, N.N. Privalikhin, D.M. Syrovatsky, L.V. Tyu, Ya.I. Cherkassky, B.I. Shaitan, I.V. Schetinina; Candidates of Science I.A. Abzaev, E.K. Andrusevich, S.K. Bessonov, M.Z. Golovatyuk, M.N. Kashmanova, A.S. Kovalenko, G.T. Korchuganova, I.T. Kuydin, V.S. Starodubtsev, and others have made a great contribution to the formation of the economic component of agricultural science in Siberia.

During the period of operation of the Siberian Branch, breeding scientists have created more than 1,560 varieties of agricultural crops, including 321 varieties of cereals and grain crops, 184 varieties of fodder crops, 31 varieties of industrial crops, 159 varieties of potatoes and vegetables, 325 varieties of fruit and berry crops, and 61 varieties of flower and ornamental crops. Computerized information and reference systems of field crop varieties, diseases and pests of crops have been developed. The effective methods of agrotechnics with the use of modern sowing complexes, providing an increase in the yield of grain crops by 18.0-20.0%, elements of regeneration and microclonal plant propagation technologies with the use of nanocomposites have been proposed. Much attention was paid to the creation of fodder base for farm animals. Scientists have improved the structures of fodder crop rotations, proposed methods of increasing the productive longevity of fodder lands, the technology of cultivation of mixed crops, which increases the productivity of 1 hectare of rotational area by an average of 23.5%.

Siberian varieties of grain and forage crops, characterized by high yields and complex stability, occupied more than 90.0% of all the crops in the Siberian Federal District. Thus, in the Novosibirsk, Kemerovo, Tyumen and Tomsk Regions, Altai and Krasnoyarsk Territories, varieties of the Siberian Research Institute of Plant Growing and Selection in varietal crops occupy more than 2.7 million hectares. Grain crops of selection of the Siberian Research Institute of Agriculture (Omsk) occupy more than 9 million ha not only in Russia, but also in Kazakhstan (more than 5 million ha, 36.9% of spring wheat sown areas). Potato varieties of the Kemerovo Research Institute of Agriculture selection were cultivated in 14 republics and 34 regions of the Russian Federation. According to the data of the Federal State Budgetary Institution "Len Agency", flax varieties of the Siberian Research Institute of Agriculture and Peat (Tomsk) had the widest distribution in Russia – 35.6% of areas were sown with fiber flax of the Tomsk selection. Annually 12-16 tons of elite flax seeds were produced, which amounted in some years to 23.0% of the all-Russian volume. The varieties of fruit and berry crops created by the specialists of the Lisavenko Research Institute of Horticulture for Siberia significantly renewed the assortment of orchards in the region and were widely spread in Russia and foreign countries. Seedling sales volumes reached more than 1.5 mln pieces per year [2].

A great contribution to the development of Siberian crop and forage production has been made by the leading scientists: academicians P.L. Goncharov, I.P. Kalinina, R.B. Kondratyev, N.A. Surin, A.I. Tyutyunnik, V.A. Zykin, N.I. Kashevarov, S. N. Khabarov; corresponding members K.G. Aziev, R.I. Rutz, A.V. Goncharova, K.P. Afendulov; Doctors of Science N.V. Barashkova, Z.V. Dolganova, M.G. Evdokimov, M.D. Konstantinov, V.P. Kuzmin, A.P. Krepkov, N.A. Lapshinov, I.E. Lichenko, A.M. Mustafin, I.Ya. Ovcharenko, G.M. Osipova, V.N. Pakul, E.I. Panteleeva, R.I. Polyudina, V.S. Saprykin, A.N. Skalozubov, V.S. Sokolov, P.I. Stepochkin, N.A. Udolskaya, R.A. Tsilke, E.R. Shukis; Candidates of Science A.M. Belykh, V.A. Benz, V.I. Bogachkov, V.A. Borodulina, L.V. Valiulina, E.G. Grinberg, N.V. Dergacheva, L.P. Dolgova, L.N. Zabelina, Yu.A. Zubarev, V.V. Kolchanov, N.I. Korobeinikov, S.N. Krasnikov, A.P. Krepkov, S.A. Makarenko, L.I. Nazariuk, V.V. Novokhatin, T.V. Plaksina, N.T. Popov, I.A. Puchkin, M.A. Rozova, A.V. Sidorov, A.I. Cheremisin, A.A. Yudin, A.V. Bakharev, L.I. Bobyleva, V.N. Gubko, G.A. Denisenko, N.E. Lyakhova, T.N. Meleshkina, G.A. Michkina, A.D. Safonova, A.N. Skalozubova and others.

In the field of farming and plant protection, research institutes of the Siberian Branch have presented over 1200 scientific developments, of which the most effective are landscape farming systems based on soil-protective contour-reclamation organization of the territory. Scientific bases of farming on flat agro-landscapes and modern resource-saving technologies of cultivation of new high-yielding varieties of grain crops providing yields of more than 3–4 tons/ha have been created. Scientific principles of adapting basic crop cultivation technologies to the weather conditions of different zones of the Siberian region have been developed, providing effective management of soil fertility resources, environmental protection, soil protection from erosion, stabilization of phytosanitary condition of agrocenoses.

Academicians I.I. Sinyagin, A.N. Kashtanov, V.I. Kiryushin, N.Z. Milashenko, A.N. Vlasenko, I.F. Khramtsov, G.P. Gamzikov, and N.G. Vlasenko; corresponding members E.L. Klimashevsky, K.P. Gorshenin; doctors of science V.B. Bokhnev, A.P. Batudaev, Yu.F. Yedimeichev, A.Ya. Zhezher, P.F. Ionin, V.K. Kalichkin, A.E. Kochergin, T.P. Lapukhin, V.T. Maltsev, Yu.B. Moschenko, A.F. Neklyudov, N.V. Orlovsky, N.E. Pavlov, S.S. Sdobnikov, N.V. Semendyaeva, N.N. Nereshkova, E.V. Titova, V.I. Usenko, V.G. Kholmov, M.E. Cherepanov, I.N. Sharkov, V.N. Shoba, A.I. Yuzhakov; candidates of science P.G. Alinovsky, N.L. Voronova, A.A. Garkusha, L.N. Iodko, Yu.P. Filimonov, A.N. Chudnovskaya, F.P. Shevchenko, V.A. Khmelev, V.V. Yakovlev et al. made a significant contribution to the development of Siberian agriculture and agrochemistry.

The works in the field of plant protection by RAS academician N.G. Vlasenko, doctos of science N.N. Gorbunov, P.P. Okhlopkov, A.I. Stepanov, V.A. Chulkina, M.V. Shternshis, candidates of science O.A. Ivanova, B.A. Malynovsky et al. are widely known.

In the field of animal breeding, scientists of the Siberian Branch have developed 23 breeds, 31 types and 15 lines of farm animals adapted to the harsh climate of the region. The Mountain Altai breed of downy goats is world famous. The selectionists of this breed were awarded the State Prize of the Russian Federation in the field of science and technology. The Altai-Sayan breed of red deer was bred for the first time in the world. Recipes of the diets, additives and premixes for different age and sex groups of animals have been developed. Technological projects of dairy, meat, pig breeding, sheep breeding and maral breeding farms have been proposed. Academicians A.P. Kalashnikov, V.G. Guglya, A.I. Ovsyannikov, V.A. Soloshenko, V.A. Moroz, Sh.A. Mkrtchan; corresponding members M.D. Chamukha, M.O. Simon, M.I. Ragimov; Ph. Simon, M.I. Ragimov; doctors of science Ts.R. Batozhargalov, V.A. Bekenev, S.I. Biltuev, Yu. M.Burdin, N.G. Gamarnik, G.M. Goncha, N.I.Gorokhov, A. P. Grishkova, I.I. Gudilin, V.S. Deyeva, A.M. Eranov, P.T. Zolotarev, Z.A. Ivanova, B.O. Inerbaev, R.V. Ivanov, V.G. Katyunov, I.I. Klimenok, G.P. Kotov, A.G. Kryuchkovsky, A.P. Kuzovlev, I.T. Litvinenko, B.I. Nikolaev, N.S. Permyakov, S.B. Pomishin, V.S. Pimenov, A.T. Podkorytov, N.P. Sadovskaya, N.O. Sukhova, I.I. Filatov; candidates of science R.Ya. Bakhmutova, I.M. Labuzova, S.S. Mongush, Yu.P. Khil, I.K. Khlebnikov et al. have made a great contribution to the development of Siberian cattle breeding.

Scientists of the Siberian Branch have created and offered to veterinary practice more than 1380 scientific developments in the field of veterinary medicine (instructions, manuals, complex technologies, systems and schemes of prevention and control of diseases of farm animals, diagnostic test systems, vaccines, bacteriophages, therapeutic preparations, breeding achievements and veterinary devices). More than 200 scientific and methodical recommendations, manuals and regulations, 80 instructions, manuals and TU, 39 veterinary preparations, 12 computer programs, certificates of registration of databases have been introduced into practice. Significance of scientific developments has been confirmed by 268 author's certificates, patents and breeding achievements.

252 candidate dissertations including 83 (32.0%) by graduate students and applicants of the Institute have been defended at the Dissertation Doctoral Council at the Institute of Experimental Veterinary Science of Siberia and Far East SB VASKHNIL/RASKHN, as well as 60 doctoral dissertations including 19 (31.6%) by the Institute's personnel.

The use of scientific developments in agricultural production has made it possible to eliminate foot-and-mouth disease and tuberculosis in cattle herds in Siberia, to practically minimize brucellosis and anthrax in animals, and to reliably prevent outbreaks of rhinotracheitis, leptospirosis, necrobacillosis, rabies, etc.

Successful solution of the most important problems of veterinary medicine is associated with the names of the academicians A.A. Sviridov, A.S. Donchenko, V.Z. Yamov, K.A. Laishev, V.A. Moroz, Yu. A. Makarov; corresponding members N.A. Donchenko, A.I. Solomakha, V.G. Shelepov; doctors of science S.I. Djupina, P.K. Arakelyan, A.F. Abramov, M.A. Bazhin, F.A. Volkov, A.G. Glotov, T.I. Glotova, G.N. Glotov, I.I. Guslavskii, S.K. Dimov, Yu.Ya. Dolnikov, I.S. Elistratov, I.N. Zyubin, R.R. Ignatiev, S.I. Isakov, I.A. Kosilov, S.V. Lopatin, V.G. Lunitsin, A.V. Lyskov, N.S. Mager, V.A. Marchenko, V.F. Martynov, I.M. Migunov, A.V. Muruev, P.M. Mitrofanov, M.P. Neustroev, P.N. Nikanorov, A.D. Reshetnikov, V.I. Semenikhin, A.V. Nefedchenko, P.N. Paskalskaya, N.I. Prokopyev, S.I. Prudnikov, A.A. Samolovovov, M.G. Safonov, G.S. Sivkov, E.S. Sleptsov, E.Yu. Smertina, P.N. Smirnov, Yu.I. Smolyaninov, N.P. Tarabukina, Yu.A. Tarnuev, I.S. Tretyakov, V.R. Filippov, B.Ya. Khajkin, A.A. Khoch, V.V. Khramtsov, A.G. Khlystunov, V.Ts. Tsydypov, V.M. Chekishev, R.B. Chysyma, V.G. Chernykh, A.M. Shadrin, N.S. Shepilov, N.A. Shkil, N.N. Shkil, Y.G. Yushkov, L.Y. Yushkova; candidates of science T.A. Agarkova, V.N. Afonyushkin, A.K. Brehm, V.N. Donchenko, O.A. Donchenko. Donchenko, E.A. Efremova, E.M. Stepanov, T.N. Samolova, G.M. Stebleva, S.V. Ionina, A.F. Kopyrin, A.S. Kim, L.A. Minina, N.E. Panova, I.I. Feldman, P.D. Shatko, M.N. Shadrina et al.

Scientific institutions of engineering profile prepared more than 500 experimental and about 140 prototypes of machinery, more than 100 devices and appliances for mechanization of agricultural processes. For example, FSUE "Omsk Experimental Plant" produced more than 30 items of modern agricultural machinery, the novelty of which is protected by copyright certificates and patents (straw choppers, cultivators, deep looseners), breeding machinery, livestock and other equipment. Modern machinery produced by OAO "Siberian Agro-Industrial House" (SC "Leader", PA "Ob", harrows "Liler-BK", etc.) was successfully used in 56 regions of Russia, in Kazakhstan, Azerbaijan, Uzbekistan, Mongolia.

Computer programs and databases of agro-industrial complex management, regulatory documents for processing of agricultural products, the concept and methodology of forming a unified information space of agricultural science on the basis of high technologies and methods of IT-industry have been developed.

The leading scientists in the engineering direction of Siberian agricultural science include academicians V.A. Kubyshev, N.V. Krasnoshchekov, A.I. Selivanov, V.V. Alt; corresponding members V.A. Domrachev, V.V. Lazovsky, G.E. Chepurin, N.M. Ivanov; doctors of science A.F. Aleynikov, V.V. Guborev, B.D. Dokin, V.N. Delyagin, A.M. Krikov, P.G. Kulebakin, V.M. Livshits, V.S. Mkrtumyan, N.E. Nemtsev, V.S. Nestyak, V.M. Natarzan, N.A. Petukhov, V.A. Stremnin; candidates of science I.D. Bukhtiyarov, M. M. Gogolev, V.S. Kozachenko, A.A. Kem, V.P. Kolinko, V.F. Kluster, A.V. Kuznetsov, B.V. Pavlov, P.A. Pylnik, V.S. Stremnin, V.S. Surilov, V.R. Toropov, M.K. Yagupov; engineers V.S. Kozachenko, V.V. Chirkov and others.

Scientists of the Siberian Branch in the field of processing of agricultural products prepared regulatory documents for new products from venison, poultry, rabbit, beef and other raw materials; for the production of sugar-containing animal feed from wheat and rye grain, granulated mixed fodder for poultry and pigs; for 40 types of national sour-milk products, drinks and low-fat animal oil. Production technologies for 30 new types of cheeses, cheese pastes and products have been introduced at cheese-making enterprises in 50 regions of Russia and neighboring countries (Ukraine, Belarus, Kazakhstan).

Leading scientists in the field of agricultural products processing are: corresponding member K.Ya. Motovilov; doctors of science S.S. Bernadzhevsky, T.I. Bokova, A.Ya. Leonov, V.G. Lunitsyn, A.A. Mayorov, A.A. Nepriyatel, L.A. Osintseva, V.V. Pankratov, E.G. Porsev, N.A. Yurchenko; candidates of science V.V. Aksenov, S.K. Volonchuk, T.T. Volf, V.V. Voronin, V.G. Ermokhin, I.V. Naumenko, A.I. Oberemchenko, A.I. Onishchenko, V.V. Tkachenko, V.A. Uglov, G.P. Chekryga and others.

In 2013 alone, scientists of the Siberian Regional Branch of the Russian Agricultural Academy created 194 types of scientific products, including 27 varieties, 1 breed and 2 types of animals, developed 24 methodological manuals, 16 guides, 24 technologies and technological schemes, 5 techniques and 4 methods, 5 computer programs, 10 databases and databanks, 7 pilot and experimental samples, 5 feed additives, 10 veterinary drugs, etc. 115 patents and certificates for scientific developments were obtained. The finalized developments of the department were implemented in 12 subjects of the Siberian Federal District (SFD), as well as in the Tyumen region and other regions of the Russian Federation. The total economic efficiency from the use in agriculture of the developments of scientists of the Siberian Regional Branch amounted to 6.8 billion rubles [3].

The system of training young scientific personnel, including several stages, was effective in the Siberian Branch. The first one is the formation of interest in natural sciences in children of early school age at the School of Young Naturalists. The next important link is the Small Agricultural Academy (SAA) with its branches. These are specialized classes with advanced study of chemistry and biology, where along with theoretical training scientific work of schoolchildren in the laboratories of research institutions of the department in the field of crop production, animal husbandry, veterinary medicine, mechanization and automation under the guidance of doctors and candidates of sciences was envisaged [4]. Subsequently, 28 of those who passed the SAA school defended candidate dissertations, 6 became doctors of sciences, including one corresponding member of the Russian Academy of Sciences.

Postgraduate educational activities were carried out in 14 scientific institutions of the Department. The number of postgraduate students at the end of 2013 amounted to 79 people.

Dissertation councils worked in the Institute of Experimental Veterinary Science of Siberia and the Far East, the Siberian Research Institute of Mechanization and Electrification of Agriculture, the Siberian Research Institute of Animal Husbandry and the Siberian Research Institute of Agricultural Economics.

Under the leadership of the Presidium of the Siberian Branch of the Russian Agricultural Academy the Council of Young Scientists, which united scientific youth from 29 scientific institutions of the Novosibirsk Scientific Center and Siberian regions, was actively working. The Council annually organized participation of young scientists in various contests of the Russian Agricultural Academy, federal and regional levels, cooperated with similar structures of the Siberian Branch of the Russian Academy of Sciences, universities of the region, held conferences and thematic seminars for young scientists, excursions and open days for students of the Moscow Agricultural Academy. In accordance with the Federal Law "On Promotion of Housing Construction Development" together with the Federal Fund for Housing Construction Development, members of the Council of Young Scientists of the Department established a housing and construction cooperative "Akademichesky" from among the employees of the Novosibirsk Scientific Center of the Siberian Branch of the Russian Agricultural Academy for individual low-rise construction of economy class housing.

In order to develop innovation processes, new forms of integration of academic science, agrarian education and production were created - agrarian research, education and production complexes (AREPC). The federal state unitary enterprises (FSUE) included in their structure functioned as demonstration sites for familiarization with innovative technologies developed by the scientists of the department, conducted practical training of production workers.

Three departments and four branches of departments of the Novosibirsk Agrarian University were established in the system of the Novosibirsk AREPC in the State Scientific and Research Institution SB of the Russian Agricultural Academy; leading scientists of the Siberian Branch were involved in teaching. Joint activities of young scientists and postgraduate students were held, pre-diploma practice was organized on the basis of the institutes of the department.

Integration of intellectual and material capabilities was the result of joint activities of the Siberian Branch with research institutions of other academies, Siberian universities, and the Ministry of Agriculture of the Russian Federation. Within the framework of the interdepartmental coordination program of fundamental and priority applied research on scientific support for the development of agro-industrial complex of the Russian Federation, the activities of the Siberian Branch of the Russian Agricultural Academy, the Russian Academy of Sciences, Siberian Branch of the Russian Academy of Sciences, as well as various structures of ministries and departments were coordinated. Agreements and cooperation agreements were concluded with 15 scientific organizations of the RAS (Institute of Solution Chemistry of the RAS, Institute of Cytology and Genetics SB RAS, Tecnological Design Institute of Scientific Instrument Engineering SB RAS, Institute of Soil Science and Agrochemistry SB RAS, Institute of Chemical Biology and Fundamental Medicine, etc.) and with more than 27 universities [5].

Work was carried out in accordance with cooperation agreements with the Altai Republic, Buryatia, Tyva, the Republic of Sakha (Yakutia), the Altai and Trans-Baikal Territories, the Novosibirsk and Irkutsk regions.

The Siberian Regional Branch of the Russian Agricultural Academy carried out international scientific and technical cooperation with 14 near and far abroad countries under 96 agreements, including China, Ukraine, Canada, France, the Netherlands, Kazakhstan, South Korea, Poland, Finland, Norway, Mongolia and others. In total, over the years of activity – with more than 40 countries of the world.

In 1971, the Siberian Scientific Agricultural Library was established on the initiative of the first chairman and organizer of the Siberian Branch of the Russian Agricultural Academy

(VASKhNIL) academician I.I. Sinyagin. Thanks to its staff, the system of information support of agrarian science and education in Siberia was developed, a library fund with a total volume of more than 650 thousand copies was formed, an electronic catalog of books and continuing editions, an electronic catalog of periodicals, an authoritative file of titles of the collective author, 42 bibliographic and 2 full-text databases with a total volume of more than 90 thousand records were created.

Since 1971, the scientific journal "Siberian Herald of Agricultural Science" has been published, which is included in the list of peer-reviewed journals recommended by the Higher Attestation Commission for publishing the main scientific results of dissertations for the degrees of candidate and doctor of sciences. More than 6 thousand scientific articles and reports have been published in 302 issues since the journal's inception.

Since 1973 the regional newspaper "Kolos Sibiri" has been published with O.P. Teploukhova as its permanent editor. Over 2300 issues have been published during this period. The volume of products of the publishing center of the Siberian Branch of the Russian Agricultural Academy in 2013 amounted to more than 600 printed sheets. These are monographs, books, scientific and technical manuals, recommendations, catalogs and other reference literature. Scientific institutions of the Siberian Branch annually presented more than 150 expositions at regional and territorial exhibitions-fairs. Only for 2006-2013 scientists of the department received 287 medals and 347 diplomas.

Over the years of the Department's existence, many scientists have been recognized by the state for their great contribution to the development of agricultural science. Winners of the State Prize of the USSR are I.P. Kalinina, M.A. Prokofiev, S.N. Khabarov, E.I. Panteleeva, F.F. Streltsov, E.E. Shishkina, O.A. Nikonov, T.M. Pletneva, A.K. Naumov, V.S. Ilyin, I.T. Skorik and others; State Prize of the Council of Ministers of the USSR – A.P. Kalashnikov, A.I. Ovsyannikov, I.T. Litvinenko, N.V. Nyushkov, M.I. Ragimov, I.K. Khlebnikov, Y.V. Kolmakov, B.S. Koshelev, N.V. Krasnoshchekov, A.R. Makarov, A.F. Neklyudov, S.S. Sinitsyn, and others; State Prize of the Russian Federation – S.S. Bednarzhevsky, A.N. Vlasenko, V.G. Tkachenko, G.V. Alkov, V.N. Tadykin, and others. For their significant contribution to agricultural practice, many scientists were awarded orders and medals: "For Merit to the Fatherland" IV degree – P.L. Goncharov, A.S. Donchenko, I.P. Kalinina; Order of Honor – P.L. Goncharov, A.S. Donchenko, I.T. Litvinenko, V.Z. Yamov, G.E. Cheparin, V.V. Alt, V.K. Lips, V.G. Lunitsyn, V.N. Nikonov, V.K. Savostyanov, and others; Order of Friendship – A.V. Goncharova, I.T. Bakhtushkin, N.A. Surin. More than 100 people were awarded honorary titles of the Russian Federation – "Honored Scientist", "Honored Worker of Agriculture", "Honored Agronomist", "Honored Inventor", "Honored Agricultural Worker", "Honored Veterinary Doctor", "Honored Zootechnician", etc.

Today it can be confidently concluded that the establishment of the agrarian scientific complex in Siberia by the government of our country represented by the SB VASKhNIL (Russian Academy of Agricultural Sciences) allowed to significantly improve the situation of Siberian agricultural production.

Despite extremely unfavorable agro-ecological conditions, Siberian agrarians, relying on the scientific developments of the scientists of the Siberian Branch of the Russian Agricultural Academy, have achieved tangible production results.

Grain yields in the regions of the Siberian Federal District reached 21.1 c/ha (Krasnoyarsk Territory). In addition to the Krasnoyarsk Territory, the "top three" include the Irkutsk and Tomsk regions with an average yield of 20 c/ha. The group with an average yield of 16.9 c/ha consists of the Kemerovo, Novosibirsk and Omsk regions. It should be noted that the highest yields were recorded in the northern regions, which indicates that Siberian scientists are conducting effective breeding work. The highest grain yield in the SFD was harvested in 2022 – 19.1 million tons, i.e. more than 1 ton per inhabitant of the district. At the same time, this indicator amounted to 5.6 million tons (2 tons per inhabitant of the region) in the Altai Territory, and 3.4 million tons (1.2 tons per inhabitant of the region) in the Novosibirsk region.

Potato yield in the Siberian Federal District amounted to 166.3 c/ha, which is higher than the average for Russia (163.5 c/ha). The highest potato yield was recorded in the Omsk region – 190.3 c/ha, which is more than 2 times higher than the lowest mark in the SFD (84.7 c/ha, Altai Republic). High yields were also recorded in Tomsk, Kemerovo regions and the Altai Territory.

The average vegetable yield in the Siberian Federal District is 243.8 c/ha, which is also higher than the average value in Russia (237.6 c/ha). The leader in this indicator is the Tomsk region, where vegetable yields amounted to 295.9 c/ha, which is almost 3 times higher than the lowest value in the SFD – 109.1 c/ha in the Republic of Tyva. Vegetable yields above the average for the federal district were recorded in six subjects of the region.

Good results were also obtained in such branch of agricultural production as livestock breeding. The largest number of cows was observed in the Altai Territory – 299.5 thousand cows. In other regions the number of cows varies from 33.6 thousand to 188.4 thousand. The size of cow population depends on a number of factors, including availability of fodder lands, material and technical support, breed composition of the herd, etc.

High productivity of cows is characteristic of the Irkutsk region and the Krasnoyarsk Territory – 5,390 and 5,355 kg, respectively, which is associated with the use by farms of the Sibiryachka dairy breed selected by the scientists of the Siberian Branch of the Russian Academy of Agricultural Sciences, which is adapted to local natural and climatic conditions. In dynamics, milk yields are increasing due to the revision of fodder base, results of selection and breeding work, improvement of herd structure and quality, ensuring animal health on a scientific basis.

Despite the reorganization of the Siberian Branch of the Russian Academy of Agricultural Sciences and the establishment of independent scientific centers, the coordination of scientific activities in Siberia continues to be successfully carried out by the Joint Scientific Council for Agricultural Sciences at the Siberian Branch of the Russian Academy of Sciences.

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ОПРЕДЕЛЕНИЕ ОПТИМАЛЬНОЙ КОНЦЕНТРАЦИИ ОРГАНИЧЕСКИХ УДОБРЕНИЙ ДЛЯ ПОСЕВНЫХ КАЧЕСТВ СЕЛЬСКОХОЗЯЙСТВЕННЫХ КУЛЬТУР НА ПРИМЕРЕ ТЫКВЫ

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Изучение эффективности воздействия полученных удобрений на посевные характеристики семян тыквы *Cucurbita pepo* L. проводилось в Центре коллективного пользования «Перспективные технологии и материалы» Севастопольского государственного университета. В работе приводятся данные о влиянии органических удобрений на основе вермикомпоста и куриного помета на посевные качества семян тыквы. Проведен сравнительный анализ по энергии прорастания и лабораторной всхожести семян, прироста корня и ростка сельскохозяйственной культуры *Cucurbita pepo* L. Для сравнения результатов взяты сертифицированные удобрения «Сила Роста» и «Риверм», полученные на основе вермикомпоста. Выявлена оптимальная концентрация куриного помета – 200 мг на 2 л, по признаку энергии прорастания значения составили 87% и всхожести – 95%. Также по приросту длины ростка для удобрения на основе куриного помета 127,7%, что на 15% больше, чем удобрения «Сила Роста». Опытные образцы на базе вермикомпоста дали отрицательные результаты: прирост корешка – минус 21,9%, отрицательный прирост ростка – минус 6,3%. Описан способ получения новых видов органических удобрений на основе куриного помета, базирующегося на эффекте кавитации. Проведена оценка эффективности применения удобрений для сельскохозяйственной культуры – тыквы *Cucurbita pepo* L.

Ключевые слова: органическое удобрение, энергия прорастания, лабораторная всхожесть, семена тыквы, вермикомпост, прирост длин корня, кавитационная обработка

DETERMINATION OF THE OPTIMAL CONCENTRATION OF ORGANIC FERTILIZERS FOR THE SOWING QUALITIES OF CROPS USING THE EXAMPLE OF PUMPKIN

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The research of the effectiveness of the obtained fertilizers impact on the sowing characteristics of pumpkin seeds *Cucurbita pepo* L. was conducted at the Center for Collective Use "Advanced Technologies and Materials" of the Sevastopol State University. The work provides data on the effect of organic fertilizers based on vermicompost and chicken manure on the sowing qualities of pumpkin seeds. A comparative analysis of the energy of germination and laboratory viability of the seeds, root and sprout growth of the agricultural crop *Cucurbita pepo* L. was carried out. To compare the results obtained, the certified fertilizers “Power of Growth” and “Riverm” based on vermicompost were taken. The optimal concentration of chicken manure was identified with a concentration of 200 mg per 2 liters based on the germination energy, the values were 87% and the viability 95%. Also, the increase in the sprout length for the fertilizer based on chicken manure was 127.7%, which is 15% more than the "Power of Growth" fertilizer. Test samples based on vermicompost gave negative results: root growth – minus 21.9%, negative shoot growth – minus 6.3%. A method for producing new types of organic fertilizers based on chicken manure, based on the cavitation effect, has been described. An assessment of the effectiveness of using fertilizers for an agricultural crop – pumpkin Cucurbita pepo L. has been made.

Keywords: organic fertilizer, germination energy, laboratory germination, pumpkin seeds, vermicompost, root length increase, cavitation treatment

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Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

According to the National Organic Union of the Russian Federation, the market of organic products is one of the most dynamically developing in the world [1]. To reduce the negative impact of chemical fertilizers on the environment, their replacement by organic fertilizers for producers is the optimal solution [2, 3]. Recently, in the field of determining the optimal concentrations of organic fertilizers and their effect on sowing characteristics, studies have been conducted on the following crops: wheat and barley [4], corn and rice [5]. As a rule, the works determine the optimum concentration and composition of fertilizer, such as mineral-organic; and search for a new method of processing the feedstock to obtain organic fertilizer is conducted.

The purpose of the research is to assess the effectiveness of the impact of the received fertilizers on the sowing characteristics of the seeds of agricultural crop – pumpkin *Cucurbita pepo* L.

In order to achieve this goal, the following tasks must be accomplished:

– describe the method of creating new types of organic fertilizers;

– evaluate the efficiency of fertilizer application for different types of crops.

The subject of the study is germination energy and viability of germinated seeds.

Scientific novelty of the obtained results consists in obtaining organic fertilizers on the basis of chicken manure based on the effect of cavitation.

The work involves obtaining new complex fertilizers of organic type which will perform the following functions:

– shortening seed germination time, accelerating their growth;

– solving problems on waste utilization at poultry farms.

MATERIAL AND METHODS

The research was conducted at the Center for Collective Use "Advanced Technologies and Materials" at the Sevastopol State University. As it is known, sowing qualities of seeds include purity, germination, germination energy, seed weight, equalized grain unit, moisture and absence of infestation (GOST R 52325-2005). The germination energy and viability were determined in laboratory conditions in accordance with the Interstate Standard GOST 12038-84 "Seeds of agricultural crops. Methods of determining germination".

To study the effect of the fertilizer concentration on the sowing qualities of agricultural crops and to determine the optimal composition of organic fertilizer (ratio of dry substrate to liquid phase) the proportions of 1 : 5, 1 : 10 were chosen.

In the course of work, new types of organic fertilizers based on vermicompost and poultry manure in different concentrations were obtained. Cavitation effects were used in the preparation of the fertilizers [6, 7].

Concentrates of organic fertilizer were prepared in two ratios of solid and liquid phase (1 : 10 and 1 : 5). For this purpose, suspensions of initial raw materials (poultry manure and vermicompost) weighing 200 and 400 g were diluted with bidistilled water and brought to the volume of 2 liters. The solutions were kept in constant conditions at a temperature of 20 ^{o}C and pressure of 760 mm Hg for 14 days.

To obtain the organic fertilizer, the solutions were treated on the Activator-Gd cavitation unit. The exposure time was 15 min at a frequency of 30 Hz[1]. Biohumus and poultry manure were used as feedstock for the production of organic fertilizers.

Spectroscan MAKS-GVM was used to determine the composition of the mineral part of the raw material, and the substrate was not subjected to pretreatment (thermal, disinfection or other), which prevented the loss of mineral components[2].

The following labeling was introduced for the identification of organic fertilizers.

KP-2, KP-4 – laboratory prepared organic fertilizer based on chicken manure of different concentration (KP-2 was 200 g of chicken manure per 2 l of water, KP-4 respectively 400 g of chicken manure per 2 l of water).

B-2, B-4 – laboratory prepared organic fertilizer based on vermicompost of different concentration (B-2 was 200 g vermicompost per 2 l of water, B-4 respectively 400 g vermicompost per 2 l of water).

PG – "Power of Growth" brand organic fertilizers.

R – "Riverm" brand organic fertilizers.

Cavitation treatment due to local mechanical and temperature effect produces a disinfecting effect[3] on the pathogenic microflora of raw materials, including the destruction of helminth eggs [8– 10].

During the experiment, the finished preparations (KP-2, KP-4, B-2, B-4) and the fertilizers used for comparison (PG, R) were diluted with distilled water in the ratios: 1 : 25.

The efficiency of application of new types of fertilizer was assessed by determining the seed germination energy and germination capacity of the selected crops [7].

The study of the effect of the preparations was evaluated by means of the germination energy and seed germination. Bidistilled water was used as a control sample.

To compare the effectiveness of the developed organic fertilizers, certified fertilizers "Power of Growth" and "Riverm", based on vermicompost, were used.

The preparation "Riverm" is recognized by the international organization System of Independent Certification (SIC) as an ecologically clean fertilizer, corresponding to the international standard ISO 14024 : 1999.

The seeds were germinated under the conditions stipulated in appendix 1 of the GOST 12038- 84. The thermostats maintained the set temperature, checking it 3 times a day – in the morning, in the middle of the day and in the evening; there had to be no deviations by more than plus or minus 2 °C.

Seed germination at variable temperatures of 20–30 °C was carried out by switching the thermoregulator from low to high or from high to low temperature. Since the variable temperature was not controlled at weekends, the seeds were germinated at the lower of the two temperatures specified in the appendix 1 of the GOST 12038-84. The moistened state of the bed was checked daily, and if necessary, it was moistened with water or fertilizer at room temperature, avoiding overwatering. Constant ventilation in the thermostats was provided. The lids of petri dish-

[1]User Manual. Hydrodynamic mill-cavitator "Activator-Gd". Activator, 2022.

[2]User Manual. Spectroscan MAKS-GVM. OOO NPO SPECTRON, 2022.

[3]Patent No. 2,735,961. Russian Federation: IPC C05F 3/00/ B82B 3/00/ B82Y 40/00/ Cavitation method of disinfection of liquid organic waste and preparation of organomineral fertilizers. Kostenko M. Yu. and others; applicant and patentee Federal State Budgetary Educational Institution of Higher Education "Ryazan State Agrotechnological University named after P.A. Kostychev". N 2019138106; app. 25.11.2019; published 11.11.2020, Bul. N32.

es were opened for a few seconds daily. Water in the tray at the bottom of the thermostat was changed every 3–5 days.

Evaluation and recording of the germinated seeds in determining the germination energy was done on the 3rd day and germination on the 5th day in accordance with the appendix 1 of the GOST 12038-84. At the same time, the day of putting the seeds for germination and the day of calculating the germination energy or the germination capacity were counted as one day.

RESULTS AND DISCUSSION

The composition of the organic part of chicken manure and vermicompost was studied, namely, the quantitative composition of fulvic acids and humic acids was determined[4].

Preliminary moisture content of the studied raw material was determined according to the method specified in the GOST 26713-85[5], then it was completely dried and its composition was analyzed according to the methods[6-8]. To determine the composition of the mineral part, the raw material was analyzed on the spectroscan MAKS-GVM. The general results of the analysis of initial raw materials were obtained for the confidence probability of $P = 0.95\%$ and are presented in Table 1.

Normally germinated seeds were considered as germinated seeds. For germination energy recording (see Fig. 1), only normally germinated and obviously rotten seeds were counted and removed, and for germination capacity recording, normally germinated, swollen, hard, rotten and abnormally germinated seeds were counted separately.

The arithmetic mean of the germination results of all the analyzed samples was taken as the result of the analysis. The results of the study are presented in Tables 2 and 3.

Qualitative and quantitative counting of the studied seeds was carried out on the 3rd day in accordance with the appendix 1 specified in the GOST 12038-84. The results of the study were evaluated in accordance with the GOST R ISO 21748-2021[9, 10] (see Table 3).

According to the results of the study, it can be concluded that for pumpkin seeds in terms of germination energy and germination capacity, the best indicators were achieved when treated with fertilizer based on chicken manure KP-2 in a concentration of 200 g per 2 l of water and the preparation "Power of Growth", it was 87 and 85%, respectively.

Also, on the day of recording the germinated seeds, measurements of root and shoot lengths

Табл. 1. Состав исходного сырья
Table 1. Composition of the feedstock

Raw materials	pH	Moisture content, %	Minimal part, %	Proportion of organic matter, %	Percentage of fulvic acids, %	Proportion of humic acids, %
Chicken manure (dried product)	6,1	24,4	35,4	64,6	4,3	0,5
Vermicompost (wetted product)	6,2	75,3	45,2	54,8	3,7	0,2

[4]GOST 12038-84. Seeds of agricultural crops. Methods of determination of germination. Moscow: Standardinform, 2020, p. 40.
[5]GOST 12036-85. Seeds of agricultural crops. Acceptance rules and methods of sampling. Moscow: Standardinform, 2020, p. 14.
[6]GOST 26713-85. Organic fertilizers. Method for determination of moisture and dry residue, 1985, p. 6.
[7]GOST 26712-94. Organic fertilizers. General requirements for methods of analysis, 1994, p. 12.
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[9]GOST 31461-2012. Poultry litter. Raw material for the production of organic fertilizers, 2020, p. 6.
[10]GOST R ISO 21748-2021. National standard of the Russian Federation. Statistical methods. Guide to the use of the estimates of repeatability, reproducibility and correctness in the estimation of measurement uncertainty, 2021, p. 43.

Рис. 1. Учет семян при определении энергии прорастания на сельскохозяйственной культуре – тыква

Fig. 1. Seed recording in determining the germination energy of the crop – pumpkin

Табл. 2. Влияние удобрений на энергию прорастания и всхожести

Table 2. The effect of fertilizers on the germination energy and viability

Indicator	C	CM-2	CM-4	PG	R	V-2	V-4
Germinated seeds							
Germination energy, %	67	87	78	85	72	67	75
Germination ability, %	76	95	90	97	91	72	81
Number of ungerminated seeds, pcs.	12	3	5	2	5	14	10
Undergerminated seeds							
Healthy	5	2	4	1	4	3	2
Rotten	1	1	–	1	–	6	3
Abnormally germinated	1	–	–	–	–	1	1
Damaged by pests	5	–	1	–	1	5	4

Note. Steamed, empty ones were not observed during the course of the experiment

Табл. 3. Прирост длин корня/ростка по отношению к контрольной серии, %

Table 3. Growth of root/growth lengths in relation to the control series, %

Parameter	CM -2	CM -4	PG	R	V-2	V-4
Sprout length growth	127,7	85,7	112,7	31,1	–6,3	101,9
Root length gain	2,4	30	17,5	17,6	–21,9	–20,5

were taken to evaluate the biomass growth under the influence of the tested fertilizers.

Seed germination and germination energy were calculated in percentage terms. The arithmetic mean of the results of germination of all the analyzed samples was taken as the result of the analysis. The results of the measurements are presented in Table 3.

Also, on the day of germination determination (see Fig.2) of the germinated seeds, measurements of root and shoot lengths were taken to assess the biomass growth under the influence of the tested fertilizers.

It can be seen that in terms of the germination energy and germination capacity the best results were achieved by the seeds treated with fertilizer from chicken manure with low concentration and organic fertilizer "Power of Growth". In terms of the biomass growth of the above-ground organs, the leading influence was the effect of chicken manure fertilizer with a concentration of 200 g per 2 l of water, and in terms of the effect on the root part – chicken manure fertilizer in high concentration.

Based on the evaluation of the seed biomass growth at the germination stage, it can be concluded that the use of fertilizer based on chicken manure at a concentration of 200 g per 2 l of water showed results on the growth of sprout length 4 times more than the fertilizer brand "Riverm", and 13% more than "Power of Growth".

It should be noted that organic fertilizers based on B-2 and B-4 gave negative root growth of minus 21.9% and minus 20.5%, respectively, while the combination of B-2 gave negative shoot growth of minus 6.3%.

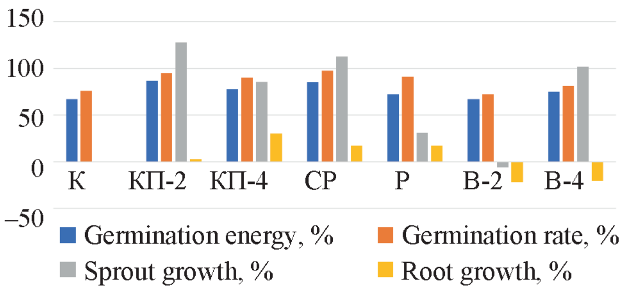

Рис. 2. Результаты исследования удобрений на сельскохозяйственной культуре – тыква

Fig. 2. Results of the study of fertilizers on an agricultural crop – pumpkin

CONCLUSIONS

1. Two variants of organic fertilizer were investigated in the work: the initial raw material – chicken manure and vermicompost, which was processed at the cavitation unit. Based on the results of the multiseries experiment, it can be concluded that the prepared organic fertilizer based on chicken manure is effective in increasing the germination energy and germination capacity for pumpkin, and also provides the greatest increase in the biomass of sprouts and roots for pumpkins.

2. Determination of the germination capacity, germination energy allowed to establish that the maximum stimulating effect for pumpkin seeds was observed when soaking the seeds with fertilizer based on chicken manure with a concentration of 200 g per 2 l, it was 95 and 87%, respectively. In the second place, the best performance was obtained for liquid humic fertilizer "Power of Growth" and was 97 and 85%, respectively. Taking into account the characteristics of sprout length growth, the efficiency of fertilizer CM-2 was 127.7%, or 15.0% more than PG, and the efficiency of PG was 17.5%, which is 15.1% more than when CM-2 was used for sprout length growth.

3. The obtained results allow us to state that the studied preparations on the basis of chicken manure are comparable in their germination energy, germination capacity and biomass growth and they can be recommended for pre-sowing treatment of the pumpkin crop *Cucurbita pepo* L.

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ВЛИЯНИЕ УРОВНЯ ВЛАГООБЕСПЕЧЕННОСТИ НА УРОЖАЙНОСТЬ И ПИТАТЕЛЬНУЮ ЦЕННОСТЬ СОРГОВЫХ КУЛЬТУР

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Снижение урожайности из-за засухи происходит довольно часто. Потери урожая могут составлять до 60,0%. Особенно это касается кормовых культур. Цель данной работы – выявить зависимость урожайности и качества зеленой массы сорговых культур от влагообеспеченности в период вегетации растений. В качестве объектов исследования использованы суданская трава сорта Алиса, сорго сахарное сорта Южное, а также сорго-суданковый гибрид сорта Густолистный. Исследования проводили в Ростовской области. Почва опытного участка – обыкновенный карбонатный чернозем. Для изучения изменчивости продуктивности и питательных качеств были взяты года с уровнем гидротермического коэффициента (ГТК) от 0,34 до 0,88 с интервалом 0,8–1,2 (2018–2022 гг.). Закладку опытов осуществляли согласно методике государственного сортоиспытания. При повышении ГТК с 0,34 до 0,88 прослеживалась тенденция к увеличению урожайности зеленой массы на 23,3–35,0% и снижению содержания протеина на 41,8–55,54%. Выявлена отрицательная связь количества сырого протеина с величиной ГТК (r = –0,78…–0,92). Сбор переваримого протеина снижался на 22,22–31,03% при росте уровня влагообеспеченности. Наибольшее среднее значение отмечено у сорго-суданкового гибрида (0,70 т/га) и сорго сахарного (0,71 т/га). Коэффициент варьирования по содержанию клетчатки имел значения 2,16–5,42%, что свидетельствует о слабой изменчивости признака по годам, а следовательно, о слабой зависимости от уровня влагообеспеченности, что подтверждается корреляционным анализом (r = –0,03…0,32). Наибольшее значение обменной энергии в наших исследованиях отмечено у сорго-суданкового гибрида (10,42–10,80 МДж/кг). При этом не выявлено зависимости данного показателя, как и суммы кормовых единиц, от уровня влагообеспеченности. Наибольшая обеспеченность 1 корм. ед. переваримым протеином зафиксирована у сорго сахарного (83,4 г). Обнаружена тенденция к снижению данного показателя на 22,6–42,5% по мере увеличения уровня ГТК (r = –0,69…–0,90).

Ключевые слова: суданская трава, сорго-суданковый гибрид, сорго сахарное, протеин, клетчатка, обменная энергия, качество, урожайность

THE EFFECT OF THE MOISTURE AVAILABILITY RATE ON THE PRODUCTIVITY AND NUTRITIONAL VALUE OF SORGHUM CROPS

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Productivity reduced by drought is quite common. There can be up to 60.0% of the harvest losses. This is especially true for forage crops. The purpose of the current work was to identify the dependence of productivity and quality of green mass of sorghum crops on moisture availability during a vegetation period of plants. Sudan grass variety Alice, sugar sorghum variety Yuzhnoye, and sorghum-sudangrass hybrid variety Gustolistny were used as research objects. The study was carried out in the Rostov region. The soil of the experimental plot was ordinary carbonate black earth (chernozem). In order to study the variability of productivity and nutritional qualities, the years with the HTC level from 0.34 to 0.88 with an interval of 0.8–1.2 (2018–2022) were taken into account. The trials were conducted according to the methodology of the State Variety Testing. When the HTC increased from 0.34 to 0.88, there was a tendency to improve green mass productivity by 23.3–35.0% and decrease the protein percentage by 41.80–55.54%. A negative relationship between the amount of crude protein and the HTC value was revealed (r = –0.78... –0.92). The digestible protein yield decreased by 22.22–31.03% with increasing moisture content. The largest mean value was identified for the sorghum-sudangrass hybrid with 0.70 t/ha and the sweet sorghum variety with 0.71 t/ha. The variation coefficient of fiber content was 2.16–5.42%, which indicated weak variability of the trait over the years, and, consequently, a weak dependence on the moisture availability rate, which was confirmed by the correlation analysis (*r* = –0.03...0.32). The largest value of the metabolic energy was found in the sorghum-sudangrass hybrid (10.42–10.80 mJ/kg). At the same time, there was no dependence of this indicator, as well as the amount of feed units, on the moisture availability rate. The highest amount of digestible protein per feed unit was identified in sweet sorghum (83.4 g). A tendency to decrease this indicator by 22.6–42.5% was found as the HTC level increased (*r* = –0.69...–0.90).

Keywords: Sudan grass, sorghum-sudangrass hybrid, sweet sorghum, protein, fiber, metabolic energy, quality, productivity

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INTRODUCTION

For the development of livestock breeding, first of all, it is necessary to create a solid fodder base. In drought conditions, one of the ways to stabilize the volume and quality of fodder is to expand the area under crops that can use winter moisture reserves in the soil and give stable yields in the most extreme conditions. Particular attention should be paid to sorghum, a drought-resistant crop, which is not only more productive than corn in case of lack of moisture, but also has quality indicators on a par with them [1]. It is a universal crop used for feeding all kinds of animals in the form of both concentrated and bulky fodder. Green mass of sorghum is as rich in nutrients as annual crops and can be used for silage, haylage, hay, green fodder, grass meal, grazing [2].

Despite scientific and technological progress, a lot of research and development, the dependence of crop yields and the quality of obtained products on soil and climatic conditions remains significant. According to N.F. Demina [3], the share of variety in yield growth is from 25.0 to 40.0%, the rest is determined by such external factors as temperature regime, precipitation, intensity of sunlight, length of daylight hours, resistance to diseases, pests, etc. According to the results of L.I. Storozhik's research, the influence of growing conditions in a particular year on the productivity of sugarcane sorghum is 12.3%. Thus, at hydrothermal coefficient (HTC) at 1.1 the yield of green mass amounted to 59.4 t/ha, at HTC 0.9 it reached 53.3 t/ha[1]. Yield reductions due to drought are considered to be quite frequent. Losses can amount up to 60.0% of the yield [4]. This is especially true for fodder crops, which have an enhanced growth of vegetative mass under wet conditions.

It has been established that under drought conditions there is an increase in the protein content, but its digestibility decreases [5]. In the

[1]*Storozhik L.I.* Productivity of sugar sorghum as a source of liquid biofuel production in joint crops with other crops // Innovations in agroindustrial complex: problems and prospects, 2014, N 3 (3), pp. 79-84.

studies of G.V. Sedukova et al. [6], the content of crude protein and fiber changed slightly from 11.41 to 11.29% and from 31.43 to 29.39%, respectively, when the HTC increased from 0.9 to 1.9. In general, insufficient attention has been paid to the issue of sorghum green mass quality changes. Therefore, the study of the influence of vegetation conditions on the indicators of feed nutrition, in this case green mass, is of scientific and practical interest and is relevant.

The purpose of this work is to determine the dependence of yield and quality of sorghum crop green mass on moisture availability during the growing season. The following tasks were set accordingly to this goal:

1. Evaluate the level of moisture availability during sorghum growing season and identify the years of the study that are contrasting in terms of this indicator.
2. Identify changes in nutritional and yield parameters in sorghum varieties and hybrids at different hydrothermal coefficients.
3. Conduct correlation analysis of the main economically valuable traits of sorghum crops and the HTC.

MATERIAL AND METHODS

The objects of research are Sudan grass variety Alice, sugar sorghum variety Yuzhnoye, as well as sorghum-sudangrass hybrid variety Gustolistny, created in the Agricultural Research Center "Donskoy".

The study was conducted in the Rostov region. Soil cover – ordinary carbonate chernozem. Soil characteristics: pH 7.3; humus content – 3.36%; P_2O_5 – 24.4 mg/kg of soil; K_2O– 360 mg/kg of soil [7].

Earlier it was established that at HTC less than 0.4 there is very severe drought, at 0.4–0.5 – severe drought, at 0.5–0.7 – medium drought, and at 0.7–1.0 – insufficient moisture[2]. To study the variability of productivity and nutritional quality, we took the years with the HTC level from 0.34 to 0.88 with an interval of 0.8–1.2. Such a range allows us to cover different conditions (from severe drought to insufficient moisture) and make a comprehensive assessment. Thus, very severe drought is observed in 2018 at HTC = 0.34, medium drought in 2022 at HTC = 0.52, insufficient moisture in 2019 at HTC = 0.70, and insufficient moisture in 2020 at HTC = 0.88.

Soil treatment, crop care and planting of experiments were carried out in accordance with the methodology of state variety testing[3]. Crude protein content was determined by the Kjeldahl method (GOST 53951-2010), crude fat – by the amount of skimmed residue using the method of S.R. Rushkovsky (GOST 31700-2012), crude fiber – by Henneberg and Stohmman (GOST 31675-2012).

For statistical analysis of the obtained data the methods outlined by B.A. Dospekhov[4] were used.

RESULTS AND DISCUSSION

Yield is the main indicator of value of the varieties, hybrids and lines of all agricultural crops without exception [8]. On average, the following highest yields were observed during the years of study: sorghum-sudanrass hybrid – 45.5 t/ha, Sudan grass – 33.3 t/ha, sugar sorghum – 32.0 t/ha. At the same time, all sorghum crops have a tendency to increase this indicator with increasing HTC from 0.34 to 0.88, i.e. by 23.3–35.0% (see Table 1).

Based on 2016-2022 data, it was found that yield has a close positive correlation relationship with HTC (r = 0.77–0.91). When HTC increases by 0.1, Sudan grass yield increases by 2.05 t/ha, sorghum-sudanrass hybrid – by 3.78 t/ha, sugar sorghum – by 1.74 t/ha (see Fig. 1).

These data are consistent with earlier studies by N.A. Kovtunova and G.Y. Krivosheev, according to which the greatest contribution to the variability of sorghum and corn yields is made by the factor "cultivation conditions". The yield

[2]Reference book of ecological and climatic characteristics of Moscow / edited by A.A. Isaev. M., 2005, vol. 2, 412 p.

[3]Methodology of state variety testing of agricultural crops // Cereals, groats, legumes, corn and fodder crops. M., 1989, Issue 2, 194 p.

[4]*Dospekhov B.A.* Methodology of field experiment (with the basics of statistical processing of research results). Moscow: Alliance, 2014, 351 p.

of Sudan grass green mass in the first cutting had a close positive relationship with the amount of precipitation during the period of sprouting - ear formation (*r* = 0.78) [9]. Average positive correlations between the productivity of corn hybrids and HTC values were found (*r* = 0.64-0.74) [10].

The main role in the system of complex evaluation belongs to protein. Its deficiency in the diet of animals leads to a decrease in productivity and deterioration of its quality, slow growth of animals and, accordingly, an increase in the duration of their fattening. For the development of animal breeding, it is necessary to increase the protein content in forages. It was found that green mass yield and crude protein content in dry matter in Sudan grass variety Alice and sorghum-sudanrass hybrid variety Gustolistny have a medium negative relationship (*r* = –0.56 ± 0.37 and –0.65 ± 0.34, respectively), in sorghum-sugar variety Yuzhnoye – a strong negative relationship (*r* = –0.89 ± 0.20). This indicator has a negative relationship with HTC (*r* = –0.78...–0.92). An increase in HTC by 0.1 is accompanied by a decrease in crude protein content by 0.82 –1.22% (see Fig. 2).

According to Table 1, the increase in HTC from 0.34 to 0.88 leads to a decrease in protein concentration in Sudan grass by 41.8% (from 12.36 to 7.20%), in sorghum-sudanrass hybrid by 52.12% (from 14.89 to 7.13%), and in sugar sorghum by 55.54% (from 14.80 to 8.22%). On average, the highest indicator was observed in sorghum-sudanrass hybrid – 10.15%.

The crude protein content in 1 kg of cereal grasses should not be lower than 13.0%, the

Табл. 1. Изменение показателей питательной ценности сорговых культур при разной величине гидротермического коэффициента

Table 1. Changes in the nutritional value of sorghum crops at different value of the hydrothermal coefficient

Indicator	HTC			
	0,34	0,52	0,70	0,88
Sudan grass, Alice variety				
Green mass yield, t/ha	30	32	34	37
Crude protein content, %	12,36	8,95	8,12	7,20
Digestible protein yield, t/ha	0,52	0,50	0,45	0,37
Total forage units	91,80	97,40	94,40	95,60
Provision of 1 forage unit with digestible protein, g	56,60	51,30	42,40	38,20
Crude fiber content, %	33,46	35,03	31,75	30,32
Exchangeable energy, mJ/kg	9,31	9,83	9,56	9,49
Sorghum-sudan hybrid, Gustolistnyi variety				
Green mass yield, t/ha	40	42	46	54
Crude protein content, %	14,89	10,04	8,54	7,13
Digestible protein yield, t/ha	0,87	0,70	0,62	0,60
Total forage units	103,50	105,10	104,50	103,50
Provision of 1 forage unit with digestible protein, g	84,00	66,60	57,40	48,30
Crude fiber content, %	29,20	30,58	30,95	30,17
Exchangeable energy, mJ/kg	10,44	10,80	10,75	10,42
Sugar sorghum, Yuzhnoye variety				
Green mass yield, t/ha	27	33	33	35
Crude protein content, %	14,80	8,64	8,51	8,22
Digestible protein yield, t/ha	0,81	0,72	0,63	0,68
Total forage units	83,70	84,60	84,10	88,60
Provision of 1 forage unit with digestible protein, g	96,80	85,10	74,90	76,70
Crude fiber content, %	39,15	35,14	37,63	39,88
Exchangeable energy, mJ/kg	8,54	8,64	8,57	8,73

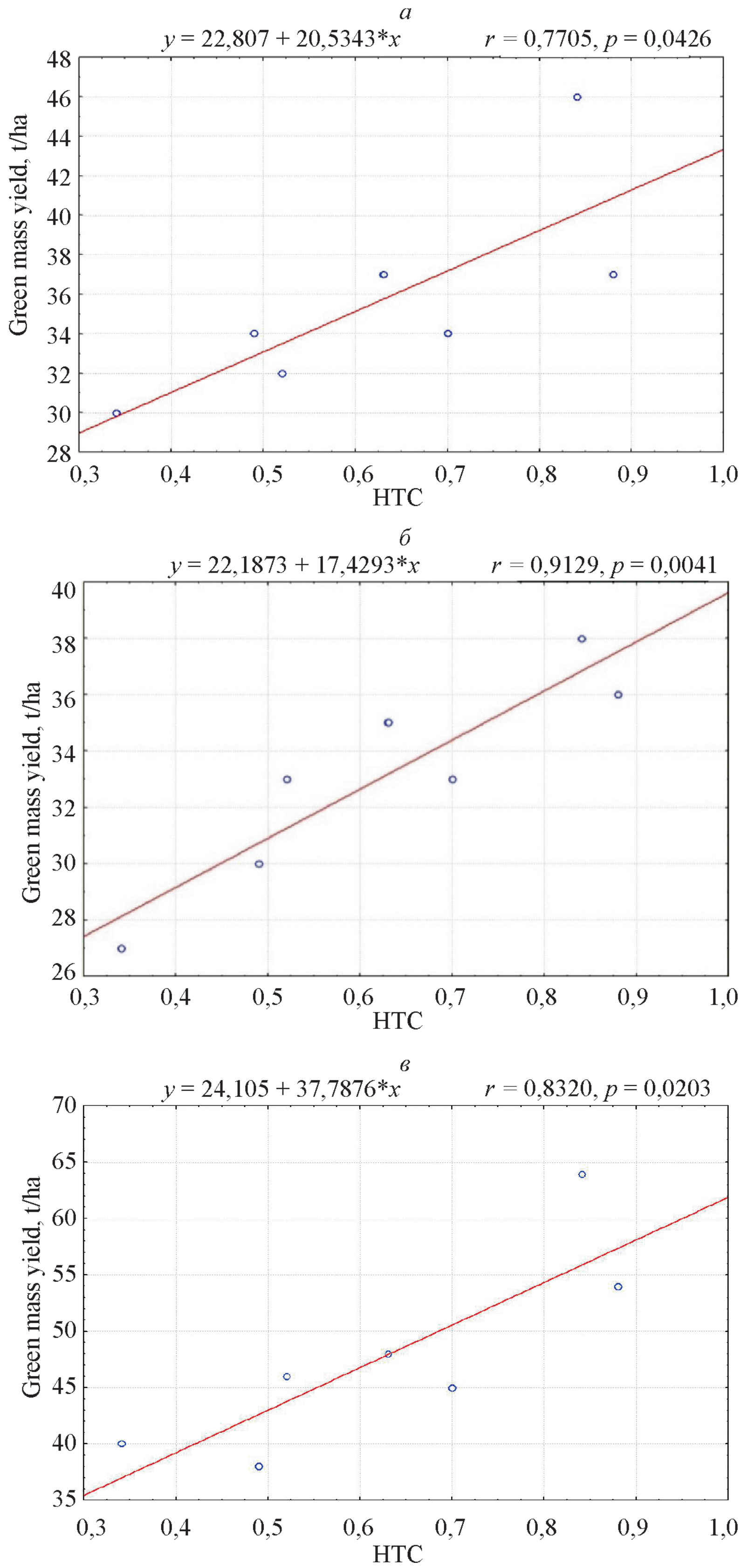

Рис. 1. Зависимость урожайности зеленой массы от величины ГТК:
а – суданская трава; *б* – сорго-суданковый гибрид; *в* – сорго сахарное

Fig. 1. Dependence of green mass yield on the HTC:
а – sudan grass; *б* – sorghum-sudangrass hybrid; *в* – sweet sorghum

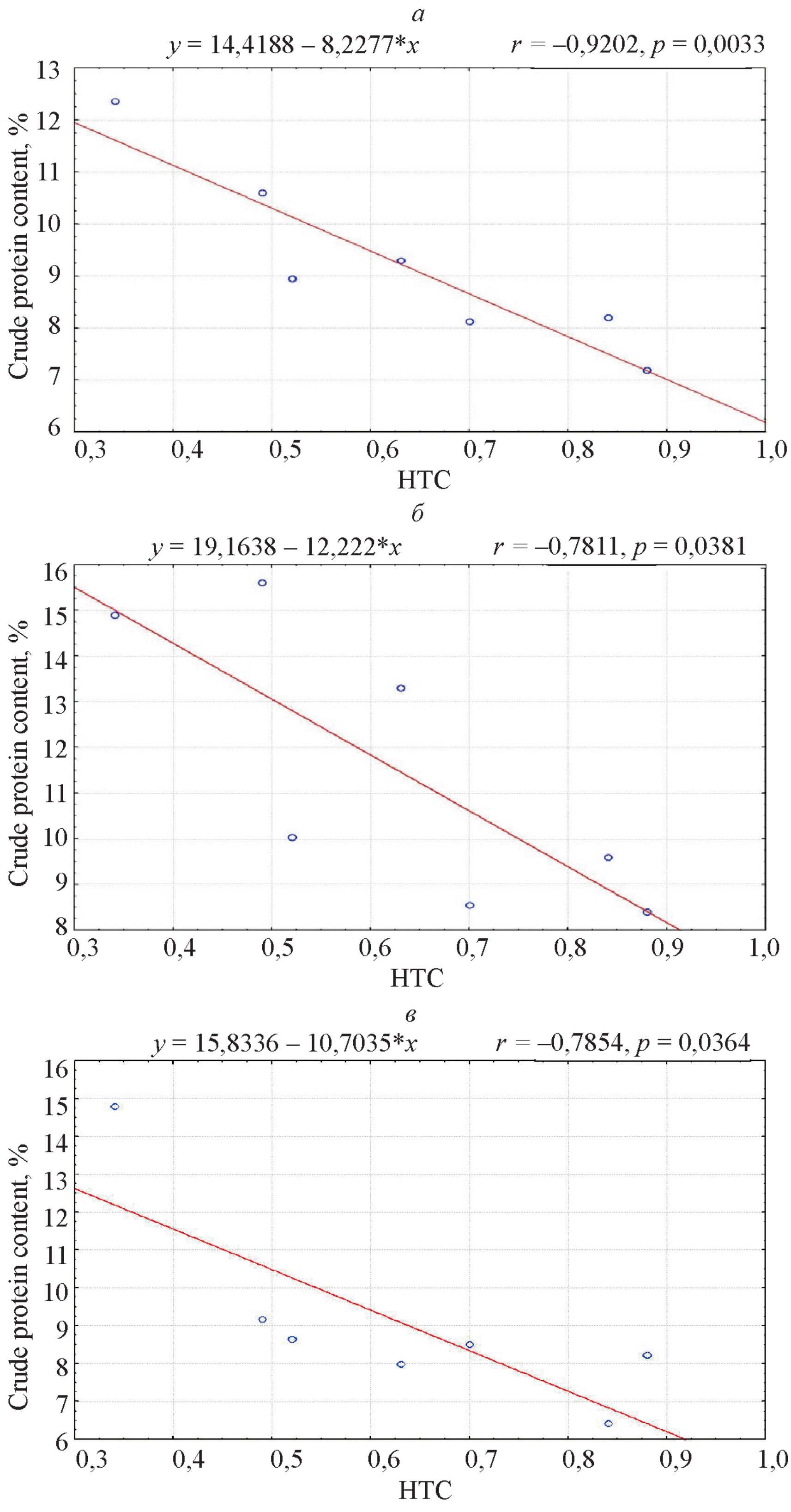

Рис. 2. Зависимость содержания сырого протеина от величины ГТК:
а – суданская трава; *б* – сорго-суданковый гибрид; *в* – сорго сахарное

Fig. 2. Dependence of crude protein content on HTC:
а – sudan grass; *б* – sorghum-sudangrass hybrid; *в* – sweet sorghum

amount of dry matter should not be less than 20.0%[5]. In our studies, these requirements were met by sorghum-sudanrass hybrid and sugar sorghum at HTC of 0.34 (14.89 and 14.80%, respectively).

Digestible protein yield is an important quality indicator in characterizing varieties and hybrids, depending on green mass yield and dry matter content. According to Table 1, this indicator decreases by 22.22–31.03% with increasing moisture availability. The highest average value was observed in sorghum-sudangrass hybrid and sugar sorghum – 0.70 and 0.71 t/ha, respectively.

Fiber content in the dry matter of green mass is one of the indicators of feed nutrition. In the studies of I. Golubinova et al. [11] found that the protein content in green mass of Sudan grass has a negative correlation with the fiber content (*r* = –0.51... –0.99).

According to our study, the fiber content of Sudan grass and sorghum-sudangrass hybrid varied within the range of 31.0–35.0%, while that of sugar sorghum was higher – 35.0–40.0%. The coefficient of variation had values of 2.16–5.42%, indicating weak variability of the trait by years, and, consequently, weak dependence on the level of moisture availability. This is confirmed by the correlation analysis. The correlation coefficient of crude fiber content and the HTC indicates the absence of relationship in Sudan grass (*r* = –0.03), weak positive relationship in sorghum-sudangrass hybrid and sugar sorghum – (*r* = 0.32 and 0.26, respectively) (see Table 2).

The dry matter of voluminous fodder for cattle should contain 10–11 MJ/kg of metabolizable energy. The highest value of exchangeable energy in our studies was observed in sorghum-sudangrass hybrid (10.42–10.80 MJ/kg), the lowest – in sugar sorghum (8.54-8.73 MJ/kg). At the same time, no dependence of this indicator, as well as the sum of feed units, on the level of water availability was revealed.

Currently, there is a decrease in the quality of forages in our country, in particular, their protein nutrition. For all groups of forages, the protein content of 1 feed unit does not exceed 80-90 g (norm – 105–110 g), which makes them low-protein[6]. According to the results of research, the highest value of this indicator was recorded in sugar sorghum (83.4 g). In addition, the tendency to decrease by 22,62–42,5% the level of provision of 1 feed unit with digestible protein as the HTC increases was revealed. Correlation analysis confirms the obtained data (*r* = –0.69...–0.90), which indicates an inverse strong dependence.

CONCLUSION

All sorghum crops show a tendency to increase the yield of green mass by 23.3-35.0% at increasing the HTC from 0.34 to 0.88 (*r* = 0.77–0.91). An increase in HTC from 0.34 to 0.88 leads to a decrease in protein content in Sudan grass by 41.8% (from 12.36 to 7.20%), in sorghum-sudangrass hybrid by 52.12% (from 14.89 to 7.13%), and in sugar sorghum by 55.54% (from 14.80 to 8.22%). Negative relationship of

Табл. 2. Корреляционная связь урожайности и показателей качества зеленой массы с ГТК у сорговых культур

Table 2. Correlation between yield and quality indicators of green mass with HTC in sorghum crops

Crop	Green mass yield	Crude protein content	Digestible protein yield	Crude fiber content	Total forage units	Provision of 1 forage unit with digestible protein, g	Exchangeable energy, mJ/kg
Sudan grass	0,77	–0,92	–0,61	–0,03	–0,36	–0,69	0,09
Sorghum-sudan hybrid	0,83	–0,78	–0,50	0,32	0,62	–0,87	0,45
Sugar sorghum	0,91	–0,78	–0,90	0,26	0,08	–0,90	0,69

[5] Методические указания по оценке качества и питательности кормов. М., 2002. 75 с.

[6] *Косолапов В.М., Трофимов И.А., Шевцов А.В.* Инновационная система кормопроизводства России // Техника и технологии в животноводстве. 2012. № 1 (5). С. 42–52.

the trait with HTC was revealed (r = –0.78...–0.92). Collection of digestible protein decreases by 22,22-31,03% with increasing the level of water availability. The coefficient of variation of fiber content reached 2.16–5.42%, which indicates weak variability of the trait by years, and, consequently, weak dependence on the level of water availability, which is confirmed by the correlation analysis (r = –0.03...0.32). According to the results of the study, the highest availability of 1 feed unit of digestible protein was recorded in sugar sorghum – 83.4 g. The tendency to decrease of this indicator by 22,62–42,5% with an increase of HTC was revealed (r = –0,69...–0,90).

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АНАЛИЗ МЕЖСОРТОВЫХ ГИБРИДОВ СОИ НА НАЧАЛЬНЫХ ЭТАПАХ СЕЛЕКЦИИ

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Представлены результаты изучения рекомбинантных гибридов сои с точки зрения степени проявления эффекта гетерозиса, фенотипического доминирования и трансгрессивной изменчивости по хозяйственно ценным признакам с последующим выделением наиболее перспективных гибридных комбинаций. Исследование проводили с 2018 по 2022 г. в лаборатории селекции сои в условиях степной зоны Приморского края. Из десяти полученных гибридных комбинаций максимальный эффект гетерозиса в первом поколении отмечен у комбинаций Приморская 1385 × Кофу, Приморская 1385 × Dong nong 690, Hei He 38 × Тайфун. Фенотипическое сверхдоминирование наследования показателей (от 1,6 до 76,7) зафиксировано у всех гибридов. Трансгрессивная изменчивость межсортовых гибридов сои во втором и третьем поколениях варьировала в зависимости от комбинации и поколения. Высокие значения степени трансгрессии в третьем поколении по комплексу элементов структуры урожая наблюдали в комбинациях Приморская 1385 × Кофу и Hei He 38 × Talppod-Fisk, по числу семян с растения – Приморская 1385 × Тайфун и Кофу × Тайфун, по массе семян с растения – Dong nong 690 × Тайфун и Hei He 38 × Тайфун. Установлено снижение частоты трансгрессии гибридов к третьему поколению. Наибольшие значения степени и частоты трансгрессии по высоте растений отмечены у гибридных комбинаций Hei He 38 × Тайфун и Hei He 38 × Talppod-Fisk. По итогам изучения перспективных генотипов сои выделены рекомбинантные гибриды с высокими показателями продуктивности и массы 1000 семян в комбинациях Киото × Dong nong 690 и Муссон × Тайфун. Тестируемые гибриды имели разные группы спелости. Не всегда проявление высокого эффекта гетерозиса и трансгрессивной изменчивости в первом – третьем поколениях служит гарантией дальнейшего получения образцов с высокими хозяйственно ценными показателями.

Ключевые слова: соя, гибрид, гетерозис, трансгрессия, комбинация, фенотипическое доминирование

ANALYSIS OF INTERVARIETAL SOYBEAN HYBRIDS AT THE INITIAL BREEDING STAGES

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The results of the study of recombinant soybean hybrids in terms of the degree of heterosis effect, phenotypic dominance and transgressive variability in economically valuable traits with the subsequent selection of the most promising hybrid combinations are presented. The study was conducted from 2018 to 2022 in the laboratory of soybean breeding in the conditions of the steppe zone of the Primorsky Territory. Of the ten hybrid combinations obtained, the maximum effect of heterosis in the first generation was observed in the combinations Primorskaya 1385 × Kofu, Primorskaya 1385 × Dong nong 690, Hei He 38 × Taifun. Phenotypic overdominance of inheritance of indicators (from 1.6 to 76.7) was recorded in all hybrids. Transgressive variability of intervarietal soybean hybrids in the second and third generations varied by combination and generation. High values of the degree of transgression in the third generation were observed in the combinations Primorskaya 1385 × Kofu and Hei He 38 × Talppod-Fisk, in terms of the number of seeds per plant – Primorskaya 1385 × Taifun and Kofu × Taifun, in terms of seed weight per plant – Dong nong 690 × Taifun and Hei He 38 × Taifun. A decrease in the frequency of transgression of hybrids by the third generation was found. The highest values of the degree and frequency of transgression in plant height were observed in the hybrid combinations Hei He 38 × Taifun and Hei He 38 × Talppod-Fisk. Based on the results of the study of the promising soybean genotypes, recombinant hybrids with high productivity and 1000-seed weight in the combinations Kyoto × Dong nong 690 and Monsoon × Taifun were isolated. The hybrids tested had different ripeness groups. Not always the manifestation of high effect of heterosis and transgressive variability in the first – third generations serves as a guarantee of further obtaining samples with high economically valuable indicators.

Keywords: soybean, hybrid, heterosis, transgression, combination, phenotypic dominance

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Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

The main task in soybean breeding is to create the varieties with high indices of quantitative and qualitative characteristics, adapted to the growing conditions [1–3]. For this purpose, it is necessary to conduct a study and careful selection of seed parents on the complex of traits for the purpose of further involvement in the process of hybridization, to assess their negative and positive aspects, the nature of inheritance [4–6].

The main method of obtaining source material of soybean is intervarietal hybridization, as a result of which it is possible to create a large variety of recombinant forms. With a favorable combination of crossing components in subsequent generations there is an increase in trait indices compared to parental forms, which allows to identify heterosis and transgressive hybrids at the initial stages of breeding. Due to recombination and a new set of genes of the forms selected for crossing in heterosis combinations, there is an increase in productivity, viability and power of hybrids of the first generation[1, 2] [7-9]. The effect of heterosis, expressed in the second and third generations of hybrids in a stable increase in the selection trait compared to the seed parents, is considered positive transgression, while the decrease in the selection trait is defined as negative transgression[3, 4] [10, 11]. As a rule, breeding improvement of a crop and growth of its economically valuable traits occur due to obtaining forms with positive transgression in generations of intervarietal hybrids.

The purpose of the study was to investigate the inheritance of economically significant traits in intervarietal hybrids of soybean at the first stages of the breeding process.

MATERIAL AND METHODS

The study was conducted in 2018-2022 in the laboratory of soybean breeding of the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K. Chaiki.

In the years of the experiments, weather and climatic conditions were contrasting. In some months of 2018, periods of excessive moisture prevailed: the sum of precipitation in May amounted to 110.9 mm (long-run annual average – 51.0), in July – 138.8 mm (long-run annual

[1]*Drobysh A.V., Taranukho G.I.* The use of intraspecific hybridization in breeding winter soft wheat // Bulletin of the Belarusian State Agricultural Academy, 2017, N 2, pp. 30-33.

[2]*Shapturenko M.N., Khotyleva L.V.* Heterosis: modern trends in the study of molecular mechanisms // Vavilov Journal of Genetics and Breeding, 2016, vol. 20, N 5, pp. 683-694.

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[4]*Nalobova V.L., Maksimenya E.V.* Selection and genetic evaluation of intervarietal hybrids of vegetable pea (*Pisum sativum* L.) of the second generation // Bulletin of the Belarusian State Agricultural Academy, 2014, N 4, pp. 34-37.

average – 90.0), in August – 347.7 mm (long-run annual average – 134.0). Excessive soil moisture during flowering and filling of soybeans had a negative impact on the yield. Overwatering was also observed in 2019: the sum of precipitation in May amounted to 77.0 mm (long-run annual average – 51.0), in August – 226.5 mm (long-run annual average – 134.0). Due to low temperature background in June and July, soybean development was delayed, as a result of which low-growing plants were formed and low productivity was recorded. The sum of precipitation in June 2020 amounted to 193.5 mm (long-run annual average – 81.0), in the third ten-day period of August – 75.6 mm (long-run annual average – 45.0), in September – 129.2 mm (long-run annual average – 104.0). A favorable combination of moisture and heat promoted active growth and development of soybean, which positively affected the crop yield. Weather conditions in 2021 differed radically from the average annual norm by increased temperature regime (exceeded by 1.8–6.7 °C) and long periods of absence of precipitation. These factors in the period from the third ten-day period of June to the second ten-day period of August negatively influenced the process of soybean growth and development, caused low percentage of beans setting. In 2022 from June to September the sum of precipitation exceeded the long-run annual average values by 24,7–101,0 mm per month. The highest amount of precipitation was recorded in the third ten-day period of June – 78.8 mm (long-run annual average – 25.0), second ten-day period of July - 163.4 mm (long-run annual average – 38.0), third ten-day period of August – 81.7 mm (long-run annual average – 45.0). The weather conditions had a positive effect on the formation of productive bean ovaries and yield level.

The selection of seed parents for hybridization was carried out taking into account their ecological and geographical remoteness. The samples from the bioresource collection of soybeans of the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K. Chaiki were used as the source material. Based on the results of testing of the seed parents, the following groups of varieties were identified: adapted to the meteorological conditions of the Primorsky Territory – Primorskaya 1385 and Monsoon; productive, with a high content of protein and oil in the seeds, differing in the duration of the growing season – Kofu and Kyoto (Canada), Typhoon (Serbia), Hodson (USA), Dong nong 690 and Hei He 38 (China), Talppod-Fisk (Poland).

Soybean breeding material was created by artificial hybridization in 2017, resulting in 225 hybrid seeds. In 2018, first-generation hybrids (F1) and their seed parents were sown manually on the plots with the area of 0.5 m^2 according to the scheme "mother - hybrid - father". Each combination was subjected to hybridological and structural analysis, and the degree of phenotypic predominance (H_p) and heterosis (H, %)[5] was determined according to the weight and the number of seeds per plant.

In 2019-2022, the plot area in the nurseries of soybean hybrids from the second (F2) to the fifth generation (F5) was 1.8 m^2. The number of hybrid plants in F2 was 6158 pcs, F3 – 11 032, F4 – 4280, F5 – 6160 pcs. The degree and frequency of transgressions (T_d and T_f) of a number of breeding traits in F2 and F3 were determined: plant height, number and weight of seeds per plant, number of beans and branches[6]. Hybrids F4 and F5 were characterized by the main economically valuable indicators. Soybean varieties approved for cultivation – Primorskaya 13 (medium-early) and Primorskaya 4 (medium-ripening) – were used as standards. The obtained data were processed by the method of analysis of variance[7].

RESULTS AND DISCUSSION

Based on the results of the soybean seed parent recombinant crosses, ten hybrid combina-

[5]Methodology of breeding works till 2010 on creation of high-yielding, complexly valuable varieties of grain, soybean, perennial grasses, potatoes, vegetables and fruit and berry crops in the Far East zone / under general ed. P.B. Kondratyev, Novosibirsk, 1990, 208 p.

[6]*Voskresenskaya G.S., Shpota V.I.* Transgression of the traits in *Brassica* hybrids and the methodology of quantitative accounting of this phenomenon // Reports of VASKHNIL, 1967, N 7, pp. 18-20.

tions with heterosis effect on the traits "number of seeds per plant" and "seed weight per plant" were obtained (see Table 1). High values of heterosis were revealed in all the combinations. Simultaneously for two traits, the maximum effect was observed in the following hybrid combinations: Primorskaya 1385 × Kofu, Primorskaya 1385 × Dong nong 690, Hei He 38 × Typhoon. The minimum heterosis in terms of "seed weight per plant" was observed in the combinations Kyoto × Dong nong 690, Hei He 38 × Talppod-Fisk. In the hybrids of the first generation, the value of phenotypic predominance ($H_p > 1$) was at the level of 1.6–76.7, the maximum values were recorded in the hybrids Hei He 38 × Typhoon and Primorskaya 1385 × Kofu.

The data of Table 2 indicate a wide range of transgression in intervarietal soybean hybrids. The indices in F2 and F3 populations varied depending on the combination and generation. The degree of transgression on the main elements of the yield structure in most hybrids decreased by the third generation by 2.6–86.5%. The decrease in the values of selection indices in hybrid combinations is probably due to the instability of these traits in the genotype. Maximum values of the degree of transgression in F3 were observed

Табл. 1. Величина гетерозиса и степень фенотипического доминирования у гибридов первого поколения (2018 г.)

Table 1. Heterosis magnitude and the degree of phenotypic dominance in the first-generation hybrids (2018)

Hybrid combination	P ♀	F1	P ♂	H_p	H, %
Number of seeds per plant, pcs.					
♀ Primorskaya 1385 × ♂ Kofu	107,7	242,0	101,7	45,8	124,7
♀ Primorskaya 1385 × ♂ Dong nong 690	107,6	268,1	116,5	34,7	130,1
♀ Primorskaya 1385 × ♂ Hodson	107,6	230,3	148,0	5,1	55,6
♀ Primorskaya 1385 × ♂ Taifun	139,0	230,3	108,4	6,9	65,7
♀ Kofu × ♂ Taifun	107,6	208,0	131,0	7,6	58,7
♀ Kyoto × ♂ Dong nong 690	132,0	199,3	96,5	4,8	51,0
♀ Monsoon × ♂ Taifun	133,6	207,9	142,2	16,3	46,2
♀ Dong nong 690 × ♂ Taifun	103,4	285,5	167,4	4,7	70,5
♀ Hei He 38 × ♂ Taifun	93,6	233,4	97,2	76,7	140,1
♀ Hei He 38 × ♂ Talppod-Fisk	74,2	96,7	36,5	2,2	30,3
$LSD_{0,95}$	25,9	50,3	42,1	–	–
Seed weight per plant, g					
♀ Primorskaya 1385 × ♂ Kofu	11,6	31,1	13,8	16,7	125,4
♀ Primorskaya 1385 × ♂ Dong nong 690	11,6	25,8	10,1	18,7	122,4
♀ Primorskaya 1385 × ♂ Hodson	11,6	26,6	18,5	3,3	43,8
♀ Primorskaya 1385 × ♂ Taifun	12,7	26,2	10,9	16,0	106,3
♀ Kofu × ♂ Taifun	15,9	29,3	14,3	17,7	84,3
♀ Kyoto × ♂ Dong nong 690	22,0	26,3	8,8	1,6	19,5
♀ Monsoon × ♂ Taifun	18,6	32,2	15,3	9,0	73,1
♀ Dong nong 690 × ♂ Taifun	8,3	27,7	18,1	2,9	53,0
♀ Hei He 38 × ♂ Taifun	12,9	30,8	9,2	10,4	138,7
♀ Hei He 38 × ♂ Talppod-Fisk	11,5	14,7	5,6	2,1	27,8
$LSD_{0,95}$	5,3	7,1	5,2	–	–

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

Табл. 2. Определение степени и частоты трансгрессий у гибридов второго и третьего поколений (2019, 2020 гг.)

Table 2. Determination of the degree and frequency of transgression in the second and third generation hybrids (2019, 2020)

Hybrid combination	Degree of transgression, %		Frequency of transgression, %	
	F2	F3	F2	F3
Number of seeds per plant				
Primorskaya 1385 × Kofu	–17,4	20,7	0,0	57,1
Primorskaya 1385 × Dong nong 690	10,0	–14,3	52,0	0,0
Primorskaya 1385 × Hodson	–7,8	–18,5	0,0	0,0
Primorskaya 1385 × Taifun	48,9	12,6	65,4	65,5
Kofu × Taifun	18,6	11,4	56,7	42,8
Kyoto × Dong nong 690	43,3	–4,3	78,9	0,0
Monsoon × Taifun	22,6	–1,8	61,1	0,0
Dong nong 690 × Taifun	5,8	–3,6	35,7	0,0
Hei He 38 × Taifun	–6,3	–8,9	0,0	0,0
Hei He 38 × Talppod-Fisk	14,3	22,1	61,1	70,0
Seed weight per plant				
Primorskaya 1385 × Kofu	–37,6	29,2	0,0	71,4
Primorskaya 1385 × Dong nong 690	5,4	–2,5	32,9	0,0
Primorskaya 1385 × Hodson	7,7	–2,2	53,3	0,0
Primorskaya 1385 × Taifun	49,1	1,5	106,7	15,6
Kofu × Taifun	0,6	3,5	53,3	4,8
Kyoto × Dong nong 690	16,9	–1,0	68,4	0,0
Monsoon × Taifun	10,7	1,9	60,0	14,1
Dong nong 690 × Taifun	–8,8	11,5	0,0	41,7
Hei He 38 × Taifun	10,7	22,2	40,9	65,6
Hei He 38 × Talppod-Fisk	6,2	33,6	61,1	80,0
Number of beans per plant				
Primorskaya 1385 × Kofu	–28,4	27,0	0,0	28,6
Primorskaya 1385 × Dong nong 690	54,8	6,5	50,3	11,1
Primorskaya 1385 × Hodson	0,16	10,9	35,1	50,0
Primorskaya 1385 × Taifun	87,8	1,3	21,1	18,7
Kofu × Taifun	17,8	2,8	50,0	4,8
Kyoto × Dong nong 690	27,1	2,3	57,1	0,0
Monsoon × Taifun	43,0	3,8	54,4	1,3
Dong nong 690 × Taifun	6,1	–1,7	28,6	0,0
Hei He 38 × Taifun	–16,7	6,5	0,0	21,9
Hei He 38 × Talppod-Fisk	2,3	28,8	46,1	65,0

in the combinations Primorskaya 1385 × Kofu and Hei He 38 × Talppod-Fisk. In the third generation, the combinations Primorskaya 1385 × Typhoon (12.6%) and Kofu × Typhoon (11.4%) should be considered no less promising for the degree of transgression of the indicator "number of seeds per plant", and Dong nong 690 × Typhoon (11.5%) and Hei He 38 × Typhoon (22.2%) for the indicator "seed weight per plant".

The frequency of transgression of the hybrids in the third generation compared to the second generation significantly decreased. The combination Primorskaya 1385 × Typhoon was characterized by the stability of the values for the trait "number of seeds per plant". In the combination Hei He 38 × Talppod- Fisk, an increase in the number of hybrid plants exceeding the seed parents in three traits was recorded. The appearance of transgressive forms in the third generation in the combination Primorskaya 1385 × Kofu should be emphasized – from the complete absence of transgression frequency in F2 hybrids to its increase to 71.4% in F3. During the study period of F3 (2020), weather conditions contributed to the realization of the potential of this hybrid combination.

As a result of the analysis of transgressive variability of soybean hybrids in plant height and number of branches, it was found that relatively high values of the degree and frequency of transgression are consistent with each other (see Table 3).

Weather conditions in 2020 had a favorable effect on the formation of morpho-biological traits. Thus, when comparing two generations, the degree of transgression increased by 7.4–118.6% in 50.0% of the recombinant hybrids. Hybrid combinations Hei He 38 × Typhoon and Hei He 38 × Talppod-Fisk had high values of the degree and frequency of transgression in plant height.

For the trait "number of branches per plant", contrasting changes in the degree of transgression in the subsequent generation were observed, both in the direction of increasing values and in the direction of decreasing – this indicator

Табл. 3. Трансгрессивная изменчивость морфобиологических признаков гибридов второго и третьего поколений (2019, 2020 гг.)

Table 3. Transgressive variability of morphobiological traits of the second and third generation hybrids (2019, 2020)

Hybrid combination	Degree of transgression, %		Frequency of transgression, %	
	F2	F3	F2	F3
Plant height				
Primorskaya 1385 × Kofu	6,8	14,2	88,8	35,7
Primorskaya 1385 × Dong nong 690	–1,4	–2,7	0,0	0,0
Primorskaya 1385 × Hodson	23,7	10,6	71,4	66,7
Primorskaya 1385 × Taifun	22,1	12,6	75,5	46,9
Kofu × Taifun	3,8	42,8	33,3	47,6
Kyoto × Dong nong 690	–8,3	–63,2	0,0	0,0
Monsoon × Taifun	11,4	–14,6	38,9	0,0
Dong nong 690 × Taifun	–12,7	5,3	0,0	10,0
Hei He 38 × Taifun	28,6	44,6	81,8	81,2
Hei He 38 × Talppod-Fisk	32,0	77,6	77,8	85,7
Number of branches per plant				
Primorskaya 1385 × Kofu	–30,0	50,0	0,0	35,7
Primorskaya 1385 × Dong nong 690	45,4	–9,1	62,3	0,0
Primorskaya 1385 × Hodson	6,7	–14,0	17,8	0,0
Primorskaya 1385 × Taifun	71,1	63,8	76,7	46,9
Kofu × Taifun	–9,7	3,8	0,0	47,6
Kyoto × Dong nong 690	4,3	–69,7	21,0	0,0
Monsoon × Taifun	7,5	–25,5	14,4	0,0
Dong nong 690 × Taifun	–2,3	7,5	0,0	8,3
Hei He 38 × Taifun	–38,6	80,0	0,0	40,6
Hei He 38 × Talppod-Fisk	11,1	60,0	61,1	90,5

Табл. 4. Характеристика гибридов четвертого и пятого поколений (2021, 2022 гг.)
Table 4. Characteristics of hybrids of the fourth and fifth generations (2021, 2022)

Hybrid combination	Vegetation period, days	Productivity, g	Weight of 1000 seeds, g
Primorskaya 4 (standard)	115	7,5	165
Primorskaya 13 (standard)	109	7,2	170
Primorskaya 1385 × Kofu	109–116	9,4–17,5	152–170
Primorskaya 1385 × Dong nong 690	100–118	7,1–17,2	127–160
Primorskaya 1385 × Hodson	102–109	6,2–13,7	135–149
Primorskaya 1385 × Taifun	102–118	7,4–15,2	150–183
Kofu × Taifun	109–118	10,7–17,4	164–181
Kyoto × Dong nong 690	109–114	10,2–19,6	165–188
Monsoon × Taifun	102–118	11,2–21,2	170–192
Dong nong 690 × Taifun	104–115	6,6–13,4	138–149
Hei He 38 × Taifun	105–118	9,9–16,3	152–187
Hei He 38 × Talppod-Fisk	105–106	8,6–15,7	141–180
$LSD_{0,95}$	6,5	5,9	26,3

did not remain stable over the years, except for the combination Primorskaya 1385 × Typhoon. The maximum frequency of transgression was found in the combinations Primorskaya 1385 × Typhoon (46.9%), Kofu × Typhoon (47.6), Hei He 38 × Talppod-Fisk (90.5%). Transgressive variability of soybean genotypes Hei He 38 × Typhoon was observed – the indicator changed from negative to positive status, the degree of transgression increased by 118.6 units, the frequency by 40.6 units.

Based on the results of two years of studying transgressive combinations of soybean, the best hybrids were selected for a number of quantitative traits relative to the seed parents. In the future, the selected promising genotypes were tested for other positive traits (see Table 4).

In hybrid combinations, on average for two years of the tests, productivity was obtained both below (by 17.3%) and above the standards (by 194.4%). Formation of relatively low productivity was characteristic of the genotypes with seeds of small size (weight of 1000 seeds up to 149 g) and earlier maturity (up to 104 days). Some recombinant hybrids with high values of productivity and 1000-seed weight in the combinations Kyoto × Dong nong 690 and Monsoon × Typhoon were observed. Hybrids of the combinations Primorskaya 1385 × Hodson and Dong nong 690 × Typhoon showed formation of smaller seeds.

The tested set of soybean hybrids belonged to different maturity groups, the stability of the trait for early- and mid-early maturity was noted in the combinations Primorskaya 1385 × Hodson and Hei He 38 × Talppod-Fisk. The greatest range of variation in the vegetation period of hybrids (from 100 to 118 days) was recorded in the combination Primorskaya 1385 × Dong nong 690.

Not always the manifestation of high effect of heterosis and transgressive variability in the first - third generations is a guarantee of further production of soybean samples with high economically valuable indicators.

CONCLUSION

According to the results of the study, high values of heterosis in the number and weight of the seeds per plant were found in the combinations Primorskaya 1385 × Kofu, Primorskaya 1385 × Dong nong 690, Hei He 38 × Typhoon. Phenotypic overdominance of the inheritance of indicators was recorded in all the hybrids. The magnitude of transgression in the intervarietal hybrids of soybean in F2 and F3 populations varied by generation and combination. Recombinant hybrids possessed a high degree of transgression: in terms of the main elements of the yield structure – Primorskaya 1385 × Kofu and Hei He 38 × Talppod-Fisk, in terms of the number of seeds per plant – Primorskaya 1385 × Typhoon and Kofu × Typhoon, in terms of seed weight per plant – Dong nong 690 × Typhoon and Hei He 38 × Typhoon. A decrease in the frequency of transgression of the hybrids by the third generation was observed. High values of the degree and frequency of transgression by plant height were observed in hybrid combinations Hei He 38 × Typhoon and Hei He 38 × Talppod- Fisk. According to the results of two years of study of transgressive combinations of soybean F4 and F5, recombinant hybrids with high productivity and 1000 seed weight in the combinations Kyoto × Dong nong 690 and Monsoon × Typhoon were identified. Stability of the trait for early- and mid-early maturity was noted in the combinations Primorskaya 1385 × Hodson and Hei He 38 × Talppod-Fisk. The greatest range of variation in the vegetation period of hybrids (from 100 to 118 days) is characteristic of the combination Primorskaya 1385 × Dong nong 690. The obtained source material will be further used in breeding practice in the development of soybean varieties of different directions.

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ИЗУЧЕНИЕ СОРТОНОМЕРОВ КАРТОФЕЛЯ В СЕЛЕКЦИОННОМ ПРОЦЕССЕ В СЕВЕРНЫХ РЕГИОНАХ РОССИИ

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В условиях Архангельской области в питомниках селекционного процесса проведено изучение гибридов картофеля и выделены сортообразцы, обладающие высокой урожайностью, устойчивостью к патогенам и различным факторам природной среды. В 2019 г. из отдела селекции Всероссийского научно-исследовательского института картофельного хозяйства (ВНИИКХ) им. А.Г. Лорха поступило 759 гибридных образцов 9 популяций с последующим изучением и отбором лучших из них в питомниках селекционного процесса: гибридов 1-го и 2-го года, предварительного и основного испытания 1-го года. В результате проведенных исследований и комплексной оценки в питомнике основного испытания 1-го года в первую динамическую копку (через 60 дней после посадки) в группе «среднеранние» по общей и товарной урожайности выделился гибрид 2553/1, превышающий сорт-стандарт Холмогорский в 2,4 раза, в основную уборку – только на 11%. В группе «среднеранние» в основную уборку выделился гибрид 2553/4, превышающий сорт-стандарт Елизавета по общей урожайности на 7,4 т/га, по товарной – на 3,2 т/га. Высокая общая и товарная урожайность картофеля в основную уборку получена у образца 2462/3 (44,3 и 42,5 т/га соответственно). Наблюдения за растениями картофеля в течение вегетационных периодов показали, что поражение их ризоктониозом, микроспориозом и вирусными болезнями не отмечено ни на одном клоне. Выявлены также высокая устойчивость к фитофторозу гибридов картофеля в первый срок наблюдений и снижение ее устойчивости к концу периода вегетации – перед удалением ботвы. Это, возможно, связано с невысокой температурой воздуха и выпадением значительного количества осадков в этот период. Селекционные образцы, показавшие высокую продуктивность и устойчивость к основным заболеваниям, будут изучены в дальнейшем селекционном процессе с целью создания новых сортов для выращивания в условиях северных регионов России.

Ключевые слова: картофель, сортономера, питомники, селекционный процесс, гибриды, урожайность, устойчивость

STUDY OF POTATO VARIETY NUMBERS IN THE BREEDING PROCESS IN THE NORTHERN REGIONS OF RUSSIA

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In the conditions of the Arkhangelsk region in the nurseries of the breeding process the study of potato hybrids was carried out and the varieties with high yield, resistance to pathogens and various environmental factors were selected. In 2019, 759 hybrid samples of 9 populations were received from the breeding department of the All-Russian Research Institute of Potato Farming by A.G.Lorh with further study and selection of the best of them in the nurseries of the breeding process: hybrids of the 1st and 2nd year, preliminary and main trials of the 1st year. As a result of research and complex evaluation in the nursery of the main trial of the 1st year in the first dynamic digging (60 days after planting) in the group "medium early" hybrid 2553/1 stood out on the total and marketable yield exceeding the standard variety Kholmogorsky by 2.4 times, in the main harvest – only by 11%. In the group "medium early" in the main harvesting hybrid 2553/4 stood out exceeding the standard variety Elizaveta on the total yield by 7.4 t/ha, on marketable – by 3.2 t/ha. High total and marketable potato yields in the main harvest were obtained in sample 2462/3 (44.3 and 42.5 t/ha, respectively). Observations of potato plants during vegetation periods showed that no clone was affected by rhizoctoniose, microsporiosis and viral diseases. High resistance to late blight of potato hybrids in the first observation period and decrease of its resistance to the end of the vegetation period, before removal of haulm, was also revealed. This is probably due to low air temperature and significant precipitation during this period. Selection samples that showed high productivity and resistance to major diseases will be studied in further breeding process in order to create new varieties for cultivation in the conditions of northern regions of Russia.

Keywords: potatoes, variety numbers, nurseries, breeding process, hybrids, productivity, resistance

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INTRODUCTION

Potato production in the northern natural-climatic region of Russia is limited by variety assortment, late maturing groups of varieties do not have time to form a full yield of tubers. Effective potato production here is based on the use of early maturing released varieties characterized by high adaptability to soil and climatic conditions. Such varieties should have high productivity and nutritional value, suitability for processing and resistance to various diseases and pests [1, 2].

The European North is characterized by a moderately continental climate – summers are cool and short, precipitation is uneven. Sharp temperature changes and unstable distribution of precipitation during the growing season create stressful situations for potato plants. In this regard, the selection material used in the breeding process should correspond to the growing conditions and biological requirements of the crop[1] [3].

In different weather conditions, the use of potato varieties with high adaptability to environmental factors, resistance to various pathogens allows to obtain high stable yields and quality products. In potato cultivation technology the main link is a variety. It is established that the share of the variety influence in the formation of crop yields reaches 50-70%. It is revealed that due to the improvement of cultivation technology the increase in yield[2] is provided only by 20-25% [4]. On this basis, obtaining new potato varieties capable of early formation of marketable yield with high productivity and resistance to a complex of harmful pathogens[3] is of high urgency [5, 6].

Taking into account the natural and climatic conditions of the northern territories of Russia, it

[1]*Zhuchenko A.A.* Theory and practice of adaptive intensification of crop production // Economics of Agriculture, 1985, N 8, pp. 13-24.

[2]*Rafalsky S.V., Rafalskaya O.M.* Results of practical breeding of potato culture in Priamurie // Far East Agrarian Bulletin, 2009, N 4, pp. 18-20.

[3]*Simakov E.A., Anisimov B.V., Korshunov A.V., Durkin M.L.* On the concept of development of original, elite and reproductive potato seed production in Russia // Potato and Vegetables, 2005, N 2, pp. 2-5.

is established that for this region early maturing varieties with a growing season length of 60-65 days and medium-early varieties with a growing season of 70-75 days are necessary. Such conditions allow to preserve the biological potential of new potato varieties and provide high-quality phytopathogen-free source material for the development of new varieties [7, 8].

In this regard, studies on potato hybrids conducted in the breeding nurseries in the conditions of the Arkhangelsk region are of practical interest. They allow to select varieties with high potential productivity and the highest degree of adaptation to the conditions of a particular region.

The purpose of the study is a comprehensive evaluation of hybrid potato samples in breeding nurseries in the conditions of the northern regions of the European North of Russia.

The objectives of the research included:

– conducting field trials and comprehensive evaluation of the main economically useful traits of the source material in different nurseries of the breeding process;

– selection of the promising breeding numbers to be used in further breeding work to create a new variety.

MATERIAL AND METHODS

The research was conducted in 2019-2022 on the lands of the OOO "Agrofirma Kholmogorskaya" (Arkhangelsk region, Kholmogorsky district). Field experiments were laid on highly cultivated sod-fine-podzolic ferruginous sandy loam soils. The forecrop was vetch-oat mixture for silage.

Soil preparation consisted of fall disking of the forecrop stubble followed by plowing to a depth of 22 cm. In spring, cultivation and ridge cutting with a row spacing of 70 cm were carried out. Planting was carried out in late May – early June by hand. Care for potato planting consisted of harrowing and perching with a cultivator KON-2,8. Herbicide Zenkor Ultra SC at a dose of 0.8 liters/ha was used to control the weeds. According to the objectives, the use of fungicides and insecticides was excluded in the plantings.

The trials were conducted according to the approved scheme of the breeding process, presented as follows:

1) selection nursery (single tubers);
2) nursery of the 2nd year hybrids;
3) pre-trial nursery;
4) 1st year main trial nursery.

In the nurseries, observations, records and culling were carried out according to the methodological recommendations on potato breeding[4-6]. Kholmogorsky (early maturing) and Elizaveta (mid-early) varieties were used as the standard varieties. According to the results of the tests, the ripeness group, yield, resistance to diseases in field conditions and during storage were determined. The evaluation of economically valuable traits was carried out according to the International CMEA Classifier. Yield and fractional composition were evaluated on the 60th day after planting and in the main harvest (90 days after planting). Starch content – according to GOST 7194-81, dry matter – according to GOST 27548-97. Statistical processing of the data was performed by the method of dispersion analysis according to B.A. Dospekhov[7].

RESULTS AND DISCUSSION

During the research period, weather conditions of the vegetation periods differed in terms of average daily air temperatures and the amount of precipitation. The average daily air temperature in 2019 (the 1st year of research) was 13.0 °C (–1.2 °C to the mean annual value), the sum of precipitation was 238.6 mm, which

[4] Methods of state varietal testing of agricultural crops. Issue one. General part. Moscow: Ministry of Agriculture of Russia; FSBI "Gossortkomissiya", 2019, 329 p.

[5] *Zhevora S.V., Fedotova L.S., Starovoitov V.I. et al.* Methodology of agrotechnical experiments, records, observations and analyses on potatoes. M.: FSBSI VNIIKKH, 2019, 120 p.

[6] International CMEA classifier of potato species of selection *Tuderarium* (Dun.) Buk. of the genus *Solanum* L. L.: VIR, 1984, 43 p.

[7] *Dospekhov B.A.* Methodology of field experiment. Moscow: Agropromizdat, 1985, 351 p.

is 20% higher than the mean annual values. The amount of precipitation in June corresponded to the mean annual value, while in July and August this indicator was above the mean annual value by 36 and 99%, respectively. As a result, during the period from potato planting to the first dynamic digging up the conditions of optimal moistening were formed – the hydrothermal coefficient (HTC) was 1.4, and during the period from planting to the main harvesting – conditions of excessive moistening with the value of HTC = 1.7.

In the 2nd year of observations (2020), the average daily air temperature corresponded to the mean annual value and amounted to 14.3 °C. The sum of precipitation amounted to 268.8 mm, which was 119.9% of the multiyear average. The distribution of precipitation in the summer months was uneven. Thus, in June only 54% of the norm fell, while in July this value amounted to 228%, and in August – 190.3%. The period of planting – first dynamic digging up (60 days) and the period of planting – main harvesting were characterized as optimally moistened (HTC = 1.3) and excessively moistened (HTC = 1.7), respectively.

In 2021, the temperature regime during the growing season was formed at the level of mean annual value with average daily air temperature of 14.3 °C. Precipitation was only 2.5% less than the norm – 218.3 mm. The main amount of precipitation occurred in June (243% of the norm). In July, 30% fell, and in August – 22%. The vegetation period as a whole was characterized as optimally humidified with the HTC = 1.5.

The warmest was 2022 with an average daily air temperature of 17.4°C, which is 4.2°C above the multiyear average. The amount of precipitation amounted to 184.4 mm (–4.7% of the norm). Under the prevailing weather conditions, the period of planting – first dynamic digging up (60 days) was characterized as provided with moisture with the HTC = 1.6, and the period of planting – main harvesting – as slightly dry with the HTC = 1.1.

In general, weather conditions of the vegetation periods were favorable for the growth and development of potato plants and did not have a significant impact on the passage of phenological phases. In the nurseries of selection and the main trial of the 1st year, sprouts were observed on the 21st–25th day, and in the nurseries of hybrids of the 2nd year and the preliminary trial – after 25–28 days. The duration of phenological phases from sprouting to flowering was 31–37 days, and from flowering to harvesting was from 32 to 40 days, depending on the ripeness group.

In 2019, studies were conducted in the selection nursery, where single-tuber hybrids of 9 populations (total 759 tubers) were studied: 2442 (Tuleevsky × Golubka), 40 tubers; 2462 (Red Scarlet × Labadia), 107 tubers; 2495 (Nixe × BP808), 84 tubers; 2511 (2559-24 × Innovator), 56 tubers; 2522 (Irbitsky × Innovator), 87 tubers; 2552 (Elmunde × Bellarosa) – 128 tubers; 2553 (Fidelia × Bellarosa) – 115 tubers; 2570 (Kibitz × Bellarosa) - 50 tubers; 2586 (Ramos × Phelox) - 92 tubers (see Table 1). According to the results of visual evaluation of single-tuber hybrids for resistance to viral diseases, hybrids 2462, 2553, 2586, 2442, 2495 showed relatively high resistance – 7 points (less than 10% were affected). The other hybrids were not affected by viral diseases, *Macrosporium solani*, *Rhizoctonia solani*, *Phytophthora infestans*. During tuber harvesting, each excavated cluster was evaluated for shape and size of the tubers, depth of eyes, number of tubers in the cluster, length of stolons, and absence of diseases. According to the results of the evaluation, 71 hybrids were selected for planting in the nursery of the 2nd year hybrids, the average percentage of selection was 10%. The main reasons for culling hybrids: few tubers (less than 8–10), ugly or small tubers, long stolons (more than 20 cm).

In 2020, hybrids of 9 populations (71 clones) were tested in the nursery of the 2nd year hybrids. During visual evaluation of the hybrids for resistance to *Rhizoctonia solani*, *Macrosporium solani* and viral diseases, no diseased plants were detected. Low resistance (3 points) to *Phytophthora infestans* before haulm removal was noted in hybrid populations 2570, 2462, 2553 (more than 50% of leaf surface was affected), in the rest – 5 points (25 to 50% of leaf surface was affected). As a result of the research, 37 hybrids were selected for planting in the nursery

Табл. 1. Результаты отбора одноклубневых гибридов (2019 г.)
Table 1. Results of selection of single-tuber hybrids (2019)

No.	Selection number	Number of the tubers received, pcs.	Hybrids selected, pcs.	Average number of the tubers in a seedbed, pcs.	Average weight of the tubers in a seedbed, g	Average tuber weight, g	% of selection
1	2442	40	5	10	601,6	60,7	12,5
2	2462	107	12	10	811,3	85,6	11,2
3	2495	84	6	13	869,0	65,6	7,1
4	2511	56	6	11	662,7	63,3	10,7
5	2522	87	4	9	728,5	82,3	4,6
6	2552	128	11	10	767,4	74,2	8,6
7	2553	115	15	11	752,0	69,4	13,0
8	2570	50	6	10	394,1	70,8	12,0
9	2586	92	6	11	904,7	69,8	6,5
Total		759	71	10	721,2	71,3	10

pre-test. The highest average weight of one tuber was observed in the hybrid 2462 (78.9 g), smaller tubers were observed in the hybrids 2442 and 2553 (55.5 g), at the same time these hybrids had a higher selection percentage (100 and 80%.) The average selection percentage in the nursery was 55.5% (see Table 2).

In 2021 for planting in the nursery pre-test as a result of selection by morphological features and recording of disease incidence during the storage period, 23 samples of 9 populations remained. The power of plant development by haulm in the flowering phase of the hybrids was good – 7 points, the type of bushes upright and semi-wide (9 and 5 points, respectively). At visual assessment of the hybrids for resistance to viral diseases, *Rhizoctonia solani* and *Macrosporium solani*, no diseased plants were found in the plantings. In the first term of evaluation for resistance to *Phytophthora infestans*, high resistance of all the hybrids (7–9 points) was noted. Before removing the haulm, the hybrids 2586/1, 2462/1, 2462/2 showed high resistance (7 points), in the hybrids 2495/2, 2552/2, 2442/1, 2553/1 – medium resistance (5 points). The rest had low (3 points) and very low resistance, which was favored by cool and rainy weather in August. The average tuber weight in the nursery

Табл. 2. Результаты отбора клубней картофеля в питомнике гибридов 2-го года (2020 г.)
Table 2. Results of selection of potato tubers in the second-year hybrid nursery (2020)

No.	Selection number	Origin	Hybrid families selected, pcs.	Average tuber weight per bush, g	Average tuber weight, g	% of selection
1	2442	Tuleevsky × Golubka	5	534,0	55,5	100
2	2553	Fidelia × Bellarosa	12	458,5	55,5	80
3	2462	Red Scarlett × Labadna	3	343,3	78,9	30
4	2495	Nikse × BP808	2	389,3	71,5	40
5	2511	2559-24 × Innovator	2	411,2	67,4	33,3
6	2522	Irbitsky × Innovator	2	495,6	71,3	50
7	2552	Elmundo × Bellarosa	3	398,4	69,6	33,0
8	2570	Kibitz × Bellarosa	5	411,6	68,3	83,3
9	2586	Ramos × Felox	3	398,3	71,4	50
Total			37	426,7	67,7	55,5

was 82.0 g, and the percentage of selection was 74.1%. In the populations 2395, 2522, 2552 and 2589, the selection percentage was 100%.

As a result of this work, 18 hybrid accessions of 9 populations were selected for planting in the nursery of the main trial in 2022 (see Table 3).

After winter storage (2021/22), 10 hybrid samples of 5 populations remained for planting in the 1st year nursery of the main trial. During the growing season, good (7 points) development of plants in the nursery of the fourth field generation was noted. Visual evaluation of the hybrids to viral diseases, *Rhizoctonia solani* and *Macrosporium solani* did not reveal diseased plants. Before removing the haulm, the hybrid 2553/1 showed high resistance to *Phytophthora infestans*, hybrids 2570/1, 2380/2, 2553/4, 2553/2, 2462/1, 2462/2 – medium resistance, low – in the hybrid 2495/1.

The nursery evaluated the hybrids for early maturity – dynamic digging up 60 days after planting and during the main harvest. In the group "early maturing" on the total and marketable yield the hybrid 2553/1 stood out (see Table 4). Its total yield in the first digging amounted to 38.1 t/ha, marketable yield – 37.4 t/ha, which is 21.9 and 22.0 t/ha more than that of the Kholmogorsky variety, in the main harvest – 47.1 t/ha, which is 4.9 t/ha higher than that of the standard variety. Marketable yield of the released hybrid obtained at the same level with the standard variety Kholmogorsky.

In the group of "medium-early" in the main harvesting the hybrid 2553/4 with a total yield of 46.8 t/ha and marketable – 42.5 t/ha, which is higher than the standard variety Elizaveta by 7.4 and 3.2 t/ha, respectively, stood out. High total and marketable potato yields in the main harvest were in the sample 2462/3 (44.3 and 42.5 t/ha, respectively), although in the first dynamic digging up the total yield was only 2.8 t/ha, and no marketable tubers were received at all.

In the process of study in the nursery the evaluation of potato variety-standard potato tubers for starch and dry matter content was carried out. In potato tubers of the standard potato variety Kholmogorsky the content of starch was 11.2%, dry matter – 16.9%. In the studied hybrids the starch content varied from 10.0 to 11.0%, dry matter – from 15.7 to 16.7%. In the group "medium-early" on the content of starch and dry matter the standard variety Elizaveta stood out – 17.5 and 23.2%, respectively. In the studied hybrids their content was 10.0 – 13.7% and 15.7 – 19.2%, respectively.

This work resulted in the selection of 10 hybrids for planting in 2023 in the nursery of the main 2nd year trial.

Табл. 3. Результаты отбора гибридов в питомнике предварительного испытания (2021 г.)
Table 3. Results of selection of the hybrids in the nursery of the preliminary trial (2021)

No.	Selection number	Origin	Hybrids selected, pcs.	Average number of the tubers in a seedbed, pcs.	Average weight of the tubers in a seedbed, g	Average tuber weight, g	% of selection
1	2442	Tuleevsky × Golubka	1	9	933,2	103,7	50
2	2553	Fidelia × Bellarosa	4	10	833,0	83,3	66,7
3	2462	Red Scarlett × Labadna	3	9	711,1	79,0	50
4	2395	Nikse × BP808	2	11	666,7	90,9	100
5	2511	2559-24 × Innovator	1	9	802,3	89,1	50
6	2522	Irbitsky × Innovator	1	10	720,8	72,1	100
7	2552	Elmundo × Bellarosa	3	9	578,8	64,3	100
8	2570	Kibitz × Bellarosa	2	12	845,7	70,4	50
9	2586	Ramos × Felox	1	11	933,2	84,8	100
Total			18	10	780,5	82,0	74,1

Табл. 4. Урожайность гибридов в питомнике основного испытания 1-го года (2022 г.), т/га
Table 4. Yield of the hybrids in the nursery of the main trial of the 1st year (2022), t/ha

Variety number	Yield in the first dynamic digging (after 60 days)			Yield in the main harvest		
	General	Commer-cial	Increase* to the standard	General	Commer-cial	Increase* to the standard
Early maturing varietal numbers						
Kholmogorsky (standard)	16,2	15,4	–	42,2	42,3	–
2553/1	38,1	37,4	+21,9/+22,0	47,1	42,1	+4,9/–0,2
2570/1	30,3	28,1	+14,1/+12,7	34,9	34,7	– 7,3/–7,6
2495/1	26,8	23,2	+10,6/ +7,8	28,7	25,1	–13,5/–17,2
2552/1	26,2	25,4	+10,0/+10,0	37,9	33,4	–4,3/–8,9
LSD_{05}	2,3	1,9	–	2,3	1,9	–
Medium-early varietal numbers						
Elizaveta	21,2	20,0	–	39,4	39,3	–
2553/2	9,7	6,1	–11,5/–13,9	38,9	35,7	–0,5/–3,6
2553/3	14,3	10,4	–6,9/–9,6	35,8	28,9	–3,6/–10,4
2553/4	19,9	12,9	–1,3/–7,1	46,8	42,5	+7,4/+3,2
2462/1	23,9	12,3	+2,7/–7,7	34,5	31,6	–4,9/–7,6
2462/2	5,0	2,7	–16,2/–17,3	34,5	33,1	–4,9/–6,2
2462/3	2,8	–	–18,4/ –20,0	44,3	43,4	+4,9/+4,1
LSD_{05}	1,8	2,1	–	2,8	1,5	–

*Numerator – to total yield, denominator – to marketable yield

CONCLUSIONS

1. In the conditions of the Arkhangelsk region in the nurseries of the breeding process the study of potato hybrids was carried out and varietal samples with high yield, resistance to pathogens and various environmental factors were isolated in order to create new varieties for the northern regions of Russia.

2. In the nursery of single-tubers 759 hybrid accessions of 9 populations received in 2019 from the selection department of the All-Russian Research Institute of Potato Farming by A.G Lorh were tested with their subsequent study in the nurseries of the breeding process.

3. In the nursery of the main 1st year trial (2022) 10 hybrid samples of 5 populations were studied. In the group "early maturing" by total and marketable yield in the first dynamic digging up the hybrid 2553/1 stood out, exceeding the standard variety Kholmogorsky by 2.4 times, in the main harvest by total yield – by 11%. In the group "medium-early" in the main harvesting the hybrid 2553/4 stood out, exceeding the standard variety Elizaveta on the total yield by 7.4 tons / ha, on marketable – by 3.2 tons / ha. High total and marketable yield of potatoes in the main harvest was obtained in the sample 2462/3 (44.3 and 42.5 t/ha respectively).

4. Observations of potato plants during vegetation periods showed that *Rhizoctonia solani*, *Macrosporium solanum* and viral diseases were not observed on any clone. High resistance to *Phytophthora infestans* of potato hybrids in the first period of observation and decrease of its resistance by the end of vegetation period before haulm removal were also revealed. When evaluating hybrids to viral diseases *Rhizoctonia solani* and *Macrosporium solani*, no diseased plants were found. Before removing the haulm in the hybrid 2553/1 high resistance to *Phytophthora infestans* (8 points) was observed, in the hybrids 2570/1, 2380/2, 2553/4, 2553/2, 2462/1, 2462/2 – medium resistance (5 points), low (3 points) – in hybrid 2495/1. This may be due to low air temperature and significant precipitation during this period.

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ИЗМЕНЕНИЕ И ВЛИЯНИЕ АГРОКЛИМАТИЧЕСКИХ УСЛОВИЙ НА УРОЖАЙНОСТЬ ОВСА В ЯКУТИИ

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Изложены результаты анализа динамики многолетних метеорологических показателей и изучения их влияния на урожайность районированных сортов овса в разных агроклиматических зонах Якутии. Показано, что в период с 1960 по 2021 г. среднегодовая температура воздуха на территории Центральной Якутии (метеостанция Покровск) повышалась ежегодно на 0,045 °С, с 1999 по 2021 г. – на 0,088 °С, количество засушливых лет в июне возросло с 67 до 92% за счет увеличения на 21% лет со средней (ГТК = 0,41–0,60) и очень сильной (ГТК < 0,21) засухой. В июле засуха отмечена в 50% лет, августе – в 38%. Во всех агроклиматических зонах в период с 2014 по 2021 г. за июнь – август ежегодно повышалась среднесуточная температура воздуха на 0,16…0,34 °С и их сумма – на 14…28 °С, уменьшалось количество осадков на 3–16 мм и значение ГТК – на 0,04–0,12 ед. Климатические изменения с 2014 по 2021 г. проходили в 3–8 раз интенсивнее, чем с 1999 по 2022 г. Отмечена сильная изменчивость урожайности районированных сортов овса в каждой агроклиматической зоне: Центральной – от 0,38 до 2,14 т/га (V = 60–73%), Заречной – от 0,31 до 3,55 т/га (V = 41–49%), Среднеленской – от 1,51 до 4,66 т/га (V = 30–36%). Наибольшее ежегодное снижение урожайности зерна сортов овса (на 0,25–0,26 т/га) наблюдалось в засушливых агроклиматических зонах – Центральной (Якутский ГСУ) и Заречной (Мегино-Кангаласский ГСУ) – в сравнении с более влажной Среднеленской зоной (Олёкминский ГСУ – на 0,10 т/га). Более значительное влияние на урожай в Центральной и Заречной зонах оказывали осадки и ГТК вегетационного периода (r = 0,77…0,84), в Среднеленской зоне – температура (r = –0,79). Негативное влияние температуры на урожай в Центральной зоне отмечено в июне (r = –0,83), в Заречной – июле (r = –0,83), в Среднеленской зоне – в августе (r = –0,86). Осадки и ГТК наибольшее влияние на урожайность в Центральной зоне оказывали в июне и июле (r = 0,56…0,59), в Заречной зоне – в июле и августе (r = 0,60…0,76). В Среднеленской зоне связь урожайности с осадками и ГТК в июне и июле была положительной (r = 0,23…0,37), в августе – отрицательной (r = –0,57…–0,71). Значительная вариабельность урожайности зерна районированных сортов овса указывает на изменчивость погодных условий и необходимость возделывания сортов овса, обеспечивающих получение более стабильного урожая в разных агроклиматических зонах Якутии.

Ключевые слова: Якутия, агроклиматические зоны, овес, сорт, урожайность, изменчивость, корреляция, регрессия

CHANGE AND INFLUENCE OF AGROCLIMATIC CONDITIONS ON OAT YIELD IN YAKUTIA

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The results of the dynamics analysis of multi-year meteorological indicators and study of their influence on the yield of the released oat varieties in different agroclimatic zones of Yakutia are presented. It is shown that in the period from 1960 to 2021 the mean annual air temperature in Central Yakutia (Pokrovsk meteorological station) increased annually by 0.045 °C, from 1999 to 2021 – by 0.088 °C, the number of dry years in June increased from 67 to 92% due to a 21% increase in years with medium (HTC = 0.41-0.60) and very strong (HTC < 0.21) drought. In July, drought was recorded in 50% of the years, in August – in 38%. In all agroclimatic zones in the period from 2014 to 2021 for June – August the average daily air temperature annually increased by 0.16...0.34 °C and their sum by 14...28 °C, with precipitation decreasing by 3-16 mm and HTC value by 0.04-0.12 units. Climate change from 2014 to 2021 was 3 to 8 times more intense than from 1999 to 2022. There was a strong variability of yields of the released oat varieties in each agroclimatic zone: Central – from 0.38 to 2.14 t/ha (V = 60–73%), Zarechnaya – from 0.31 to 3.55 t/ha (V = 41–49%), Srednelenskaya – from 1.51 to 4.66 t/ha (V = 30–36%). The greatest annual decrease in grain yield of oat varieties (by 0.25–0.26 t/ha) was observed in arid agroclimatic zones – Central (Yakutsk SCTS) and Zarechnaya (Megino-Kangalassky SCTS) – compared to the wetter Srednelenskaya zone (Olyokminsky SCTS – by 0.10 t/ha). More significant influence on the yield in the Central and Zarechnaya zones was made by precipitation and HTC of the growing season (r = 0.77...0.84), in the Srednelenskaya zone – by temperature (r = – 0.79). Negative effect of temperature on the yield in the Central zone was observed in June (r = – 0.83), Zarechnaya zone - in July (r = – 0.83), in the Srednelenskaya zone – in August (r = –0.86). Precipitation and HTC had the greatest influence on the yield in the Central zone in June and July (r = 0.56...0.59), Zarechnaya zone – July and August (r = 0.60...0.76). In the Srednelenskaya zone the relationship of the yield with precipitation and HTC in June and July was positive (r = 0.23...0.37), in August – negative (r = – 0.57...– 0.71). Significant variability in grain yields of the released oat varieties indicates the variability of weather conditions and the need to cultivate oat varieties that provide a more stable yield in different agroclimatic zones of Yakutia.

Keywords: Yakutia, agroclimatic zones, oats, variety, yield, variability, correlation, regression

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INTRODUCTION

Oats are cultivated in different agroclimatic zones due to their early maturity and ecological plasticity and are one of the main strategic grain-forage crops[1–3] [1, 2]. It occupies more than 65%, or about 7.5 thousand hectares in the structure of grain crops sown areas in Yakutia. Its average yield is higher than that of winter rye, wheat and barley in the republic, but its level remains low (0.9–1.2 t/ha), so the increase in gross grain yields of oats in the region is very important[4]. It is essential to take into account the peculiarities of changes in agrometeorological conditions of the vegetation period in a particular natural-climatic zone in order to increase the yields and stability of grain production, as

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well as in the development of long-term breeding programs to create new adapted varieties of agricultural crops. Climate change significantly affects the growth, development and productivity of agricultural crops, including oats[5, 6] [3-5].

Currently, the cultivation of high-yielding varieties adapted to specific soil and climatic conditions is becoming increasingly important [6-8]. The value of the varieties is largely determined by their resistance to environmental stress factors and their ability to form a stable level of high-quality yield under different agrometeorological conditions. Identification of the features of genotype-environment interaction is one of the priority directions in modern genetic and breeding research [9-11]. Significant variability in yields from year to year indicates the instability of weather conditions and insufficient adaptability of the varieties[7] [12–15].

Yakutia is located in the zone of risky agriculture, in which the limiting factors for obtaining high-quality crop yields are arid conditions, especially in the early summer period, late summer and early autumn frosts, low-temperature permafrost rocks and cold soils with low fertility and insufficient content of macro- and microelements[8] [16]. In recent decades, there has been a significant increase in air temperature in Russia, including Yakutia; in some regions, the amount of precipitation decreases, and there is a deterioration in the conditions of moisture availability to plants during the growing season[9, 10] [17]. In this regard, the analysis of long-term data on the yield and identification of the features of its formation in different agroclimatic conditions is of great importance for planning the strategy of the breeding programs for oats and increasing its productivity in the region.

The purpose of the research is to reveal the change and influence of agro-climatic conditions on the yield of the released oat varieties in different natural zones of Yakutia.

MATERIAL AND METHODS

The objects of the study were released varieties of sown oats and agrometeorological factors over a multi-year period in different agroclimatic zones of Yakutia. Climatic changes in Central Yakutia were assessed according to the data of the Pokrovsk weather station for the period from 1960 to 2022. Changes in agrometeorological conditions of the growing season (June – August) and their effect on the yield of the released varieties of oats Pokrovsky (standard), Pokrovsky 9 and Khibiny 2 were studied from 1999 to 2022 at the Pokrovsky station of the Yakutsk Research Institute of Agriculture named after M.G. Safronov (YANIISKh) in the nursery of competitive variety testing (CVT). The study area of the plots was 25 m^2, 4-fold repetition with randomized placement. The soil of the experimental plot is slightly alkaline permafrost taiga-pale light gray sandy loam, humus content in the arable layer – 2.7%, mobile phosphorus according to Egner – Rim – 10.4 mg/100 g of soil, exchangeable potassium according to Maslova – 27.4 mg/100 g of soil. Observations and records in the field experiment were carried out according to the generally accepted methods[11]. The conditions of heat and moisture availability during the vegetation period (June–August) in the years of study varied significantly: from severe drought (HTC = 0.22–0.36) to increased moisture availability (HTC = 1.41),

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the sum of average daily air temperatures – from 1330 to 1708 °C.

The influence of agroclimatic conditions on the yield of oat varieties Pokrovsky 9 (standard), Pokrovsky and Vilensky was analyzed for 2014-2021 based on the results of testing at Yakutsk, Megino-Kangalassky and Olyokminsky State Crop Testing Sites (SCTS), located respectively in the Central (meteorological station Yakutsk), Zarechnaya (meteorological station Tyungyulu) and Srednelenskaya (meteorological station Olyokminsk) agroclimatic zones of Yakutia. During the years of varieties testing, the conditions of vegetation of the plants in these zones differed significantly. On average, the sum of average daily air temperatures for June–August amounted to 1508 °C in the Srednelenskaya zone, 1585 °C in the Zarechnaya zone, and 1650 °C in the Central zone; average daily temperatures: 16.7, 17.3, and 18.1 °C; precipitation: 155, 128, and 99 mm, respectively. In terms of moisture availability, the Central Zone is characterized as a zone of medium drought (HTC = 0.60), the Zarechnaya and Srednelenskaya zones – as a zone of weak drought and insufficient moisture (HTC = 0.80 and 1.04, respectively).

Moisture availability during the vegetation period was estimated by the Selyaninov hydrothermal coefficient (HTC)[12] taking into account its more detailed gradation[13]. Experimental data were processed by the method of dispersion, correlation and regression analysis using the Snedecor application program package[14, 15].

RESULTS AND DISCUSSION

The analysis of long-term observations conducted at the Pokrovsk meteorological station showed that in the period from 1960 to 2021 the mean annual air temperature (y) in Central Yakutia significantly ($p < 0.01$) increased annually by 0.045 °C (coefficient of determination = 0.44) (1), from 1999 to 2021 – 0.088 °C ($R^2 = 0.44$) (2), in the period from 2009 to 2021 – by 0.128 °C ($R^2 = 0.51$) (3):

$$y = 0{,}0453\,x - 99{,}60,\quad R^2 = 0{,}4408, \tag{1}$$
$$y = 0{,}0876\,x - 184{,}7,\quad R^2 = 0{,}4414, \tag{2}$$
$$y = 0{,}1284\,x - 267{,}0,\quad R^2 = 0{,}5148. \tag{3}$$

For 62 years of observations, the average annual temperature in the region increased by 2.8 °C. The more significant temperature increase in the last decade (2011-2020) in comparison with 1961-1970 was observed in winter (by 2.2...3.6 °C) and spring (2.9...3.7 °C) months, less – in summer (0.7...2.0 °C) and autumn (by 0.8...1.2 °C). Significant spring warming makes it possible to start sowing and harvesting of grain crops earlier. In the conditions of Central Yakutia, it is of great practical importance, as in September there is a sharp decrease in the average daily air temperature (to 5...6 °C) compared to August (14...15 °C). In every second year (48% of the years) frosts with intensity from minus 0.9 to minus 4.7°C were observed in the third ten-day period of August and from minus 3.2 to minus 9.5°C in the first ten-day period of September. It should also be taken into account that precipitation of the second half of plant vegetation often has an intensive character and causes the appearance of afterspring, which can significantly delay the maturation and harvesting of oat crops. Therefore, to obtain high-quality grain yield and its timely harvesting, oat varieties cultivated in the region should belong to the early or mid-early ripeness group and mature no later than August 15-20.

The sum of precipitation for 2011–2020 in comparison with 1961–1970 changed insignificantly: in the warm period (May – September) increased from 165 to 172 mm, in the cold period (October – April) decreased from 80 to 77 mm. During the vegetation period, the total precipitation varied from 121 to 126 mm with a norm of 119 mm, but in June their amount decreased by 14.4 mm, in July and August it increased by 16.0 and 5.8 mm, respectively.

From 1960 to 2022 in the study area dry conditions during the growing season with weak,

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medium and strong drought amounted to 48% of the years, i.e. virtually every second year was dry to a greater or lesser extent. In the years of study (1999 –2022), drought conditions during vegetation of plants were observed in 42% of the years, a decrease by 11.3% of the years with weak drought and an increase by 5.6% of the years with severe drought was noted (see Table 1).

Analysis of moisture availability conditions by months of plant vegetation showed that in the period from 1960 to 2022 in Central Yakutia, early summer (June) drought prevailed, which was observed in 67% of the years, in July such conditions were observed in 52% of the years, and in August – in 41% of the years (see Table 2).

Over the last quarter of a century (1999-2022), drought in June was observed almost annually – in 92% of the years (9 out of 10), while the number of the years with moderate (HTC = 0.41–0.60) and very severe (HTC < 0.21) drought increased from 27.0 to 37.5% and from 6.3 to 16.7%, respectively. In July and August, the region has experienced a slight improvement in moisture conditions in the last two decades, with 50 and 38% of dry years, respectively.

In the period from 1960 to 2021 in Central Yakutia, the trend of HTC for June–August was negative, indicating the deterioration of the moisture conditions in the plants. Each subsequent decade the HTC of the vegetation period decreased by 0.02 units (see Fig. 1). From 1999 to 2021 its decrease was more significant – 0.10 units for each 10 years (4), in the period from 2009 to 2021 even more – 0.15 units (5), from 2010 to 2022 – already by 0.26 units per decade (6):

$$y = -0{,}0096\,x + 20{,}04,\ R^2 = 0{,}0318, \quad (4)$$
$$y = -0{,}0153\,x + 31{,}53,\ R^2 = 0{,}0352, \quad (5)$$
$$y = -0{,}0259\,x + 52{,}97,\ R^2 = 0{,}1162. \quad (6)$$

The revealed trend of decreasing HTC values also indicates a significant climate warming and

Табл. 1. Влагообеспеченность вегетационного периода (метеостанция Покровск)

Table 1. Moisture availability of the growing season (Pokrovsk weather station)

Water availability	HTC value	From 1960 to 2022		From 1999 to 2022	
		Number of years	Percentage	Number of years	Percentage
Increased	1,50–1,41	6	9,5	1	4,1
Optimal	1,40–1,11	12	19,1	6	25,0
Insufficient	1,10–0,76	15	23,8	7	29,2
Mild drought	0,75–0,61	15	23,8	3	12,5
Average drought	0,60–0,41	8	12,7	3	12,5
Severe drought	0,40–0,21	7	11,1	4	16,7

Табл. 2. Доля лет с различной влагообеспеченностью по месяцам вегетации растений в разные периоды (метеостанция Покровск), %

Table 2. Percentage of the years with different moisture availability by months of plant vegetation in different periods (Pokrovsk weather station), %

Water availability	From 1960 to 2022			From 1999 to 2022		
	June	July	August	June	July	August
Excessive	11,1	14,3	17,5	8,3	20,8	16,7
Increased	3,2	1,6	3,2	0	0	8,3
Optimal	4,8	12,7	17,5	0	16,7	12,5
Insufficient	14,3	19,0	20,6	0	12,5	25,0
Mild drought	15,9	7,9	6,3	20,8	4,2	4,2
Average drought	27,0	23,8	14,3	37,5	25,0	20,8
Severe drought	17,4	15,9	12,7	16,7	20,8	8,3
Extreme drought	6,3	4,8	7,9	16,7	0	4,2

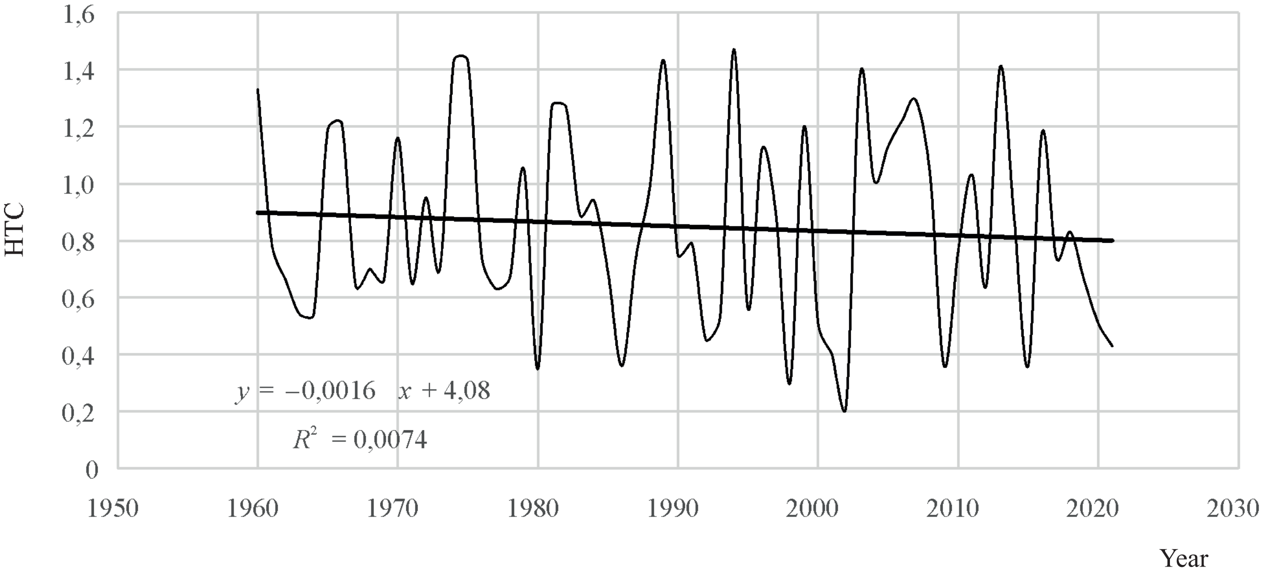

Рис. 1. Изменение ГТК вегетационного периода (*y*) в Центральной Якутии с 1960 по 2021 г. (метеостанция Покровск)

Fig. 1. Change in the HTC of the growing season (*y*) in Central Yakutia from 1960 to 2021 (Pokrovsk weather station)

deterioration of the moisture supply conditions for plants in Central Yakutia in the early summer period over the last two decades.

Regression analysis of the observations of meteorological indicators in other agroclimatic zones of Yakutia confirmed the above-mentioned regularities of climatic changes in the region. Thus, in the Central, Zarechnaya and Srednelenskaya agroclimatic zones in the period from 2014 to 2021, the average daily air temperature for June–August increased annually by 0.16...0.34 °C and their sum by 14...28 °C. At the same time, the amount of precipitation decreased by 3–16 mm and the HTC value – by 0.04–0.12 units (see Table 3). The decrease in the indicators of moisture availability during the vegetation period of the plants in the Zarechnaya zone was reliable at the 5% level of significance. Analysis of the observations conducted at the Pokrovsk weather station showed that climatic changes (warming and deterioration of the plant water availability conditions) in the period from 2014 to 2021 were 3–8 times more intense than from 1999 to 2022.

A similar pattern for the study period was observed in the dynamics of grain yield of the released oat varieties in all agroclimatic zones. The greatest annual decrease in the yield (by 0.25– 0.26 t/ha with probability by varieties from $p < 0.05$ to $p < 0.01$) was observed in arid Central and Zarechnaya agroclimatic zones in comparison with more favorable in terms of moisture conditions Srednelenskaya agroclimatic zone (by 0.10 t/ha) (see Table 4, Fig. 2). Studies at the Pokrovsk station showed that the annual decrease in the grain yield of the released varieties of oats in the period from 2014 to 2021 was 12.7 times greater than in the period from 1999 to 2022.

The above data indicate that agroclimatic conditions of the growing season in the studied zones differed significantly, but the increase in temperature, decrease in precipitation, deterioration of moisture conditions of vegetation of the plants and decrease in their productivity in the period from 2014 to 2021 were observed in each of them, but in different degrees of intensity.

Grain yield of the oat varieties at the Olyokminsky SCTS averaged 2.88–3.22 t/ha, which was 1.4–1.6 times higher than at the Pokrovsk station and Megino-Kangalassky SCTS, and 2.7–3.2 times higher than at the Yakutsk SCTS, located in the zone with the most arid conditions of the growing season (HTC = 0.60). The average yield of the Vilensky variety at the Olyokminsky SCTS was at the level of the standard

Табл. 3. Коэффициенты регрессии (тренды) количественных изменений метеорологических показателей вегетационного периода в разных агроклиматических зонах Якутии в период с 2014 по 2021 г.

Table 3. Regression coefficients (trends) of quantitative changes in meteorological indicators of the growing season in different agroclimatic zones of Yakutia in the period from 2014 to 2021

Zone (weather station)	Average daily air temperature, °C	Sum of average daily air temperatures, °C	Total precipitation, mm	HTC, units
Central (Pokrovsk)**	0,055	4,83	–0,76	–0,008
Central (Pokrovsk)	0,157	14,39	–6,23	–0,046
Central (Yakutsk)	0,339	28,12	–5,97	–0,045
Zarechnaya (Tyungyulyu)	0,201	19,17	–16,25*	–0,117*
Srednelenskaya (Olyokminsk)	0,289	27,00	–2,88	–0,036

* Significant at 5% significance level.
** Data for the period from 1999 to 2022.

Табл. 4. Изменение урожайности районированных сортов овса в разных агроклиматических зонах Якутии в период с 2014 по 2021 г.

Table 4. Changes in the yield of the released oat varieties in different agroclimatic zones of Yakutia in the period from 2014 to 2021

Variety	Yield trend, t/ha	Average yield, t/ha	Min-max yields, t/ha	Coefficient of variation, (*V*), %
*Central zone (YANIISKh station – Pokrovsk)****				
Pokrovsky 9	–0,0116	2,22	0,70–5,20	62
Pokrovsky	–0,0149	1,93	0,81–5,13	60
Khibiny 2	–0,0093	1,70	0,40–4,26	63
Average	–0,0119	1,95	0,64–4,86	62
Central zone (YANIISKh station – Pokrovsk)				
Pokrovsky 9	–0,1719	2,27	0,70–4,42	63
Pokrovsky	–0,1408	1,98	0,35–3,87	64
Khibiny 2	–0,1424	1,70	0,40–3,66	71
Average	–0,1517	1,98	0,48–3,98	66
Central zone (Yakutsk SCTS)				
Pokrovsky 9	–0,2108*	1,01	0,38–2,14	67
Pokrovsky	–0,2246*	1,05	0,32–1,92	64
Vilensky	–0,3230**	1,20	0,35–2,10	73
Average	–0,2528	1,09	0,35–2,05	68
Zarechnaya zone (Megino-Kangalass SCTS)				
Pokrovsky 9	–0,2311	2,03	0,88–3,44	41
Pokrovsky	–0,2729*	1,87	0,31–2,65	49
Vilensky	–0,2752	2,08	0,62–3,55	48
Average	–0,2597	1,99	0,60–3,21	46
Srednelenskaya zone (Olyokminsk SCTS)				
Pokrovsky 9	–0,0862	3,22	1,60–4,66	36
Pokrovsky	–0,1137	2,89	1,51–3,86	30
Vilensky	–0,0925	3,21	1,63–4,56	31
Average	–0,0975	3,11	1,58–4,36	32

* Significant at 5% significance level.
** Significant at 1% significance level.
*** Data for the period from 1999 to 2022.

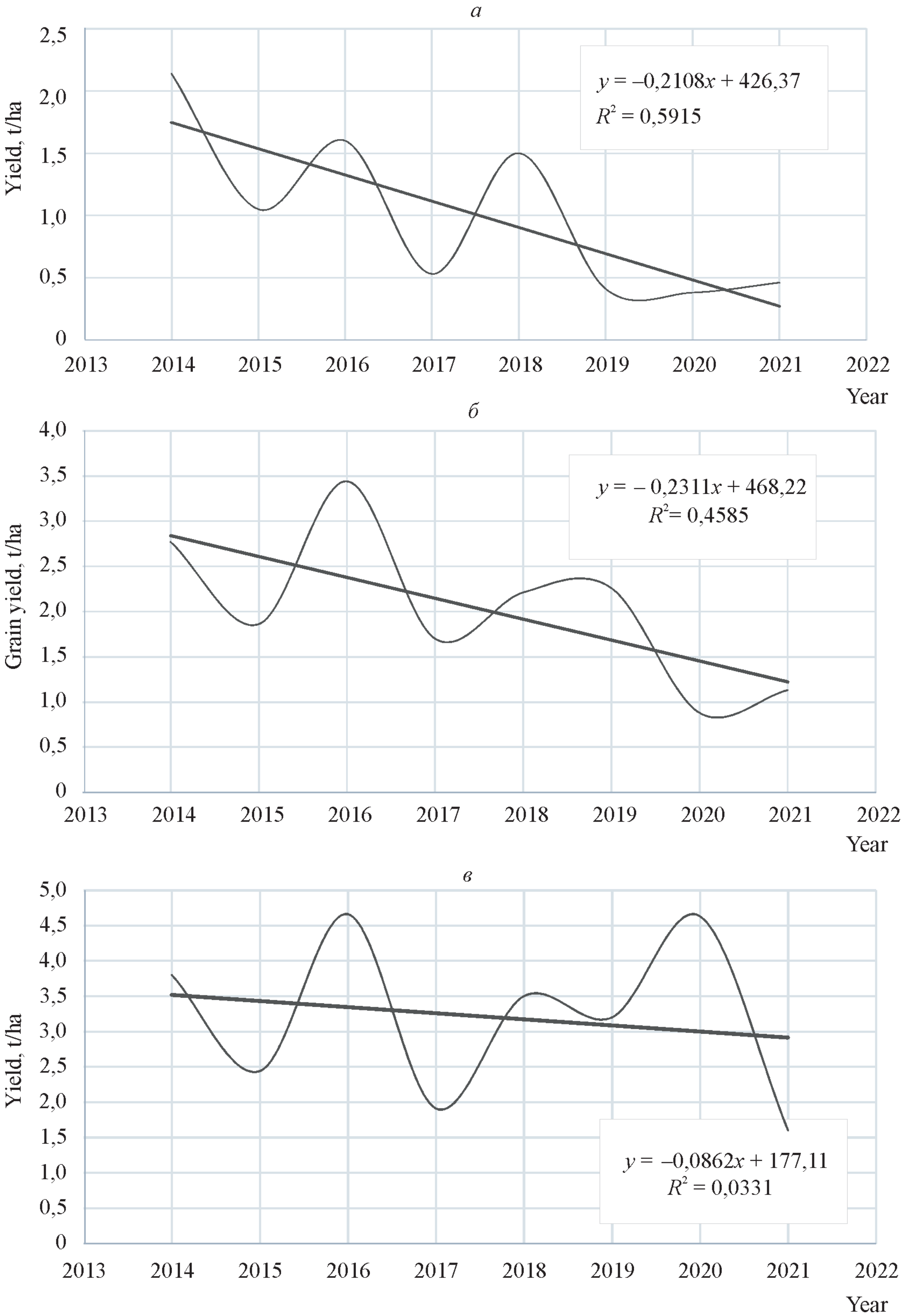

Рис. 2. Изменение урожайности зерна сорта овса Покровский 9 (*y*) в разных агроклиматических зонах Якутии в период с 2014 по 2021 г.:

а – Центральная зона (Якутский ГСУ); *б* – Заречная зона (Мегино-Кангаласский ГСУ); *в* – Среднеленская зона (Олёкминский ГСУ)

Fig. 2. Changes in the grain yield of the Pokrovsky 9 (*y*) oat variety in different agroclimatic zones of Yakutia in the period from 2014 to 2021:

а – Central zone (Yakutsk SCTS); *б* – Zarechnaya zone (Megino-Kangalassky SCTS); *в* – Srednelenskaya zone (Olyokminsky SCTS)

Pokrovsky 9 (3.21–3.22 t/ha), while at other sites it exceeded it by 0.05–0.19 t/ha. The yield of the Pokrovsky variety was lower than the Vilensky variety by 0.15–0.33 t/ha.

In each agroclimatic zone a strong variability of the oat varieties yield was observed: in Central – from 0.38 to 2.14 t/ha (*V* = 60–73%), in Zarechnaya – from 0.31 to 3.55 t/ha (*V* = 41–49%), in Srednelenskaya – from 1.51 to 4.66 t/ha (*V* = 30–36%) (see Table 4).

Significant variability in grain yield of released oat varieties indicates the variability of weather conditions and the need to cultivate oat varieties that provide a more stable yield in different agroclimatic zones of Yakutia. Studies at the Pokrovsk station in the competitive variety trial (CVT) revealed that the influence of the variety (genotype) on the variability of oat yield in Central Yakutia in different years and depending on the number of varieties ranged from 8 to 35%, weather conditions – from 29 to 61%, and the interaction of factors was also reliable – 19–22%.

The correlation analysis showed that the influence of agroclimatic indicators of the growing season on the formation of the oat varieties yield in different regions of Yakutia was different (see Table 5). In the arid and warm Central and Zarechnaya zones, precipitation and the HTC (*r* = 0.77...0.84) had a greater influence compared to temperature (*r* = – 0.60...– 0.74), in the wetter and cooler Srednelenskaya zone – temperature (*r* = – 0.79) than precipitation and the HTC (*r* = – 0.06...0.09).

The analysis of the relationship between the average yield of the oat varieties and agroclimatic conditions by months of vegetation also revealed some regional peculiarities. More significant negative influence of the air temperature on the formation of the yield in the arid Central zone was observed in June (*r* = –0.83), in the less arid Zarechnaya zone – in July (*r* = –0.83), in the more favorable in terms of moisture availability Srednelenskaya zone – in August (*r* = –0.86). Precipitation and the HTC value had the greatest influence on the yield in the Central zone in June–July (*r* = 0.56...0.59), in the Zarechnaya zone – in July–August (*r* = 0.60...0.76).

In the Srednelenskaya zone, the relationship between the yield and the indicators characterizing the conditions of plant moisture availability was positive in June and July (*r* = 0.23...0.37), and negative in August (*r*= –0.57...–0.71) (see Table 5). Significant precipitation in August often caused the formation of the afterspring, which delayed the maturation and harvesting of the crops and increased the yield losses.

Табл. 5. Связь (*r*) урожайности овса с агроклиматическими показателями в разных регионах Якутии (среднее по сортам). 2014–2021 гг.

Table 5. The relationship (*r*) of the oat yield with agroclimatic indicators in different regions of Yakutia (average by varieties). 2014–2021

Indicator	Yakutsk	Tyungyulyu	Olyokminsk
Temperature for June	–0,83**	–0,66	–0,61
Temperature for July	–0,41	–0,83**	–0,57
Temperature for August	–0,17	–0,16	–0,86**
Temperature for June – August	–0,60	–0,74*	–0,79*
Precipitation for June	0,56	0,48	0,23
Precipitation for July	0,58	0,60	0,32
Precipitation for August	–0,01	0,67	–0,71*
Precipitation for June – August	0,77*	0,84**	–0,06
HTC for June	0,59	0,48	0,23
HTC for July	0,59	0,64	0,37
HTC for August	0,05	0,76*	–0,57
HTC for June – August	0,80*	0,81*	0,09

* Significant at 5% significance level.
** Significant at 1% significance level.

The studies carried out in 1999-2022 in the CVT at the Pokrovsk station of YANIISKh showed that the oat varieties yield was significantly influenced by precipitation and the June HTC (r = 0.61...0.65). Precipitation and the June HTC – 1st ten-day period of July also had a reliable but less significant influence (r = 0.46...0.54). There was a weak negative relationship between the yield and the air temperature of the growing season (r = –0.14... –0.22).

CONCLUSION

In the period from 1999 to 2021 in Central Yakutia, the annual increase in daily-average annual air temperature amounted to 0.088 °C (R2 = 0.44), from 2009 to 2021 – 0.128 °C (R2 = 0.51). More significant temperature increase (by 2.2...3.7 °C) was in winter and spring months. Dry conditions of the growing season were observed every second year (48% of the years). The region is dominated by early summer (June) drought, which was observed in 67% of the years from 1960 to 2022, 92% of the years from 1999 to 2022 (9 out of 10), and the number of years with very severe drought (HTC < 0.21) increased by 10%. In July, drought conditions occurred in 50% of the years, and in August in 38% of the years.

In all agroclimatic zones in the period from 2014 to 2021 in June – August, the average daily air temperature increased annually by 0.16...0.34 °C and their sum – by 14...28 °C, the amount of precipitation decreased by 3 –16 mm and the HTC value by 0.04 –0.12 units. Climatic changes from 2014 to 2021 were 3–8 times more intense than from 1999 to 2022.

In the years of the study there was a strong variability of the yield of the released oat varieties in each agroclimatic zone: Central – from 0.38 to 2.14 t/ha (V = 60 – 73%), Zarechnaya – from 0.31 to 3.55 t/ha (V = 41 –49%), Srednelenskaya – from 1.51 to 4.66 t/ha (V = 30 –36%). In the arid Central and Zarechnaya zones, precipitation and the HTC (r = 0.77...0.84) had the greatest effect on the yield compared to temperature (r = –0.60... –0.74), in the wetter and cooler Srednelenskaya zone – temperature (r = –0.79) than precipitation and moisture availability (r = –0.06...0.09).

Significant variability of grain yield indicates the variability of the weather conditions and the need to cultivate the oat varieties that provide a more stable yield in different agroclimatic zones of Yakutia. Decrease in yields of the released oat varieties in the region in the last decade is caused by agroclimatic changes – an increase in temperature and a decrease in precipitation, which led to deterioration of the moisture availability of plants during the growing season, especially in the first half of it.

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КОРРЕЛЯЦИОННАЯ ЗАВИСИМОСТЬ СЕЛЕКЦИОННО-ЦЕННЫХ ПРИЗНАКОВ ЛЮПИНА ЖЕЛТОГО

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В результате проведенного исследования установлено, что комбинации скрещивания 16-20, 22-20 и 24-20 с доминантностью в F1, трансгрессией в F2 по биологически ценным в селекционном отношении признакам в F3 подтверждают их корреляционной связью и отличаются типом использования. Гибриды $16\text{-}20_{2c}$ имеют семенную направленность за счет высокой выживаемости растений и большого числа бобов на главной кисти. Материал гибридов $16\text{-}20_{4в}$, $22\text{-}20_{2c}$, $24\text{-}20_{2c}$ является универсальным, отличается высокой продуктивностью, которая подтверждается корреляционной связью с количеством семян и их массой (по зерну), с высотой оставшихся растений к уборке, числом бобов на них и боковым ветвлением (по зеленой массе). Проведенный анализ сопряженности хозяйственно полезных признаков по семенной продуктивности выявил положительную связь между количеством и массой семян с главного соцветия в комбинациях $5\text{-}20_{2c}$ (r = 0,74 и 0,82), 22-20 (r = 0,89 и 0,92), 24-20 (r = 0,80 и 0,71), 30-20 (r = 0,94 и 0,93) и др. Обнаружена высокая корреляционная зависимость между урожайностью зерна и числом выживших растений к уборке у гибридов $5\text{-}20_{2c}$ (r = 0,92), $30\text{-}20_{2c}$ (r = 0,83), $6\text{-}20_{2d}$ (r = 0,73), 22-20 (r = 0,79), 24-20 (r = 0,80). Независимо от комбинации скрещивания сильное положительное влияние на семенную продуктивность большинства гибридов оказывают число и масса семян с главного соцветия с коэффициентом корреляции от 0,71 до 0,93. Положительный эффект получен от числа бобов с главной кисти в комбинациях $17\text{-}20_{2c}$ (r = 0,90), $25\text{-}20_{2c}$ (r = 0,81), 24-20 (r = 0,77), $5\text{-}20_{2c}$ (r = 0,90). На урожайность зеленой массы желтого люпина оказывали влияние высота растений (r = 0,61–0,93), число выживших растений к уборке (r = 0,51–0,95), наличие боковых побегов с бобами (r = 0,54–0,63) у гибридов $5\text{-}20_{2c}$, $16\text{-}20_{2c}$, $22\text{-}20_{2c}$, $24\text{-}20_{2c}$ и др.

Ключевые слова: люпин желтый, гибрид, продуктивность зерна и зеленой массы, корреляционная связь

CORRELATION DEPENDENCE OF SELECTIVE VALUABLE TRAITS OF YELLOW LUPINE

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As a result of the conducted study, it was found that the combinations of crosses 16-20, 22-20 and 24-20 with dominance in F1, transgression in F2 on biologically valuable traits in selective respect in F3 confirm their correlation relationship and differ in the type of utilization. The $16\text{-}20_{2c}$ hybrids are seed oriented due to high plant survival rate and high number of beans on the main raceme. The material of hybrids $16\text{-}20_{4v}$, $22\text{-}20_{2c}$, $24\text{-}20_{2c}$ is universal, characterized by high productivity, which is confirmed by the correlation with the number of seeds and their weight (by grain), with the height of the remaining plants to harvesting, the number of beans on them and lateral branching (by herbage). The analysis of pairing of economically useful traits on seed productivity revealed a positive relationship between the number and weight of seeds from the main inflorescence in combinations 5-20_{2c} (*r* = 0.74 and 0.82), 22-20 (*r* = 0.89 and 0.92), 24-20 (*r* = 0.80 and 0.71), 30-20 (*r* = 0.94 and 0.93) and others. High correlation was found between the grain yield and the number of surviving plants to harvest in hybrids 5-20_{2c} (*r* = 0.92), 30-20_{2c} (*r* = 0.83), 6-20_{2d} (*r* = 0.73), 22-20 (*r* = 0.79), 24-20 (*r* = 0.80). Regardless of the combination of crosses, the number and weight of seeds from the main inflorescence with the correlation coefficient from 0.71 to 0.93 have a strong positive effect on the seed productivity of most hybrids. A positive effect was obtained from the number of beans from the main raceme in combinations 17-20_{2c} (*r* = 0.90), 25-20_{2c} (*r* = 0.81), 24-20 (*r* = 0.77), and 5-20_{2c} (*r* = 0.90). The herbage yield of yellow lupine was influenced by the plant height (*r* = 0.61–0.93), the number of surviving plants to harvest (*r* = 0.51–0.95), the presence of lateral shoots with beans (*r* = 0.54–0.63) in hybrids 5-20_{2c}, 16-20_{2c}, 22-20_{2c}, 24-20_{2c} and others.

Keywords: yellow lupine, hybrid, grain and herbage productivity, correlation relationship

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INTRODUCTION

Lupine (*Lupinus*) is a plant genus of the legume family (Fabaceae). In the State Register of Breeding Achievements of Russia 55 varieties are allowed for use, including 11 varieties of yellow lupine. Seeds of yellow lupine are characterized by a high content of protein (in some varieties up to 50.0%) and oil (from 5.0 to 20.0%).

In recent years, the use of lupine grain for food purposes has significantly expanded. For example, flour and protein isolates are used in bakery, pasta, confectionery and meat processing industries, production of dietary and therapeutic products. The largest consumer of lupine for food is the Australian continent, where the area under this crop is more than 1 million hectares.

The lupine root system is able to penetrate to a considerable depth and utilize phosphates that are difficult to dissolve. Due to symbiosis with nodule bacteria, lupine can accumulate up to 200 kg/ha of nitrogen in the soil. The vegetative (green) mass of lupine is successfully used in cattle feeding, as well as an organic fertilizer in the form of siderate. Lupine seeds are used in the production of paint and plastic products, in soap making.

Knowledge of the peculiarities of correlations between biologically valuable traits of plants allows determining their causal dependence and factors influencing them. For the efficiency of selection it is necessary to take into account not only environmental conditions, but also the conjugation between the main and economically valuable traits [1–5].

Research is being conducted in breeding and seed production of yellow lupine of universal type of use to create a variety with good yield of green mass and grain. The problems of shortening the vegetation period without reducing green mass productivity, increasing plant height, obtaining fast-growing forms with a more spreading bush type and active lateral branching[1, 2] were solved. [6–8].

In the process of breeding with hybrid material of fodder lupine, several correlation depen-

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dencies between individual traits were observed. For seed productivity, a close relationship between the weight of seeds from the main inflorescence and the number of beans and seeds on it has been established, so selection of the genotypes for this trait is the most effective[3, 4] [9, 10].

However, these correlations do not always provide high productivity in the process of variety development. Sometimes it is necessary to combine individual traits to obtain the desired result. In addition, attempts to recombine related traits should not be excluded[5].

Based on the proposed K.I. Savvichev program of breeding yellow lupine in 2015 breeders of the Novozybkovsk experimental station obtained a patent for yellow lupine variety Novozybkovskiy 100, which is characterized by high yield of green mass (50–60 t/ha) and grain (2.0–2.5 t/ha), high protein content (respectively 2.0 and 45.0%), less susceptibility to anthracnose, fusarium and viral blight. As a result of many years of focused work on the creation of the varieties resistant to anthracnose, specialists of the laboratory of breeding and seed breeding developed a variety of yellow lupine Antei, which in 2020 was sent to the procedure of state variety testing. As a result, a patent was obtained in 2022, allowing the use of this variety in agricultural production[6, 7] [11–13].

The purpose of our research is to create a new breeding material of yellow lupine of universal type of use for the zone of sandy and sandy loam soils with low level of natural fertility through hybridization.

The task of the research is to attract seed parents, created in local soil and climatic conditions, having resistance to various diseases and high productivity in grain and green mass, and protein accumulation.

MATERIAL AND METHODS

The study was conducted in the breeding nurseries testing progeny of hybrid material in 2020–2023 taking into account the requirements of "Field experiment methodology" by B.A. Dospekhov[8]. The soil is sod-podzolic sandy. Humus content – 1.0–1.2% (according to Tyurin), mobile phosphorus – 200–250 mg/kg, exchangeable potassium – 40-50 mg/kg (according to Kirsanov). Reaction of the soil solution is slightly acidic.

The nursery was located in the field No. 3 of the laboratory of breeding and seed production of the Novozybkovskaya Agricultural Experimental Station. Laying was carried out in the II ten-day period of April. Sowing was carried out manually with the rate of 60 pieces per plot. The forecrop was winter rye. Soil treatment consisted of fall stubble disking with light discs followed by winter plowing (in 2–3 weeks). In spring the field was harrowed to close moisture, $P_{20}K_{90}$ in the form of borophoska and potassium chloride was applied under cultivation, before sowing the field was rolled with ring rollers in one to two traces depending on the soil condition.

In 2023, a hybrid nursery was established with the involvement of seed parents and standards. Phenological observations were carried out in the nursery, as well as records of virus, fusarium and anthracnose damage.

All plants were staked before flowering for the purpose of subsequent observation. Before harvesting, a field structural analysis of hybrids and parental forms was carried out with subsequent selection of the best samples for height, number of beans on the main brush and on the plant, lateral branching, including with beans. In the laboratory, each selection of the main brush was threshed, taking into account the number

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of beans, seeds and their weight, and the worst samples were rejected. The selected material together with the seed parents and standards will be sown in the nursery of the fourth generation in one to three times repetition depending on the availability of seeds to establish the inheritance of economically valuable traits.

RESULTS AND DISCUSSION

In order to expand the area of cultivation of the yellow lupine and in connection with the change of climatic conditions by years, the hybrids of the first – third generation were evaluated by grain and green weight.

The obtained hybrid material of the year 2020 of crossing (F1) exceeded the indicators of the best parent in plant height by 1–9 times, number of beans on the main brush by 1.4–15 times, total number of beans by 1.2–11.3 times in the combinations 15–20, 16–20, 17–20, 22–20, 24–20, 25–20. In the second generation (F2), the advantage of economically valuable traits relative to the best seed parents was not preserved in all the combinations. Transgression in plant height was recorded in the hybrids 13–20 and 16–20 (36.0%), 22–20_{2c} (18.0%), 24–202c (29.0%), 30–20_{2c} (66.0%) with the frequency of occurrence of 6.6–17.7%. Positive transgression in the number of beans on the main brush was observed in six combinations and amounted to 12.5– 37.5% with the occurrence of such plants at the level of 3.0–10.0%. Four combinations of crossing were distinguished by the number of beans on the plant: 16–20, 17–20, 22–20 and 24–20. In these combinations, the number of beans increased by 48.6; 48.4; 41.1 and 19.2%, respectively, and the frequency of occurrence was 5.0; 5.0; 10.0 and 12.0%.

Transgressive forms of cross combinations 16-20 and 17-20 with different seed color (2c and 4v) were sown in blocks with seed and vegetative productivity. The analysis showed that hybrid 16 20_{2c} is preferable to cultivate for seed: its yield was 286 g / m^2 due to the survival of the plants to harvest with a correlation coefficient of 0.94. The correlation with the number of beans was low (r = 0.56), for other valuable traits there was no relationship (see the table).

It was found that families of the hybrid 16-20_{4v} are universal, they can be used both for grain (yield 375 g/m^2) and for green mass (4630 g/m^2). Correlation with plant survival was 0.82– 0.84, with the height of the plants grown for seed production – 0.79, green mass production – 0.92, with the number of the beans on the main inflorescence when used for seeds – 0.60, with the total number of the beans on the plant – 0.63 and 0.70, with the number of the seeds – 0.80 and 0.60, with the weight of the seeds – 0.89 and 0.80.

In the hybrid material of the combination 17–20_{2c} the selection of the best main inflorescences was carried out, for which high conjugation between the number of the beans and the number of the seeds (r = 0.90), the number of the beans and the seed weight (r = 0.77), rather low conjugation between the number of the seeds and their weight was established (r = 0,43).

Samples of the hybrid 17–20_{4v} formed an average of 360 g/m^2 of the grain with the following correlation coefficients: with the beans of the main brush – 0.71, with the number of the seeds – 0.52, with their mass – 0.62, indicating their seed orientation. Small sample of the results (three families) in the block with plant height does not give grounds for using it for green mass.

The material of the crossing combination 22–20_{2c} can be attributed to the universal type: seed productivity was 326 g/m^2, productivity of the green mass - 5000 g/m^2. It was found that high grain productivity was associated with the number of beans per plant (r = 0.50), the number of seeds (r = 0.89) and their weight (r = 0.82). A significant relationship between the main inflorescence bean and the number of seeds (r = 0.82), as well as their weight (r = 0.76) was revealed.

Green mass yield was confirmed to be highly dependent on the plant height (r = 0.93), average of the number of the survived plants to the harvest (r = 0.51) and lateral branching with beans (r = 0.40).

Among the hybrids 24-20_{2c} (38 numbers), seven families were identified, exceeding in plant height the best parent (49 cm) by 1–9 cm (r = 0.93), having four to six lateral shoots (*r* = 0.65), including 3–4 fruit-bearing (*r* = 0.59), which affected the yield of the above-ground mass (5400 g/m^2). It should be noted that the seed productivity of this hybrid material was 316 g/m^2, and it was more dependent on the number of the beans on the main brush (*r* = 0.77), seeds on the plant (*r* = 0.80) and seed weight from the main inflorescence (*r* = 0.71). According to the indicators of dependence of the grain and green mass productivity on economically valuable traits, these families belong to the universal type of utilization.

Under the impact of complex influence of genetic factors and environmental conditions, changes in the formation of productive organs occurred, which allowed some families to increase the performance of economically valuable traits in some other combinations.

Hybrids in the cross 30–20 with grain color 2c belong to the group of seed productivity, in which nine families with an average yield of 338 g/m^2 were obtained. Analysis of the results of the study showed that the yield was more influenced by the relationship between the number of seeds from the main inflorescence (*r* = 0.94) and seed weight from it (*r* = 0.93). The conjugate relationship between the yield and the number of beans on the main brush was lower (*r* = 0.68).

Universal hybrid material of 5–20$_{2c}$ and 6–20$_{2d}$ reciprocal crosses showed high seed productivity (392 and 379 g/m^2, respectively) due to the number of the plants survived to the harvest (*r* = 0.92 and 0.73), beans on the main inflorescence (*r* = 0.90 and 0.72), seed number (*r* = 0.74 and 0.80) and seed weight (*r* = 0.82 and 0.86). Green mass productivity was associated with plant height (*r* = 0.61 and 0.68), their survival to the harvest (*r* = 0.95 and 0.83) with equal number of lateral branches (4-5 pcs.), including those with beans (2.7 and 3.0 pcs.).

Корреляционная зависимость продуктивности от биологически ценных признаков
Correlative dependence of productivity on biologically valuable traits

Hybrid	Grain and green mass yield, g/m^2	Correlation relationship					
		Number of plants survived	Plant height	Number of beans on the main brush	Total amount of beans	Number of seeds	Seed weight
16-20$_{2c}$	286/–	0,94	–	0,56	–	–	–
16-20$_{4\text{в}}$	375/4630	0,82/0,84	0,79/0,92	0,60/0,60	0,63/0,70	0,80/0,60	0,89/0,80
17-20$_{2c}$	Small sample			0,90	0,95	0,77	0,43
17-20$_{4\text{в}}$	360/–	0,81	0,62	0,71	0,79	0,52	0,62
22-20$_{2c}$	326/5000	0,79/0,51	0,50/0,93	0,50/0,53	0,54/0,55	0,89/0,81	0,82/0,83
24-20$_{2c}$	316/5400	0,80/0,80	0,67/0,93	0,77/0,75	0,78/0,77	0,80/0,79	0,71/0,75
30-20$_{2c}$	338/–	0,83	0,65	0,68	0,70	0,94	0,93
5-20$_{2c}$	392/5200	0,92/0,95	0,60/0,61	0,90/0,85	0,92/0,87	0,74/0,79	0,82/0,84
6-20$_{2d}$	379/5200	0,73/0,83	0,60/0,68	0,72/0,77	0,71/0,77	0,80/0,85	0,86/0,86
11-20$_{2c}$	386/–	0,64	0,46	0,65	0,65	0,60	0,65
25-20$_{2c}$	380/–	0,94	0,55	0,81	0,94	0,81	0,89

Note. Data on grain are given in the numerator, green mass – in the denominator.

Hybrid 11–20_{2c}, in which eight families exceeded the best parent in the number of the beans on the main brush by 2–7 pieces, their total number on the plant – by 1–17 pieces, which allowed to form a high seed productivity (386 g/m^2), which was provided by the same correlation relationship for all traits of the main inflorescence (r = 0.65). Preliminary families of this hybrid were classified as seed direction.

Positive correlation between the seed yield and breeding-valuable traits was found in the hybrids of the cross 25 20_{2c}. High correlation coefficients were obtained with the number of the survived plants to the harvest (r = 0.94), beans on the main inflorescence (r = 0.81) and on the plant (r = 0.94), number of seeds (r = 0.81) and their weight (r = 0.89), indicating the relevance of its use for seed purposes.

Seed parents of productive varieties of the local selection were involved for crossing – Bystrorastuschy 4, Druzhny 165, Novozybkovsky 100, selection of the All-Russian Research Institute of lupine – Nadezhny, CH 1408 and its mutant (2556), Bryansky 6 (white-flowered form), Belarusian selection – Narochansky, BSKhA 382 and 387, from the collection of the All-Russian Institute of Plant Genetic Resources – K 2818 and 2816, and of foreign selection – Afus and Refusa (R-6022).

Three seed parents (4–08–116, 5–10–84, 13–10–54), which showed themselves positively as both female and male forms, were isolated. Specimen 4-08-116 was obtained by crossing white-flowered selections from yellow lupine variety Bryansky 6 and was used as a female parent form in the creation of hybrid 6–20, as a male parent form – in the creation of the universal hybrids 5–20 и 22–20.

Specimen 5–10–84 has a rich breeding record: the varieties Bystrorastuschy 4, Druzhny 165, white-flowered form of lupine, varieties Afus and Refusa, SN-1-00-2-9 (Novozybkovsky 100) participated in its creation as great- and great-great-grandparents. It was involved in the crosses as a female parent form and formed two hybrid lines of seed direction – 11–20 and 30–20.

Hybrid material 25–20, 24–20 and 30–20, created with sample 13–10–54 as female (25–20) and male (24–20 and 30–20) parent forms, was obtained from a cross between the variety Nadezhny and the sample 1–02, whose breeding record includes CH– 1408 and its mutant (2556), the Belarusian variety Narochansky and the local Bystrorastuschy 4 (B 4).

CONCLUSIONS

1. Combinations of the crosses 16–20, 22–20 and 24–20 with dominance in F1, transgression in F2 on biologically valuable in breeding respect traits in F3 confirm their correlation relationship and differ in type of utilization.
2. Hybrid material 16–20_{2c} is preliminarily seed oriented, while 16–20_{4v}, 22–20_{2c}, and 24–20_{2c} are universally oriented.
3. Regardless of the crossing combination, the number of seeds per main inflorescence (r = 0.74–0.94), plant height (r = 0.68–0.93), lateral branching with beans (r = 0.40–0.50) and plant survival rate (r = 0.51–0.91) have a strong positive effect on the seed production of the majority of hybrids.
4. Under the influence of complex effect of genetic factors and changing environmental conditions, there were changes in productive organs in the combinations 5–20_{2c}, 6–20_{2d}, 11–20_{2c}, 25–20_{2c} and 30–20_{2c}, which was confirmed by conjugation of the main traits in economic terms.
5. Seed parents of the 2020 year of crossing were adapted to soil and climatic conditions of the Bryansk region as a result of 20 years of research in the collection nursery.
6. The best families of crossbreeding combinations will be tested in the first-year breeding nursery together with the seed parents and standards to determine the inheritance of quantitative traits.

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ЗАЩИТА ОЗИМОГО ЯЧМЕНЯ ОТ СЕТЧАТОЙ ПЯТНИСТОСТИ ЛИСТЬЕВ С ИСПОЛЬЗОВАНИЕМ СОВРЕМЕННЫХ ФУНГИЦИДОВ

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Представлены результаты трехлетнего (2020–2022) изучения эффективности современного фунгицида Эйс, ККР российского производства (пираклостробин – 80 г/л + протиоконазол – 40 г/л + тебуконазол – 160 г/л) против возбудителя сетчатой пятнистости листьев ячменя. Ячмень – важная пищевая, кормовая и фуражная зерновая культура, занимающая четвертое место в мире по посевным площадям и валовым сборам после пшеницы, риса и кукурузы. Сетчатая пятнистость является доминантным заболеванием в патокомплексе листовых болезней ячменя во всем мире. Одним из наиболее эффективных способов защиты растений в мировой практике является применение высокоэффективных фунгицидов. Эксперимент проведен в условиях полевого стационара. В контроле (без обработки препаратом) развитие сетчатой пятнистости составило 64,4; 86,7 и 49,2% в 2020, 2021 и 2022 гг. соответственно. Биологическая эффективность фунгицида Эйс, ККР против *Pyrenophora teres* Drechsler при норме применения 1,0 л/га составила 98,4% в 2020 г., 89,4% – в 2021 г. и 93,9% – в 2022 г. на высоком фоне развития заболевания, что сопоставимо с известными импортными эталонами. Защита посевов озимого ячменя сорта Романс фунгицидом Эйс, ККР обеспечила прибавку урожая зерна 10,6; 18,5 и 17,9% в 2020, 2021 и 2022 гг. соответственно. Данный фунгицид рекомендован для защиты озимого ячменя от возбудителя сетчатой пятнистостью листьев.

Ключевые слова: сетчатая пятнистость ячменя, *Pyrenophora teres*, фунгициды, защита растений

PROTECTION OF WINTER BARLEY AGAINST NET BLOTCH USING MODERN FUNGICIDES

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The results of a three-year (2020–2022) study of the efficacy of the modern fungicide Ace, CSC of Russian production (pyraclostrobin - 80 g/l + prothioconazole - 40 g/l + tebuconazole - 160 g/l) against the pathogen of barley net blotch are presented. Barley is an important food, feed and fodder grain crop, ranking fourth in the world in terms of area planted and gross yields after wheat, rice and corn. Net blotch is the dominant disease in the pathocomplex of barley leaf diseases worldwide. One of the most effective ways of plant protection in the world practice is the use of highly effective fungicides. The experiment was conducted under field stationary conditions. In the control (no treatment with the drug), the development of net blotch was 64.4; 86.7 and 49.2% in 2020, 2021 and 2022, respectively. The biological efficacy of Ace fungicide, CSC against *Pyrenophora teres* Drechsler at the application rate of 1.0 l/ha was 98.4% in 2020, 89.4% in 2021 and 93.9% in 2022 on high background of disease development, which is comparable to known imported benchmarks. Protection of winter barley crops of the Romance variety with Ace fungicide, SCS provided grain yield increases of 10.6; 18.5 and 17.9% in 2020, 2021 and 2022, respectively. This fungicide is recommended for protection of winter barley against the pathogen of net blotch.

Keywords: barley net blotch, *Pyrenophora teres*, fungicides, plant protection

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INTRODUCTION

Barley (*Hordeum vulgare* subsp. vulgare L.) is the fourth most important cereal crop in the world after wheat, corn and rice [1]. It is a versatile crop, resistant to unfavorable conditions, highly adaptable and able to grow in different soil and climatic conditions [2]. It is predicted that cereal production is expected to increase by more than 50% in the next 50 years due to rapidly growing demand, so understanding the processes that determine crop development, yields and protection from harmful effects is relevant for modern agriculture [3].

The net blotch (causal agent - *Pyrenophora teres* Drechsler.) (see Fig. 1) is one of the most economically important diseases of barley worldwide [4]. In the conditions of the Krasnodar Territory, this disease also occupies a dominant position [5]. Frequent precipitation and high air humidity during the period from tillering to maturity of barley, which is common in the southern regions of Russia, contribute to the emergence of epiphytotics of the net blotch of leaves. Intensive cultivation of high-yielding and susceptible to net blotch barley varieties with violation of crop rotation, sowing dates and

Рис. 1. Сетчатая пятнистость листьев на растениях ячменя (ориг.).
Fig. 1. Net blotch on barley plants (orig.)

preservation of infected plant residues contributes to the widespread spread of the pathogen [6]. Yield losses due to reticular leaf spot worldwide range from 10 to 50% [2, 7], but can reach 100% in severely affected fields where highly susceptible varieties are sown. The economic threshold of leaf net blotch[1] is 15%. The main harmfulness of the disease is not only in direct yield losses due to disruption of plant photosynthesis, but also in the reduction of grain quality, making it unsuitable for food, brewing and fodder production [8].

Currently, much attention is paid to the development of environmentally safe methods of protection of grain crops, including barley, from diseases. A great role in this belongs to the use of new low-hazard and highly effective fungicides. To combat leaf diseases, there are a number of systemic fungicides that can successfully combat a complex of diseases. Most often treatments are carried out with combined preparations consisting of two or more active substances from different chemical classes. They have a wide range of fungicidal activity, a long period of protective action and a low risk of developing resistant races of pathogens [9].

Nowadays the development and application of domestically produced fungicides, which are not inferior to their imported counterparts, are of great importance.

The purpose of the research is to study the biological and economic efficiency of a new generation fungicide Ace, CSC of the "Shchelkovo Agrokhim" against net blotch of barley leaves in the conditions of the central agroclimatic zone of the Krasnodar Territory.

MATERIAL AND METHODS

The study was conducted in the growing seasons of 2020, 2021 and 2022 on the basis of the Federal Scientific Center for Biological Plant Protection (FSCBPP) using a unique scientific unit (USU) "Phytotron for isolation, identification, study and maintenance of races, strains, phenotypes of pathogens" (https://ckp-rf.ru/catalog/ usu/671925/) and objects of the bioresource collection of the FSCBPP "State Collection of Entomoacariphages and Microorganisms".

Efficacy against net blotch was studied with a new preparation included in the State Catalog of pesticides and agrochemicals authorized for use in the territory of the Russian Federation[2], Ace, CSC, consisting of three components (pyraclostrobin – 80 g/l + prothioconazole – 40 g/l + tebuconazole – 160 g/l), produced by AO "Shchelkovo Agrokhim". The application rate of the preparation was 0.6; 0.7 and 1.0 l/ha. Three-component preparation Amistar Trio, EC (azocsystrobin – 100 g/l, propiconazole – 125 g/l, cyproconazole – 30 g/l) (application rate – 1.0 l/ha) produced by OOO "Syngenta" was used as a reference.

Pyraclostrobin and azoxystrobin, included in the tested preparations, belong to the class of strobilurins and are broad-spectrum fungicides. These substances disrupt the energy cycles of pathogenic fungi, stopping the production of ATP, which leads to disruption of pathogen mitochondria activity, prevention of spore germination and reduction of mycelial growth. In addition to fungicidal action, strobilurins have been attributed to plant "greening" or "healing" effects (e.g., growth stimulation, hormonal changes, and delayed senescence) that contribute to greater dry matter accumulation during the seed filling period and higher yields because more photosynthetically efficient leaves persist longer [10, 11].

Substances prothioconazole and tebuconazole, included in the fungicide Ace, CSC, as well as propiconazole and cyproconazole, included in the fungicide Amistar Trio, EC, belong to the class of triazoles. The mechanism of action of these substances, regardless of the peculiarities of the chemical structure is determined by their ability to disrupt the biosynthesis of ste-

[1]KazakhZerno - news, analysis and prices of grain market in Kazakhstan and CIS countries. Rosselkhoztsentr: reticulated helminthosporiosis was detected on barley crops https://kazakh-zerno.net/149956-rosselkhoztsentr-na-posevakh-yachmenya-obnaruzhensetchatyj-gelmintosporioz/.

[2]State catalog of pesticides and agrochemicals approved for use in the Russian Federation 2023. M., 2023, 889 p.

rols in fungi, suppression of ergosterol biosynthesis. Ergosterol deficiency, inclusion of ergosterol precursors and products of their enzymatic transformations in the cell membrane of fungi cause significant disturbances in the structure, stability, density, permeability and functions of the membrane, affect the activity of the associated enzymes, lead to disorganization of the cell walls of fungi and stop their growth. In addition, the synthesis of unsaturated fatty acids stops in fungal cells, which are partially replaced by palmitic acid [12].

An important property of modern fungicides is also a low level of accumulation of residues in products. As it is known from the literature, when using fungicide preparations (one-, two- and three-component) containing active substances of different chemical classes in their composition, the danger of contamination of plant products of grain ear crops with fungicide residues is insignificant [13].

Data on weather conditions during the growing seasons 2020, 2021 and 2022 are presented in the diagram (see Fig. 2). In 2020, April, May, and June were characterized by moderate temperature and precipitation deficits compared to the long-term average. In 2021 April, May, and June were characterized by abundant precipitation but lower temperatures, especially in April. In 2022, April was undershooting; May precipitation totals were comparable to the multiyear average; and June saw heavy precipitation, nearly double the multiyear average. Cooler than normal temperatures were observed in May 2022. These weather conditions could have a strong influence both on the development of the disease under study and on the yield of the protected crop.

The soil of the experimental plot is typical for the central zone of this region – leached chernozem. The depth of the humus horizon is 80–150 cm, humus content in the arable layer up to 20 cm is 3.39% (GOST 2613– 94), mobile phosphorus – 18.2 mg/100 g of soil (GOST 26204–91), mobile potassium compounds – 30.6 mg/100 g (GOST 26205–91), soil reaction is slightly acidic (pH = 5.5–6.5). There is no exchangeable acidity, hydrolytic acidity varies from 2 to 4 mg-eq/100 g of soil, the degree of soil saturation with bases is 85–95%. Humus content is 3,8, pH = 6,7.

The area of the experimental plot was 10 m^2, threefold repetition. The experiments were conducted on winter barley of the Romance variety, which is characterized by high susceptibility to leaf spots (originator - National Grain Center P.P.

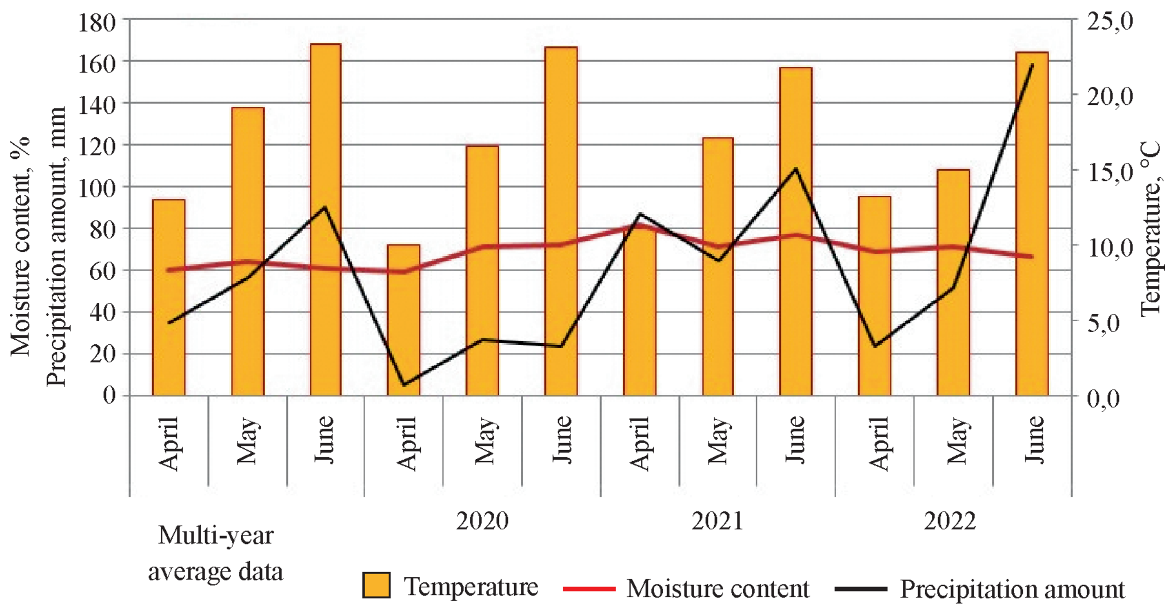

Рис. 2. Климатограмма погодных условий вегетационных сезонов 2020–2022 гг.

Fig. 2. Climatogram of weather conditions for the growing seasons 2020–2022

Lukyanenko). Treatment with fungicides was carried out twice: in the booting phase (Z33) – April 22 (in 2020), May 5 (in 2021) and May 6 (in 2022); also, in the earing phase (Z51) – May 7 (in 2020) and May 27 (in 2021 and 2022). Spraying was carried out using a hand-held pneumatic sprayer "Tecnoma", the working solution consumption – at the rate of 300 liters/ha. After detection of the disease signs, the intensity of the lesion was recorded in dynamics, looking at 20 plants in three points of the plot. Subsequent counts were conducted every 7-10 days (at least three counts, and the last one – necessarily in the phase of milk-wax ripeness). International scales of percentages of leaf lesions were used for disease surveys[3]. Harvesting was carried out with a Hege 125 combine harvester. Calculation of biological and economic efficiency was carried out according to the generally accepted methods. Statistical processing was carried out using Statistica software version 13.3 (http://statsoft.ru/products/trial/).

RESULTS AND DISCUSSION

At the time of application, net blotch development averaged 0.1–0.5%. Surveys were conducted on April 22, May 11, May 25, and June 1 in 2020; May 5, May 17, May 27, May 7, and June 7 in 2021; and May 6, May 16, May 27, and June 9 in 2022. Disease development at the date of maximum occurrence was 64.4; 87.6 and 49.2% in 2020, 2021 and 2022, respectively (see Table 1).

A significant decrease in pathogen development was observed on the variants with fungicide treatment. When fungicide Ace, CSC was applied, the development of the disease on the last date of recording was 3.0; 2.3 and 1.0% in 2020; 19.0; 11.0 and 9.2% in 2021 and 6.3; 3.7 and 3.0% in 2022 at the application rates of 0.6; 0.7 and 1.0 l/ha, respectively. In the plots treated with fungicide Amistar Trio, EC, at the application rate of 1.0 l/ha, the development of net blotch was 4.1% in 2020, 20.0% in 2021 and 3.4% in 2022.

The biological efficacy of the Ace preparation, CSC at different application rates was 95.3; 96.4 and 98.4% in 2020; 78.1; 87.3 and 89.4% in 2021 and 87.3; 92.6 and 93.9% in 2022. The biological efficacy of the Amistar Trio, EC reference was 93.6% in 2020, 76.9% in 2021, and 93.1% in 2022.

The economic efficiency of the studied fungicide was also evaluated. The yield structure was analyzed by the 1000 grain weight and the yield (see Table 2).

The mass of 1000 grains in the control (without treatment) was 29.7 in 2020; 31.1 g in 2021 and 31.7 g in 2022. In the variants with fungicide Ace, CSC the indicator of 1000 grain weight was 32.6, 32.7 and 32.9 g in 2020; 36.7, 36.6 and 36.8 g in 2021; 36.6, 36.9 and 37.0 g in 2022 at the application rates of 0.6, 0.7 and 1.0 l/ha, respectively. The weight of 1000 grains in the variant with Amistar Trio, EC amounted to 31.6 g in 2020, 36.5 g in 2021 and 34.9 g in 2022. The gain in the weight of 1000 grains amounted to: 9.8; 10.1; 10.6% in 2020; 18.0; 17.7; 18.5% in 2021 and 15.3; 16.4; 16.6% in 2022, respectively, depending on the application rate of the Ace fungicide, CSC. Amistar Trio, EC at the application rate of 1.0 l/ha gave an increase of 6.5% in 2020, 17.5% in 2021 and 9.9% in 2022.

The yield in the control (without treatment) was 59.3 c/ha in 2020, 62.0 c/ha in 2021 and 64.1 c/ha in 2022. The yields in the variants with fungicide Ace, CSC treatment at the rates of 0.6; 0.7 and 1.0 l/ha were 65.2; 66.1 and 66.8 c/ha in 2020; 71.2; 71.8 and 72.5 c/ha in 2021 and 73.9; 74.6 and 75.6 c/ha in 2022, respectively; and grain yield increase amounted to 9.9; 11.4; 12.6% in 2020; 14.8; 15.7 and 16.9% in 2021 and 15.3; 16.4; 16.6% in 2022, respectively. In the variant with the fungicide Amistar Trio, EC at the application rate of 1.0 l/ha, the yield was 64.1 kg/ha in 2020, and the grain yield increase was 8.0%. In 2021, the yield on this variant reached 73.0 c/ha and the grain yield increase was 17.7%. In 2022, the yield was 72.4 c/ha, the grain yield increase was 12.9%.

[3]Methodological guidelines for registration tests of fungicides in agriculture, St. Petersburg, 2009, 280 p.

Табл. 1. Развитие сетчатой пятнистости на последнюю дату учета и биологическая эффективность фунгицида Эйс, ККР, сорт Романс, полевой стационар, ФНЦБЗР, 2020–2022 гг.

Table 1. Development of net blotch on the last record date and biological efficacy of fungicide Ace, CSC, variety Romance, field station, FRCBPP, 2020–2022

Experiment variant	Application rate, l/ha	Development of net blotch by record dates, %				BE*, %
		22.04.20	11.05.20	25.05.20	01.06.20	
Ace, CSC	0,6	0,1	0,1	0,4	3,0	95,3
Ace, CSC	0,7	0,1	0,1	0,1	2,3	96,4
Ace, CSC	1,0	0,1	0,1	0,1	1,0	98,4
Amistar Trio, EC (standard)	1,0	0,1	0,5	3,3	4,1	93,6
Control (without treatment)	–	0,1	1,4	21,5	64,4	–
		05.05.21	17.05.21	27.05.21	07.06.21	
Ace, CSC	0,6	0,5	1,0	5,3	19,0	78,1
Ace, CSC	0,7	0,5	0,9	3,6	11,0	87,3
Ace, CSC	1,0	0,5	0,6	3,2	9,2	89,4
Amistar Trio, EC (standard)	1,0	0,5	3,7	11,5	20,0	76,9
Control (without treatment)	–	0,5	5,8	20,0	86,7	–
		06.05.22	16.05.22	27.05.22	09.06.22	
Ace, CSC	0,6	0,1	1,5	1,8	6,3	87,3
Ace, CSC	0,7	0,1	1,4	1,5	3,7	92,6
Ace, CSC	1,0	0,1	1,2	1,3	3,0	93,9
Amistar Trio, EC (standard)	1,0	0,1	1,5	1,7	3,4	93,1
Control (without treatment)	–	0,1	9,7	17,9	49,2	–

* Biological efficiency as of the last record date.

Табл. 2. Хозяйственная эффективность препарата Эйс, ККР на озимом ячмене (сорт Романс), полевой стационар, ФНЦБЗР, 2020–2022 гг.

Table 2. Economic efficiency of the fungicide Ace, CSC on winter barley (variety Romance), field station, FRCBPP, 2020–2022

Experiment variant	Consumption rate, l/ha	2020		2021		2022	
		1000 seeds weight, g	Yield, c/ha	1000 seeds weight, g	Yield, c/ha	1000 seeds weight, g	Yield, c/ha
Ace, CSC	0,6	32,6	65,2	36,7	71,2	36,6	73,9
Ace, CSC	0,7	32,7	66,1	36,6	71,8	36,9	74,6
Ace, CSC	1,0	32,9	66,8	36,8	72,5	37,0	75,6
Amistar Trio, EC (standard)	1,0	31,6	64,1	36,5	73,0	34,9	72,4
Control (without treatment)	–	29,7	59,3	31,1	62,0	31,7	64,1
			$LSD_{0,5}$= 4,8		$LSD_{0,5}$= 9,2		$LSD_{0,5}$= 8,3

Weather conditions during the growing seasons of 2020, 2021 and 2022 had a great impact on both the development of net blotch and crop yield. Heavy rainfall was observed in 2021. This resulted in higher development of the disease in the experimental plots than in the previous year. In 2022 in May, the temperature was lower than the long-term average, which had an unfavorable effect on the development of the net blotch pathogen. The abundance of precipitation observed in the 2021 and 2022 growing seasons also had an impact on the yield structure; these years had higher 1000 grain weight and yield values than in 2020.

CONCLUSIONS

1. The study of the efficacy of the fungicide Ace, CSC on winter barley variety Romance showed that it perfectly suppresses the development of the causative agent of the net blotch. Despite the high infectious background, especially in 2021, the biological efficacy of the fungicide against the dangerous pathogen was in most cases above 80%, which is comparable to the efficacy of the well-known imported standards.

2. The economic efficiency of the drug applied twice to the control (no treatment) was 12.6; 16.9 and 16.6% at the maximum application rate (1.0 l/ha in 2020, 2021 and 2022, respectively).

3. Nowadays, especially in connection with global events, there is a need for import substitution of plant protection products. Russian manufacturers are creating new products, their production volume is increasing every year. Fungicide Ace, CSC of the AO "Shchelkovo Agrokhim" showed high biological and economic efficiency against dangerous leaf blight. In this regard, this fungicide is recommended for protection of barley crops from the causative agent of net blotch.

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ПЕРСПЕКТИВНЫЕ ГЕРБИЦИДЫ ДЛЯ ПОСЛЕВСХОДОВОГО ПРИМЕНЕНИЯ В ПОСЕВАХ ЛЮПИНА УЗКОЛИСТНОГО

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Изучена техническая и хозяйственная эффективность гербицида Пилот при внесении по зеленому листу в посевах люпина узколистного. Исследования проводили в полевых, деляночных опытах по общепринятым методикам в юго-западной части Нечерноземной зоны России. Почва опытного поля серая лесная легкосуглинистая по механическому составу. Использовали следующие нормы внесения препарата: 1,5; 2,0 и 2,5 л/га в фазу появления у люпина двух настоящих листьев. Высокую чувствительность даже при минимальной норме внесения проявили: подмаренник цепкий (*Galium aparine* L.), гречишка вьюнковая (*Fallopia convolvulus* L.), марь белая (*Chenopodium album* L.), один из видов пикульника (*Galeopsis* sp. L.), пастушья сумка (*Capsella bursa pastoris* L. Medik), фиалка полевая (*Viola arvensis* Murr.), звездчатка средняя (мокрица) (*Stellaria media* L.). Применение граминицида ГалактАлт (норма внесения 1,0 л/га) после обработки посевов люпина узколистного гербицидом Пилот способствовало практически полному уничтожению однолетних злаковых сорных растений. Внесение гербицида Пилот благоприятно влияло на содержание азота как в сухой надземной массе, так и в массе корней люпина. Снижение засоренности посевов при использовании препарата Пилот способствовало повышению урожайности люпина. В варианте с применением 1,5 л/га гербицида в среднем за три года испытаний урожайность семян люпина узколистного превысила показатели контроля на 0,53 т/га. Наибольшая прибавка урожайности семян люпина узколистного (0,96 т/га) отмечена в варианте, предполагавшем применение гербицида Пилот в концентрации 1,5 л/га в фазу одного-двух настоящих листьев у люпина и гербицида ГалактАлт в концентрации 1,0 л/га в фазу бутонизации люпина. Химические анализы показали увеличение содержания сырого белка в семенах люпина узколистного на 2,3–4,2% при обработке посевов гербицидом Пилот по сравнению с контрольным вариантом, где обработку не проводили.

Ключевые слова: люпин узколистный, сорные растения, гербицид, эффективность, урожайность

PERSPECTIVE HERBICIDES FOR POST-SOWING USE IN NARROW-LEAFED LUPIN CROPS

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Technical and economic efficiency of Pilot herbicide when applied on green leaf in narrow-leafed lupine crops was studied. The research was conducted in field and plot experiments according to the generally accepted methods in the southwestern part of the Non-Chernozem zone of Russia. The soil of the experimental field was gray forest light loamy in mechanical composition. The following application rates of the preparation were used: 1.5, 2.0 and 2.5 l/ha in the phase of appearance of two true leaves in lupine. The following plants showed high sensitivity even at the minimum application rate: cleavers (*Galium aparine* L.), wild buckwheat (*Fallopia convolvulus* L.), lamb's-quarters (*Chenopodium album* L.), one of the types of hemp nettle (*Galeopsis* sp. L.), shepherd's purse (*Capsella bursa pastoris* L. Medik), field violet (*Viola arvensis* Murr.), chickweed (*Stellaria media* L.). Application of GalactAlt graminicide (application rate 1.0 l/ha) after treatment of narrow-leafed lupine crops with Pilot herbicide promoted almost complete destruction of annual grass weeds. Application of Pilot herbicide had a favorable effect on nitrogen content in both dry aboveground mass and root mass of lupine. Reduction of weediness of crops when using Pilot contributed to the increase in lupine yield. In the variant with the application of 1.5 l/ha of the herbicide, the average yield of narrow-leafed lupine seeds exceeded the control by 0.53 t/ha in three years of the trials. The highest increase in seed yield of narrow-leafed lupine (0.96 t/ha) was observed in the variant that involved the application of herbicide Pilot at a concentration of 1.5 l/ha in the phase of one or two true leaves in lupine and herbicide GalactAlt at a concentration of 1.0 l/ha in the phase of lupine budding. Chemical analyses showed an increase in crude protein content in narrow-leafed lupine seeds by 2.3–4.2% when the crops were treated with Pilot herbicide compared to the control variant, where the treatment was not carried out.

Keywords: narrow-leafed lupin, diseases, weeds, herbicides, effectiveness, yield

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INTRODUCTION

Currently, the world protein deficit is estimated at 10-25 million tons per year. One of the ways to solve this problem can be the growth of vegetable protein production. For this purpose, it is necessary to increase the area and productivity of leguminous crops – the main source of vegetable protein [1]. Narrow-leafed lupine (*Lupinus angustifolius* L.) is one of three lupine species cultivated in agricultural production. This species is characterized by a variety of ecotypes, which makes it possible to cultivate it in radically different soil and climatic zones. It can be rightfully called "northern soybean". The distribution area of narrow-leafed lupine covers the territory up to the northern limits of sustainable agriculture in our country [2].

Modern varieties of narrow-leafed lupine are capable of producing 3–4 t/ha of grain with protein content of 32–36%, oil – 5–6%, as well as 40–60 t/ha of high-protein green mass for the preparation of coarse and succulent fodder [3, 4]. Narrow-leafed lupine is a medium-forming crop capable of fixing atmospheric air nitrogen in symbiosis with nodule bacteria. Lupine can fix up to 200–250 kg of air nitrogen per 1 ha of the sown area, which allows to significantly reduce the cost of nitrogen fertilizers for the next crop of crop rotation and reduce the cost of production from 1 ha of arable land[1] [5].

Fixing atmospheric nitrogen on the basis of symbiosis with nodule bacteria, lupine throughout the growing season as a result of allelopathic interaction with rhizosphere of weed plants contributes to the rapid growth of their organic mass, as a result weed plants begin to occupy a dominant position in agrophytocenosis, shading and depressing the cultural component. Lupine

[1]*Khaletsky V.N., Anokhina V.S., Sauk I.B., Duxina V.V., Kravchuk A.D.* Influence of postemergence herbicides on weed infestation and productivity of monocenosis of narrow-leafed lupine plants of different morphotype // Actual problems of study and conservation of phyto- and microbiota: Proceedings of the second International scientific and practical conference (Minsk, November 12–14, 2013). Minsk: Publishing Center of the Belarusian State University, 2013, pp. 380-383.

shows high selectivity to herbicides, and many preparations successfully used in the cultivation of other leguminous crops, in lupine cause suppression of germination and even their death[2]. In this regard, lupine crops are the most infested among other crops. M.V. Evseenko, analyzing the infestation of single-species lupine crops in the Republic of Belarus, found that it exceeds all permissible thresholds of harmfulness[3]. This fact is noted by other researchers in their works[4-7] [6]. Productivity losses of lupine crops due to weeds are much higher than in other agricultural crops. According to literature data, the reduction of lupine grain yield can reach 50% and more [7].

Today the range of preparations for protection of lupine crops from weeds is limited and is represented mainly by soil-acting herbicides. It should be noted that at present there have been changes in climatic conditions. During the period of lupine sowing and application of soil-acting preparations there is a deficit of moisture in the soil, which does not provide the required effect, and for this reason the role of post-emergence application of herbicides is increasing [8, 9].

There is only one preparation among pesticides and agrochemicals authorized for use in Russia, which is used to suppress dicotyledonous weeds in lupine crops during the growing season, and that is herbicide Pivot and its analogs (active substance – imazethapyr, concentration of the active substance is 100 g/l)[8]. It is recommended to apply it at the application rate of 0.4–0.5 l/ha in the phase of lupine three to five true leaves. In the literature there are data on the negative effect of Pivot on the lupine varieties of domestic and foreign selection. The herbicide may have negative effect on the growing point of plants, which leads to a decrease in seed production, in some cases causes death of lupine plants. Varieties of the narrow-leafed lupine are most sensitive to Pivot. Belarusian scientists have identified a varietal reaction of the narrow-leafed lupine to the herbicide Pivot[9]. In addition, this drug has restrictions on crop rotation. The search for new herbicides for post-emergence application in lupine crops to control dicotyledonous weeds is currently an urgent task.

MATERIAL AND METHODS

The study was conducted on the experimental plots of the All-Russian Research Institute of Lupine (ARRI of lupine), located in the Bryansk region. The soil of the experimental field was gray forest light loamy in mechanical composition. The arable layer with thickness of 22–24 cm was characterized by the following indicators: pH of the salt extract – 5.5; content of mobile phosphorus (according to Kirsanov) – 13.80 mg/100 g of soil, exchangeable potassium (according to Maslova) – 14.60 mg/100 g, humus – 2.87 mg/100 g. The forecrop was winter cereals. Placement of the variants was systematic, fourfold repetition. The accounting area of the plot was 25 m^2. Mineral fertilizers were not applied to lupine.

[2]*Slesareva T.N.* Features of lupine protection from weeds // Science, production, business: the current state and ways of innovative development of the agricultural sector on the example of agricultural holding "Bayserke-Agro": collection of proceedings of the international scientific and practical conference Almaty, 2019, vol. 2, pp. 88-93.

[3]*Evseenko M.V.* Weed control in narrow-leafed lupine crops // Abstracts of reports of the international scientific conference "Scientific support of lupine sowing in Russia", Bryansk, 2005, pp. 190-193.

[4]*Samersov V.F.* Weeds, their distribution and harmfulness in the Republic of Belarus // International Journal, 1999, N 5, pp. 13-18.

[5]*Romaniuk G.P.* Efficiency of herbicide Pivot in crops of yellow lupine // Actual problems of weed control in modern agriculture and ways to solve them, Zhodino, 1999, vol. 2, pp. 86-91.

[6]*Parkhamovich I.V., Bulavin L.A.* Effectiveness of postemergence herbicide application on narrow-leafed lupine // Problems of weed vegetation and methods of weed control: abstracts of the international scientific conference in memory of N.I. Protasov and K.P. Padenov, Minsk, Priluki, 2010, pp. 140-143.

[7]*Korpanov R.V.* Perspective herbicides of imidazolinone group for post-emergence weeding of narrow-leafed lupine in Belarus // Strategy and priorities of development of farming and breeding of field crops in Belarus: materials of the international scientific and practical conference dedicated to the 90th anniversary of the founding of the RUE "Scientific and Practical Center of the National Academy of Sciences of Belarus on Agriculture" (Zhodino, July 5-6, 2017). Minsk, 2017, pp. 40-43.

[8]List of pesticides and agrochemicals authorized for use on the territory of the Russian Federation. M., 2021, 875 p.

[9]*Shik A.S., Gavrilyuk A.V., Bulavin L.A.* Effect of herbicides on the weediness and yield of narrow-leafed lupine // Farming and breeding in Belarus: collection of scientific works of the Scientific and Practical Center of the National Academy of Sciences of Belarus on Agriculture. Nesvizh, 2007, vol. 43, pp. 123-131.

Seeds of the narrow-leafed lupine variety Belozerny 110 were used for sowing. Three weeks before the sowing the seeds were dressed with Vitaros preparation at the rate of 1.5 l/t. Sowing was carried out by row sowing method with a seed drill CH 16. Herbicides Pilot, GalactAlt and Hermes were studied in the experiments. Pilot, WSC – a selective systemic herbicide for control of annual dicotyledonous weeds in beet and medicinal plants (active substance – metamitron, concentration 720 g/l, application rate 1.5–6.0 l/ha). GalactAlt, EC – a systemic herbicide for destruction of annual and perennial cereal weeds in crops of beet, sunflower, canola and soybean (active substance – haloxyfop P methyl, acid concentration 104 g/l, application rate 0.5–1.0 l/ha). Hermes, OD – a post-emergence selective herbicide of systemic action, designed to control annual dicotyledons, as well as annual and perennial cereal weeds in sunflower and pea crops (active substance – imazamox + chisalofop P ethyl, concentration 38 and 50 g/l, respectively, application rate 0.7–1.0 l/ha). The mentioned herbicides were applied manually with a knapsack electric sprayer. Consumption of the working solution was 250 liters/ha. The treatment was carried out in the phase of two true lupine leaves.

Determination of the field germination and weediness were carried out on permanently fixed plots of 0.25 m^2, four on each plot in all repetitions of the experiment. Phenological observations of growth and development of lupine plants were conducted according to the method of the State Variety Network. Weediness was counted in accordance with the methodological guidelines of the All-Russian Research Institute of Plant Protection, biometric analysis of the yield structure – according to the method of G.F. Nikitenko. The yield was measured by the method of continuous weighing at threshing by a combine harvester Sampo 500. For statistical processing of the obtained data, the method of dispersion analysis with determination of the smallest significant difference was used[10].

RESULTS AND DISCUSSION

Currently, great interest is a new generation of herbicides from the class of imidazolinones (Pulsar, Paradox, Hermes, etc.), which are used in low doses and do not pose a threat to the environment. However, such herbicides in some cases can cause short-term suppression of such a crop as lupine. Thus, long-term studies conducted by specialists of the All-Russian Research Institute of Lupine have established that when treating lupine crops of all cultivated species with herbicides of this class, negative effect on the growth point, burns of leaf plates, changes in the color of leaf surface and lag in plant development are observed.

Phytotoxic effect of herbicides can last for 10-21 days depending on the weather conditions, plant development phase and application dose. Therefore, the search for herbicides having less toxic effect on lupine plants remains an urgent task.

According to our results, herbicides from the class of triazinones (active substance – metamitron) are also the most promising for use on narrow-leafed lupine.

During the experiments, the initial weediness of the narrow-leafed lupine crops before the application of the herbicides fluctuated from 163 to 432 pcs/m^2 during the years of research. Species composition of the weed vegetation was as follows: cleavers (*Galium aparine* L.), wild buckwheat (*Fallopia convolvulus* L.), lamb's quarters (*Chenopodium album* L.), one of the hemp-nettle species (*Galeopsis* sp. L.), shepherd's purse (*Capsella bursa pastoris* L. Medik), field violet (*Viola arvensis* Murr.), chickweed (*Stellaria media* L.), creeping wheatgrass (*Agropyron repens* L.), barnyard grass (*Echinochloa crus-galli* L. Beauv.), yellow foxtail (*Setaria glaca* (L.) Beauv.), field sow thistle (*Sonchus arvensi* L.), corn bindweed (*Convolvulus arvensi* L.), clown's woundwort (*Stáchys palústri* L.), bottle brush (*Equisetum arvense* L.). On average, the share of annual monocotyledonous species was 76%, annual dicotyledonous species – 16%, pe-

[10] *Dospekhov B.A.* Methodology of field experiment. Moscow: Agropromizdat, 1985, 351 p.

rennial dicotyledonous species – 5%, perennial monocotyledonous species – 3%.

Visible signs of weed plants suppression when using Pilot herbicide appeared on the 2nd–6th day after treatment. The drug caused chlorotic leaves of weed plants, and then their desiccation. Complete death of herbicide-sensitive weeds occurred after 12–14 days.

No suppressive effect of this herbicide on lupine plants was observed. Pilot herbicide duration of action on the weeds was 5–6 weeks after treatment. The species sensitive to the herbicide were cleavers, lamb's-quarters, field violet, shepherd's purse, chickweed and one of the hemp nettle species.

The effect of the Hermes herbicide on weed plants was manifested 7–10 days after the treatment. A short-term change in the color of the leaf surface of narrow-leafed lupine plants was noted when applying this preparation, but it did not affect its growth and development.

The smallest number of weeds to harvesting was observed in the variant with the application of the herbicide Pilot at a rate of 1.5 l/ha in the phase of one or two true leaves in lupine and herbicide GalactAlt at a rate of 1.0 l/ha in the phase of lupine budding – 8 weeds per 1 m^2. In the variant with the application of anti-weed herbicide GalactAlt at a rate of 1.0 liters/ha on vegetative lupine plants the number of weed plants was also quite small – 35 pcs./1 m^2. Efficiency in these variants was at the level of 98.2 and 91.4%, respectively (see Table 1). Efficiency of the Pilot herbicide application was lower due to low sensitivity of weedy cereals to it.

In the variant with the application of the herbicide Pilot in the phase of two true leaves in lupine at a rate of 1.5 l/ha and the herbicide GalactAlt at a rate of 1.0 l/ha in the phase of three-four leaves in weeds from the group of cereals the lowest dry mass of weeds was formed – 18.0 g/m^2. This is 7.6 times lower than in the control. The above-ground mass of weeds in the variant with the Pilot herbicide and anti-weed herbicide GalactAlt was formed by 47.8% at the expense of perennial dicotyledonous weeds (see Table 2).

When using only the Pilot herbicide, the main mass of weeds was formed at the expense of weeds from the group of cereal weeds – 92.6 –95.6%. In this regard, when including the Pilot in the system of lupine protection from segetal species in case of weeding of the site with cereal weeds, it is necessary to additionally apply anti-weed preparations.

In the course of the study, an increase in the dry above-ground mass and root mass of one narrow-leafed lupine plant on the background of herbicide application to the phase of shiny bean was noted. On average for three years, the increase in the dry above-ground mass of one plant compared to the control variant amounted to 0.6–1.9 g/plant, root mass – 0.04–0.28 g/plant (see Table 3).

Табл. 1. Эффективность применения гербицидов по вегетирующим растениям люпина узколистного (среднее за три года исследований)

Table 1. Efficiency of herbicide application on vegetative plants of narrow-leafed lupine (average for three years of research)

Experiment variant	The death of weeds before harvesting, %*	Decrease in weediness before harvesting, % of the control			
		Dicotyledons		Monocotyledones	
		Annual	Perennial	Annual	Perennial
Pilot: 1,5 l/ha	74	70	75	53	75
2,0 l/ha	75	83	58	50	50
2,5 l/ha	75	94	92	50	75
Hermes, 1,0 l/ha	87	59	67	68	25
GalactAlt, 1,0 l/ha	91	19	83	100	63
Pilot, 1,5 l/ha + GalactAlt, 1,0 l/ha	98	94	58	100	88

* The share of dead weed plants relative to their number before the experiment is specified.

The use of herbicides had a favorable effect on the nitrogen content not only in the above-ground mass, but also in the dry mass of the narrow-leafed lupine roots. When increasing the dose of the Pilot application, a decrease in nitrogen content was observed both in the initial phases of development and by the end of vegetation, which indicates the toxic effect of increased doses of herbicide on the legume-rhizobial complex. When Pilot was applied at a rate of 1.5 l/ha, the nitrogen content increased by 14.6% in the above-ground mass and by 10.3% in the root system compared to the control variant in the budding phase. In the phase of shiny bean nitrogen concentration in the above-ground mass was higher by 12.6%, in the root system – by 16.3% (see Table 4).

As a result of reducing the weediness of narrow-leafed lupine crops when treated with herbicides, reliable yield increases were obtained, which on average were within the limits of 0.43–0.96 t/ha (see Table 5). The greatest increase in the yield of narrow-leafed lupine seeds was noted in the variant of application of the herbicide Pilot at a rate of 1.5 liters / ha in the phase of one or two true leaves in lupine and herbicide GalactAlt at a rate of 1.0 l / ha in the phase of budding lupine – 0.96 t / ha. When increasing the dose of the Pilot herbicide, a tendency of slight increase in the yield was observed, but it is not statistically proven. Yield at the application of the Pilot herbicide at a rate of 1.5 l/ha was at the level of the variant with the application of the Hermes herbicide at a dose of 1.0 l/ha.

On the basis of chemical analyses, the crude protein content of narrow-leafed lupine seeds

Табл. 2. Влияние гербицидов на накопление надземной массы сорных растений в одновидовом посеве люпина узколистного (среднее за три года исследований)

Table 2. Effect of herbicides on accumulation of the aboveground mass of weeds in single-species sowing of narrow-leafed lupine (average for three years of research)

Experiment variant	Accumulated for harvesting, g/m^2		
	Total	Cereals	Dicotyledons
Control, without application	138,5	67,3	71,2
Pilot: 1,5 l/ha	60,3	56,0	4,3
2,0 l/ha	69,6	64,2	5,4
2,5 l/ha	68,1	65,1	3,0
Hermes, 1,0 l/ha	52,7	36,4	16,3
GalactAlt, 1,0 l/ha	70,2	5,2	65,0
Pilot, 1,5 л/га + GalactAlt, 1,0 l/ha	18,0	9,4	8,6

Табл. 3. Накопление сухого вещества люпина узколистного по фазам развития, г/растение (среднее за три года исследований)

Table 3. Dry matter accumulation of narrow-leafed lupine by development phases, g/plant (average for three years of research)

Experiment variant	Budding stage		Shiny bean phase	
	Tops	Root system	Tops	Root system
Control, without application	0,94	0,22	5,40	0,74
Pilot: 1,5 l/ha	0,97	0,25	6,40	0,97
2,0 l/ha	0,94	0,23	7,00	0,86
2,5 l/ha	0,80	0,21	7,30	0,83
Hermes, 1,0 l/ha	0,86	0,20	6,90	1,02
GalactAlt, 1,0 l/ha	0,90	0,20	6,10	0,78
Pilot, 1,5 l/ha + GalactAlt, 1,0 l/ha	0,93	0,20	6,00	0,84

increased by 2.3–4.2% when crops were treated with the Pilot herbicide compared to the control variant, where no treatment was carried out. When increasing the application dose, there was a tendency to decrease the protein content, which indicates that the toxicity of this herbicide increases with increasing the dose. When the Pilot herbicide was used, the content of alkaloids in narrow-leafed lupine seeds increased by 5.9–23.5% compared to the control variant. The alkaloid content of lupine seeds increased with increasing the application dose. Application of the Pilot herbicide at a rate of 1.5 l/ha increased the mass of 1000 seeds by 4.5 g compared to the control.

In case of inadequate efficiency of soil herbicide action as a result of unfavorable climatic conditions, additional application of the Pilot herbicide at the rate of 1.5 l/ha is possible.

CONCLUSION

Thus, our studies have shown that for weed control in narrow-leafed lupine crops it is possible to use Pilot herbicide at a rate of 1.5 l/ha on vegetative plants, which provides effective protection from annual dicotyledonous weed species and does not have a toxic effect on the crop. Herbicide Pilot at a rate of 1.5 liters / ha does not have a toxic effect on the growth and development of lupine, as well as productivity and quality of products. To ensure high efficiency Pilot herbicide should be applied at early stages of weed plants development – the phase of "white threads" or one or two true leaves. In accordance with the obtained results, Pilot herbicide should be applied together with weed herbicides in case of weed infestation of fields from the group of cereals. Pilot can be used in combination with soil

Табл. 4. Содержание азота в сухом веществе зеленой массы и корневой системы растений люпина узколистного, % (среднее за три года исследований)

Table 4. Nitrogen content in dry matter of the green mass and root system of narrow-leafed lupine plants, % (average for three years of research)

Experiment variant	Budding stage		Shiny bean phase,	
	Green mass	Root system	Green mass	Root system
Control, without application	2,74	2,42	3,17	2,52
Pilot: 1,5 l/ha	3,14	2,67	3,57	2,93
2,0 l/ha	3,07	2,64	3,53	2,28
2,5 l/ha	2,79	2,22	3,39	2,14
Hermes, 1,0 l/ha	3,04	2,80	3,50	2,17
GalactAlt, 1,0 l/ha	3,13	2,35	3,29	2,47
Pilot, 1,5 l/ha + GalactAlt, 1,0 l/ha	3,24	2,71	3,58	2,52

Табл. 5. Урожайность и качество семян люпина узколистного (среднее за три года исследований)

Table 5. Yield and seed quality of narrow leafed lupine (average for three years of research)

Experiment variant	Yield, t/ha	Protein content in the seeds, %	Alkaloid content in the seeds, %	Weight of 1000 seeds, g
Control, without application	1,90	35,30	0,051	141,10
Pilot: 1,5 l/ha	2,43	36,80	0,054	145,60
2,0 l/ha	2,54	36,30	0,062	140,60
2,5 l/ha	2,51	36,10	0,063	140,60
Hermes, 1,0 l/ha	2,40	35,60	0,052	137,60
GalactAlt, 1,0 l/ha	2,33	35,60	0,051	142,30
Pilot, 1,5 l/ha + GalactAlt, 1,0 l/ha	2,86	35,60	0,047	144,10
LSD_{05}*	0,18; 0,32; 0,26	0,74; 1,27; 0,99	0,004; 0,008; 0,007	5,10; 4,80; 5,30

* Data by year of the study are presented.

herbicide under unfavorable climatic conditions of its application and reducing the efficiency.

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95TH ANNIVERSARY OF THE FULL MEMBER OF THE RUSSIAN ACADEMY OF SCIENCES PYOTR L. GONCHAROV

Pyotr L. Goncharov was born on February 02, 1929 in the village of Novo-Troitsk (Kansk District, Krasnoyarsk Area, Siberian Region).

After graduating from the Kansk secondary school No. 2 in 1948, he entered the Faculty of Agronomy of the Novosibirsk Agricultural Institute (NAI). In 1953 P.L. Goncharov graduated with honors in agronomy with specialization in industrial crops. He executed his graduation work "Influence of irrigation on spring wheat yield" under the supervision of Z.D. Krasikov, PhD (in Russian ‘Candidate of Science’) in Agriculture, Associate Professor.

In 1953–1954, P.L. Goncharov was the head of the Vengerovo State Plant Test System Station of the Novosibirsk Region. In 1954–1956, he attended full-time postgraduate studies at the Siberian Research Institute of Agriculture (SibNIISKhoz, Omsk). In 1957, he defended his PhD thesis "Mohar and Italian millet (chumiza) cultivation in the steppe and forest-steppe areas of the Omsk region" and earned the degree of the Candidate of Science in Agriculture (supervisor – the Director of SibNIISKhoz, Candidate of Science in Biology G.P. Vysokos) at the Irkutsk Institute of Agriculture. In his PhD thesis, P.L. Goncharov developed the methods of selecting of early ripening forms of chumiza on a provocative environment (a short-day condition) and worked out the technique of chemical emasculation of spikelets of plant flowers in relation to this crop by treating the panicles before flowering for 5 min by a 1% aqueous solution of sulfuric acid.

Since 1957 P.L. Goncharov was successively head of the group, laboratory and department of fodder crops, since 1965 – deputy director for science, since 1970 – director of the Tulun State Breeding Station and simultaneously in 1970–1976 – director of its Experimental Farm.

In 1971, he defended his Dr. Sci. (Agriculture) thesis "Alfalfa in Eastern Siberia (cultivation, breeding and seed production)" at the All-Union Research Institute of Feed named after V.R. Williams (now Federal Williams Research Center of Forage Production and Agroecology, Moscow). The thesis outlines the bases of alfalfa breeding for winter hardiness developed by the researcher – through selection on the basis of "collum (root neck) depth of location in soil" and for the drought resistance – on the basis of root-forming ability on the 9th day. Later, this technique (selection for the depth location of the tillering node) will be used by him when selecting for frost resistance of winter common wheat cultivars [1]. P.L. Goncharov also established the peculiarities of flowering–seed production and bee pollination of alfalfa in Siberia and formalized other selection traits in this crop.

Since 1976, P.L. Goncharov was the Director, later CEO of the Siberian Research Institute of Plant Industry and Breeding, and in 1984-2006, the Head of the Department of Methodological Bases of Breeding of this Institute.

From 1972 to 2016, P.L. Goncharov was the Chairman of the Joint Scientific and Problem Council on Plant Breeding, Biotechnology and Seed Production under the Presidium of the Siberian Branch of the V.I. Lenin All-Union Academy of Agricultural Sciences (VASKhNIL, since 1992 the Presidium of the Siberian Branch of the Russian Academy of Agricultural Sciences (SB RASKhN)). The Council provided scientific and methodological guidance to eight Breeding Centers in Siberia and coordinated their interaction [2]. Since 1985, he was the Chairman of the Joint Scientific Council of the SB VASKhNIL (RASKhN) for the same specialties.

From 1979 to 2004 he was the Chairman of the Presidium of the Siberian Branch and Vice-President of VASKhNIL (since 1992 – RASKhN). Until 1988, the area of scientific patronage of the Siberian Branch of VASKHNIL included the entire territory of the Russian Soviet Federative Socialist Republic (RSFSR) beyond the Urals and the Far North of the European part of the country [3].

Scientific and organizational activities. Heading the Siberian Branch of VASKHNIL (later Russian Academy of Agricultural Sciences), P.L. Goncharov conducted extensive scientific and organizational activities to provide scientific support to the agro-industrial complex [4]. Despite the costs, the results of the use of the "catching-up development" model by agrarian science [5] were positive for the development of agriculture in the country: in the end of 1980s, food supply per man in the USSR corresponded to the level of the developed countries of Western Europe and of the North America [6]. A great merit in this achievement belonged to the scientists of the Siberian Branch of VASKHNIL, whose work allowed to accelerate the practical application of scientific research results in production and in the agro-industrial complex of the region as a whole. In the 1990s, the investigations of agricultural scientists became much more difficult and onerous. P.L. Goncharov recalled: "When we were preparing the concept of stabilization of agricultural production, we were developing on three options. The first option. If resources in the agricultural sector remain as they are, then, accordingly, there will be no special changes. The second option: progressive forms of farming are used in agriculture, the work is done in accordance with the technologies worked out by science, fertilizers are applied to the soil and plant protection means and methods are used. It is estimated that by ensuring production according to the standards it is possible to restore the level of productivities of the 1990s. Finally, the third option. It is designed for progressive leaders. And, addressing them, we suggest: tell us what level of production you want to ensure and we will provide calculations on the resource equipment and appropriate technologies. Moreover, with a full guarantee" (from the interview given to L. Yudina [7, p. 5]). In the concepts of scientific and technical development of the agro-industrial complex of Siberia an important place and role was given to informatization of the agrarian science as a factor contributing to the acceleration of its development [8].

P.L. Goncharov took an active part in the social and political activities. He was elected the deputy of the Executive Committee of the Tulun District Council of People’s Deputies (1969–1976); the member of the Novosibirsk Regional Council of People’s Deputies (1980–1990), the deputy of the Supreme Soviet of the RSFSR of the tenth and eleventh convocations (1980–1990). P.L. Goncharov devoted a lot of effort to the building and enlargement of the infrastructure of the Science Campus in Krasnoobsk.

From 1979 to 2004 he was the Editor-in-Chief of the journal "Siberian Herald of Agricultural Science"; he was also a member of the editorial board of the journal "Agricultural Biology" and among other.

Scientific activities. P.L. Goncharov's research interests include methodology of plant form genesis management strategies, methods of breeding material producing (pre-breeding strategy) and selection techniques in breeding for yield, food grain quality and resistance to abiotic and biotic environmental factors (plant adaptability), optimization of the breeding process, varietal technologies, breeding and seed production of the new commercial cultivars. Along with the development of methodological basis of plant breeding, he carried out practical breeding of crops for different geographic and climatic zones of Siberia – taiga, sub-taiga, forest-steppe and northern steppe [1]. The ways and methods of producing the pre-breeding material were evaluated. He developed and improved selection techniques and methods of application of specific conditions (provocative, infectious, selective) and their combinations for comprehensive evaluation of the breeding material and carrying out negative selections. Studies on the use of climatic factor as a provocative condition in plant breeding were carried out in ecological-geographical seeding. As a result of the performed research, the breeding process schemes (algorithms) were improved and optimized; verbal, digital and figurative models of common wheat, common and yellow alfalfa, and spring vetch commercial cultivars were formulated [9] and the scheme of producing adapted varieties with high productivity potential and specified quality parameters was made [10].

P.L. Goncharov comprehensively studied the forms of forage grasses from wild Siberian flora, varieties from other climatic regions of the country and the ones of foreign origin; on the basis of their studies the parent forms (accessions) were selected and as a result of their hybridization the promising recombinants were obtained, their quality assessment by progeny was carried out, as a result of which a high polymorphic breeding material was produced. On the basis of this material P.L. Goncharov personally and in co-authorship produced 49 commercial cultivars of different crops – spring and winter common wheat (*Triticum aestivum* L.), common (*Medicago sativa* L.) and yellow (*Medicago falcata* L.) alfalfa, white (*Melilotus albus* Medik.) and yellow (*Melilotus officinalis* (L.) Lam.) sweet clover, awnless (smoth) bromegrass (*Bromopsis inermis* Holub.), meadow fescue (*Festuca pratensis* Huds.), spring common vetch (*Vicia sativa* L.), field (forage) pea (*Pisum sativum* L.), Italian millet (*Setaria italica* subsp. *italica* (L.) P. Beauv.), Sudan grass (*Sorghum ×drummondii* (Nees ex Steud.) Millsp. & Chase), etc. [11-12]. With colleagues from the Kazakh Research Institute of Agricultural and Plant Growing he produced the alfalfa cv. Kokoray registered in the «The State Register of Breeding Achievements of the Republic of Kazakhstan» since 2011.

His scientific works are widely known, and his plant breeding developments are successfully used both inside the country and abroad. They were applied in the producing of high-yielding, pest- and disease-resistant, high-protein varieties of fodder crops, common wheat, capable of growing successfully in extreme climate of Siberia, the Russian Far East, Northern Kazakhstan and the Far North of the Russian Federation. Developing the theory and practice of plant breeding, its methodology, he enriched the science with original methods allowing to optimize the breeding process and to forecast on the basis of the proposed models the producing of the future generations of commercial cultivars according to the planned parameters [9].

He founded a school of Siberian breeding. During his tenure as the Chairman of the Siberian Branch of VASKhNIL (RASKhN), the institutions of the region, as a result of the research conducted, registered 960 commercial cultivars and hybrids in the "State Register of Selection Achievements Authorized for Use for Production Purposes", including: 446 crops, 145 – potato and vegetable, 370 – fruit and berry, medicinal, ornamental and floral plants [13]. Thanks to the development of a wide assortment of crops (more than 60 species of field crops, more than 20 species of vegetables and more than 20 species of fruit and berries) and the producing of the commercial cultivars adapted to the region environments, Siberian plant industry has become more stable [11].

The breeder works for the future. If the researcher does not take into account what crop production will be like in twenty years, then his variety will never go into agricultural industry. A variety is produced only by those who consistently and purposefully hit the target point, who know the goal and possess the means to achieve it. And who know what they wish to obtain. "I absolutely do not perceive the phrase – "Events can be unpredictable". Everything is predictable if programmed correctly. If you aim at getting a certain result and take all necessary measures not to deviate from the course. If we decide on the choice of options and visualize very well what we want to get as a result of all the measures in ten, twenty, thirty years. I repeat - this is how the breeders act. And there should be no haste, ill-considered decisions, rushing from side to side. Consistency and clarity of action above all! Nothing just happens like that: what you have laid down is what you get. Everything in nature is interconnected, everything is conditioned" (from an interview with P.L. Goncharov [7, p. 5]).

Pedagogical activities. P.L. Goncharov was engaged in training of the breeders. The formula for the development of SB VASKhNIL (RASKhN) is the unity of science, education and agricultural production. He was delivering lectures and specialized courses at the Faculty of Agronomy of the Novosibirsk State Agrarian University (NSAU) since the late 1990s, for twenty years, and since September 2005, for almost ten years, at the Agronomy Department of the Biological Institute of the Tomsk State University (TSU). The lectures formed the basis of the original textbook "Methodical Basis of Plant Breeding", which went through three editions, the last of which was published with the financial support of FAO UNO [1]. Students of the TSU and NSAU underwent pre-diploma internship and carried out diploma works in the laboratories of SibNIIRS and other Institutes of the Siberian regions.

P.L. Goncharov lectured at agrarian universities in Mongolia, Kazakhstan, and Belarus.

Since 1978, he was one of the curators of the Breeding-Genetic School-Seminar, which was constantly operating in the Siberian Branch of the VASKhNIL (RASKhN) [14].

He took part in many international, national, regional and republican conferences, meetings, forums, etc., including as a keynote speaker.

He supervised 14 PhD students and was a scientific adviser to 12 Doctorate Science Holders.

P.L. Goncharov is the author and co-author of more than 600 scientific papers and 20 monographs [15]; he received 20 patents and 49 certificates of authorship for commercial cultivars.

P.L. Goncharov was the full member of VASKhNIL since 1978 (since 1992 – RASKhN, since 2014 - RAS); since 1994 – honorary member of the Academy of Sciences of the Republic of Sakha (Yakutia); since 2000 – full member of the Academy of Agricultural Sciences of the Republic of Kazakhstan; since 2002 – full member of the National Academy of Sciences of Mongolia and full member of the Mongolian Academy of Agricultural Sciences; Honored Scientist of the Russian Federation (1998), the Republic of Buryatia (1999), the Republic of Sakha (Yakutia) (2004) and the Republic of Tyva (2009); Honorary Worker of Agriculture and Food Industry of Mongolia (1999); Honorary Doctor of the Mongolian Academy of Sciences (2004), Krasnoyarsk State Agrarian University (2011) and more. The honorary citizen of Novosibirsk region (2014).

P.L. Goncharov was awarded the Order of the Red Banner of Labor (1966, 1971), the Order of the October Revolution (1976), the Order of Friendship of Peoples (1994), the fourth-class Order of Merit to the Fatherland (2003), the Order of Honor (2010); medals - "For Valorous Labor. To the 100th anniversary of V.I. Lenin" (1970), "Veteran of Labor" (1984), "For Valorous Labor in the Great Patriotic War of 1941–1945" (1995), nine medals of the USSR Exhibition of National Economic Achievements and a gold medal of the All-Russian Exhibition Center, etc. He was awarded a number of awards and honorary titles of the foreign scientific societies.

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

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

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Monograph

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Part of a book

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Periodical publication

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

REFERENCES (in English):

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

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

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

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

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Monograph

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

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FOOTNOTES:

Quated text$_1$.

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

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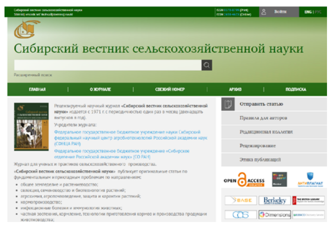

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