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Interdisciplinary approaches in plant breeding and genetics: on the anniversary of Academician N.A. Kolchanov

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Nikolai Alexandrovich Kolchanov is known primarily as the founder of Russian bioinformatics and systems computer biology, a recognized world-class specialist in this field. Distinctive features of the strategy chosen by Academician Kolchanov in relation to fundamental and practical tasks are a comprehensive view of the problem and the ability to form an interdisciplinary team to solve it. A brief review is devoted to a systematic practice-oriented approach in the field of genetics, genomics, bioinformatics and plant breeding, which have been given special attention in the work of N.A. Kolchanov in recent years. The relationship of this activity with the approval of significant legal acts in the field of genetics is reflected. Analytics in the publication activity of the teams involved in this activity are given, reflecting the time of active development of new trends and the multidisciplinary nature of research.

Keywords: bioinformatics; biocollections; genetic technologies; potato production; systems biology; phenomics.

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Персоналия

Междисциплинарные подходы для решения задач селекции и генетики растений: к юбилею академика Н.А. Колчанова

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Николай Александрович Колчанов известен в первую очередь как основатель российской биоинформатики и системной компьютерной биологии, признанный специалист мирового уровня в этом направлении. Отличительные особенности стратегии, выбранной академиком Колчановым в отношении фундаментальных и практических задач, — это комплексный взгляд на проблему и умение сформировать междисциплинарную команду для ее решения. Краткий обзор посвящен системному практико-ориентированному подходу в области генетики, геномики, биоинформатики и селекции растений, которым в деятельности Н.А. Колчанова уделено особое внимание в последние годы. Отражена взаимосвязь этой деятельности с утверждением значимых правовых актов в области генетики. Приводятся аналитические срезы публикационной активности коллективов, вовлеченных в эту деятельность, отражающие время активного развития новых трендов и мультидисциплинарный характер исследований.

Ключевые слова: биоинформатика; биоресурсные коллекции; генетические технологии; картофелеводство; системная биология; феномика.

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ЭКО•ВЕКТОР

BACKGROUND

Nikolai Alexandrovich Kolchanov, an academician of the Russian Academy of Sciences and a professor and doctor of biological sciences, whose 75th birthday we celebrate in 2022, is primarily known as the founder of the Russian Bioinformatics and Systems Computer Biology and is a recognized world-class specialist in this field. The widely known achievements of N.A. Kolchanov include the development and elaboration of databases on transcription regulation [1, 2], tools for *in silico* reconstruction of the three-dimensional structure of protein sequences based on the information of the primary structure of the coding sequences [3, 4], and the tools for the analysis and reconstruction of gene networks [5, 6].

The strategy chosen by N.A. Kolchanov in relation to fundamental and practical tasks is characterized by a comprehensive view of the problem and the ability to form an interdisciplinary team to solve it. N.A. Kolchanov is the author and co-author of many scientific papers in various fields of study (Fig. 1).

Genetic technologies and genetic resources: the emergence of modern programs

Today, when genetic technologies are rapidly developing, this field has received tangible support in Russia since the issuance of the Decree of the President of the Russian Federation No. 680 "On the development of genetic technologies in the Russian Federation" dated November 28, 2018, and the development and implementation in accordance with this decree of the Federal Scientific and Technical Program (FSTP) for the development of genetic technologies for 2019–2027 (approved by the Decree of the Government of the Russian Federation of April 22, 2019 No. 479), we must also remember that, back in 2014, on the eve of the creation of the first federal research centers in the country under the supervision of N.A. Kolchanov, a comprehensive program "Genetic Technologies" was developed and presented as a development strategy for the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences (ICG SB RAS), where he was director at the time. Soon, the institute was reorganized into the Federal Research Center (FRC) by joining the Siberian Research Institute of Plant Growing and Breeding. Later, the center opened two more branches in the field of medical sciences [7]. Today, N.A Kolchanov is the scientific director of the FRC and ICG SB RAS; he uses the program Genetic Technologies as the basis for the development of the center, which is being actively implemented in several fields. As a result, the fundamental directions of the institute (plant genetics, animal genetics, and human genetics) after its reorganization into the FRC were added with an implementation link. The implementation of the development program along with fundamental breakthrough research, the FRC received priority for full-cycle work. Some of the fields related to the introduction of genetic technologies into breeding practice and the development of industrial microbiology are being currently implemented at the world-class Center for Genomic Research, the "Kurchatov Genomic Center" in the consortium organized by Kurchatov Institute together with several institute including ICG SB RAS [8].

In the FSTP for the Development of Genetic Technologies for 2019–2027, special attention is being paid to the bioresource collections (BRC). The perception of the importance of the BRC for modern genomic and genetic research and for the development of genetic technologies was initially formed in scientific institutions that owned the collections of genetic resources in various fields (microorganisms, human and animal cell cultures, human biological materials, genetic resources of cultivated plants, farm

Fig. 1. Distribution of the number of scientific papers by N.A. Kolchanov's in various branches of study (according to Web of Science). Accessed at https://www.webofscience.com/wos/woscc/basic-search. Date of access 12/31/2021

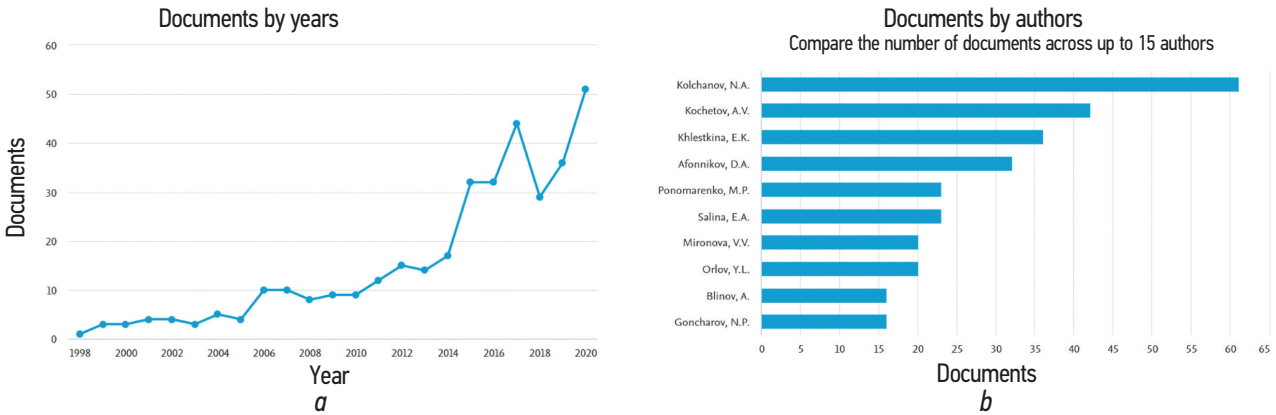
animals, etc.). Understanding the value of BRC, including the transition to a new technological mode of economics associated with the development of bioeconomy, has gone beyond scientific institutions and has become widespread in society because of the results of the systematic work on BRC conducted by the working group for the support and development of BRC for the life sciences section of the Scientific Coordinating Council under the Federal Agency for Scientific Organizations (FASO) of Russia. The working group was headed by N.A. Kolchanov. In order to form common approaches to the rational use of the existing BRC, the working group developed primary descriptive formats for the main types of BRC [9]. Then, the FASO institutes of Russia entered the information about the BRC into two internet systems: the Parus consolidated reporting system, the website of the Centers for the Collective Use of Scientific Equipment (SCU), and Unique Scientific Installations of the Russian Ministry of Education and Science [10]. However, these information resources were not intended to provide the detailed description of the BRC required for their rating. Therefore, to give the owners of the collections an opportunity to provide detailed information about the BRC and manage the documentation, the first version of the specialized information portal of the BRC was developed under the guidance of N.A. Kolchanov at the ICG SB RAS [11, 12]. At the end of 2018, 252 collections were registered on the portal, whose owners were research organizations; a subordinate to the Russian Ministry of Education and Science [13].

The result of the systematic work on the BRC issues within the activities of the working group and the FSTP for the development of the genetic technologies was the support of 65 collections in 2017 and 15 large projects in 2021, covering the activities of at least 30 significant collections. The expected result of these projects, which will continue in 2022–2023, is the improvement of standards and development of functions of the collections, the development of information infrastructure, and an increase in the availability and demand for the samples and their comprehensive characterization, including genotyping [14]. The next stage involves the integration of the collections of the same type according to the network principle of organization under the auspices of the large bioresource centers being created. The first pilot project to create such a center is already being implemented within the Decrees of the President of the Russian Federation, No. 44 “On the National Center for Plant Genetic Resources” and No. 45 “On the Interdepartmental Commission on the Formation, Preservation, and Use of Collections of Plant Genetic Resources” dated February 8, 2022 [15].

Interdisciplinary integrated approach to solving the problems of crop production

In recent years, N.A. Kolchanov, together with his associates and students, has paid special attention to a systematic, practice-oriented approach in the field of plant genetics, genomics, and bioinformatics (Fig. 2). N.A. Kolchanov spoke in detail about the prospect of using digital and genetic technologies in plant breeding at the scientific session of the general meeting of the Presidium of the Russian Academy of Sciences in October 2016 [16] (Fig. 2).

The study on the mathematical modeling of processes associated with the growth and development of plants [17–19] and on plant phenomics [20], conducted with the support and participation of N.A. Kolchanov, are widely known in this field. At the time of these studies were first published [17, 18, 20], these trends were exceptionally new not only in Russia but also in global science. At the same time, with the active assistance of N.A. Kolchanov at the institute headed by him, a new trend was developed based on an interdisciplinary approach using the methods of genetics, selection, and chemistry of plant raw materials, namely the use of genetic resources in the breeding of Russian plant varieties for the purposeful creation of raw materials for industrial production with an emphasis



a *b*

Fig. 2. Dynamics of the publication activity of the ICG SB RAS in the field of plant bioinformatics (*a*) the individual author's contribution to this publication activity (*b*). search conducted in the Scopus database using the AF-ID algorithm (Institute of Cytology and Genetics Siberian Branch of the Russian Academy of Sciences 60068684) AND ((plant)) AND (bioinformatics). Access mode: https://www.scopus.com/. Date of access: 12/29/2021

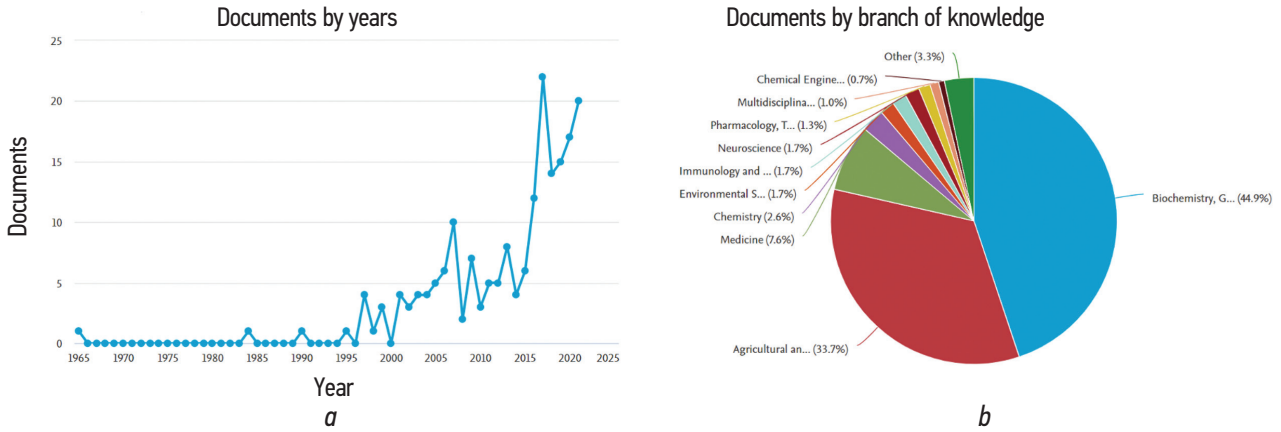
on lifetime modification of the main renewable natural organic products (cellulose and starch). With the direct participation of N.A. Kolchanov, the silver grass (*Miscanthus*) cultivar Soranovsky [21] was created and registered. These plants are able to grow successfully and in a controlled manner in Siberia, without depleting the nitrogen content of the soil and effectively converting atmospheric carbon dioxide into natural polymer cellulose. Plantations of Soranovsky silver grass are capable of producing up to 10–17 tons of lignocellulose mass per hectare per year, consisting of an average of 45 % of alpha-cellulose. Due to its physicochemical properties, the cellulose obtained from silver grass is suitable for use as a raw material for the production of paper, effective absorbents, and other products of the Russian industry. Taking into account this new trend, potato has become another object of research as a source of starch with desired properties. Starch is one of the few renewable organic products available in large capacity quantities. A group of authors, together with N.A. Kolchanov, carefully considered the potential of starch as a feedstock for one-step conversion into important chemical products for a number of industries [22]. Potato target genes from the structural and regulatory genes of starch biosynthesis were also evaluated to control the *in vivo* formation of the properties of this critical product using breeding and genetic technologies to diversify and make its use more economical in the industry [23].

Currently, the subprogram "Development of selection and seed production of potatoes in the Russian Federation" of the FSTP for the Development of Agriculture for 2017–2025 is being implemented and is widely covered in the information space (the program and subprogram were approved by the Decrees of the Government of the Russian Federation No. 996 dated 08/25/2017 and No. 559 dated 05/05/2018, respectively). However, few people know that on the eve of the release of the Decree of the President of the Russian Federation No. 350 dated July 21, 2016 "On measures to implement the state scientific and technical policy for the development of agriculture", which launched the further emergence of the FSTP for the Development of Agriculture for 2017–2025, a comprehensive program project was already formed, which launched both the FSTP and its subprogram "Development of Potato Breeding and Seed Production in the Russian Federation", as well as a number of individual projects of fundamental and fundamentally-oriented research. It referred to the Comprehensive Program for the Development of Potato Growing, the preparation of which was entrusted to N.A. Kolchanov in December 2015. It included five groups of activities covering the entire set of measures to ensure the full import independence of the production cycle of growing seed potatoes, and the program was applied not only in the research field of breeding, seed production, and the development of protective means but also in the integrated development of infrastructure for these studies, the development and pilot production of Russian equipment, activities to transfer technology and stimulate demand for Russian development, and activities for the training and retraining of personnel. The integrity of the approach became the strength of the comprehensive program, but simultaneously, this approach was ahead of its time, requiring coordinated actions from several federal executive bodies and dozens of organizations and industries subordinate to them. Five years later, significant management decisions were made in the country that created a favorable background and developed mechanisms for the implementation of such comprehensive interdepartmental programs. Five years ago, certain parts of the comprehensive program were restructured and started the aforementioned subprogram, "Development of selection and seed production of potatoes in the Russian Federation" of the FSTP for the Development of Agriculture for 2017–2025, in which, along with production, exploratory scientific research was the focus, whereas the fundamental and fundamentally-oriented research was conducted within the separate specially announced programs of the Russian Science Foundation and the Russian Foundation for Basic Research (RFBR).

The projects of the FRC ICG SB RAS, which were among the winners in these competitions, intensified their interdisciplinary research on potatoes at the Federal Center (Fig. 3). It referred to studies held in 2016–2021, supported by the RFBR No. 17-29-08006 "Genomic markers identification for advanced breeding of potato varieties with certain starch properties for food industry "within the framework of the interdisciplinary research competition, RFBR No. 17-44-540510 "Broadening potato genetic diversity in technological properties and processing in Novosibirsk region "within the regional competition, and the Russian Science Foundation No. 16-16-04073 "Genetic markers for potato breeding "in the 2016 competition for grants in the priority area of activity of the Russian Science Foundation "Conducting fundamental scientific research and exploratory scientific research on behalf (instructions) of the President of the Russian Federation" ("Scientific research in the field of potato growing", "Scientific research in the field of poultry farming"). More than 10 participants under 39 years of age were involved in these projects of the FRC ICG SB RAS, including young scientists, graduate students, and students, which was important in light of the task of training highly qualified personnel in the field of contemporary potato breeding and seed production.

CONCLUSION

Dozens of specialized organizations and several dozen scientists of various specialties, who became a friendly team, participated in the preparation of the Comprehensive Program for the Development of Potato Growing and in the activities of the working group for the support and development of the BRC under the guidance of



a *b*

Fig. 3. Dynamics of publication activity of the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences (ICG SB RAS) on potato research (*a*) distribution of publications by branches of study (*b*). search conducted in the Scopus database using the AF-ID algorithm (Institute of Cytology and Genetics Siberian Branch of the Russian Academy of Sciences 60068684) AND (potato). Access mode: https://www.scopus.com/. Date of access: 12/29/2021

Fig. 4. N.A. Kolchanov at a demonstration potato plantings during the Joint Scientific Event of Scientific and Practical Conference, "Theoretical Foundations and Applied Research in Potato Breeding and Seed Production" (31.07–01.08.2017) and "Field Day: Ecological-Geographical and Production Testing of New Varieties of Potatoes" (01.08–02.08.2017) held in Novosibirsk as part of the preparation of the subprogram "Development of selection and seed production of potatoes in the Russian Federation" of the Federal Scientific and Technical Program for the Development of Agriculture for 2017–2025 (Photo courtesy of V.S. Koval, ICG SB RAS)

N.A. Kolchanov (Fig. 4). During the several months of communication and teamwork, young scientists and managers who participated in the process received an example of not only a large-scale approach and breadth of thinking but also the ability to be approachable to the people in a large team, not to alienate anyone, and to find a rightful place for everyone. The students of N.A. Kolchanov, who have worked with him for years, know he generously shares his experience, knowledge, and skills with each new student and close associates who is not indifferent to the development of science and the practical achievements that are so necessary for Russia. Among other awards and titles, N.A. Kolchanov was awarded the Order of Friendship in 2017 for his contribution to Russian and world science and its practical implementation [7].

ADDITIONAL INFORMATION

Author contributions. All authors made a significant contribution to the development of the concept, research, and preparation of the article, and have read and approved the final version before its publication.

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