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On the Rostrum of the RAS Presidium

The RAS Presidium meeting of April 19, 2014, considered in detail the problem of replenishing, studying, preserving, and rationally using the genetic resources of cultivated plants and their wild relatives. This is a task not only for domestic selection institutes but also for the world community as a whole. Russian scientists and their foreign colleagues make colossal efforts to collect samples of wild plants in expeditions and to breed new varieties with unique agronomic traits. The continuous replenishment of the plant gene pool and its rational use is a passport to the food, environmental, and economic stability of our country. The keynote paper, presented by Director of the Vavilov Research Institute of the Plant Industry (VIR) N.I. Dzyubenko, and the coreports heard at the meeting are offered to the reader.

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Genetic Resources of Cultivated Plants As the Basis for Russia's Food and Environmental Security

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The genetic resources of cultivated plants and their wild relatives are basic components that determine the food and environmental security of each sovereign state, including Russia. At present, they have become especially topical and strategically important in connection with growing genetic erosion and the disappearance of agricultural plant varieties, species, and genera from the face of the earth. According to the data of the UN Food and Agriculture Organization (FAO) for 1998, 75% of the global genetic diversity of crops was lost in the 20th century. In addition, the number and assortment of arable crops and species have decreased substantially. Only 30 crops ensure 95% of humankind's needs for caloric vegetable food, and four of them (rice, wheat, corn, and the potato) cover more than 60% of the needs for energy and proteins. Under global and local climate changes, the loss of diversity and the shortage of crops used in production are a serious food threat to the entire world community. Hence, at the present stage, the preservation and rational use of plant genetic resources (PGRs) are nationally significant and strategically important for every country.

In Russia, the problems of PGR mobilization, preservation, research, and use have been studied for 120 years by the Vavilov Research Institute of the Plant Industry. N.I. Vavilov laid the foundation for the national and global strategy of PGR preservation and rational use. He was the first to draw the attention of the world scientific community to the colossal diversity of plant resources and selectively important genes present in the varieties of unprofessional and scientific selection and in the populations of wild and weed species. Vavilov's theory on the centers of origin of cultivated plants, law of homologous series in hereditary variation, and major works about geographical regularities in the distribution of cultivated plant genes and the role of initial material in selection, as well as other works, were internationally recognized and provided the basis for the doctrine about the mobilization, preservation, study, and use of the world's vegetation diversity. Vavilov was one of the first who understood the special importance and the real and potential value for humankind of collecting from all the continents and preserving as living collections the seeds of cultivated and related wild plant species. Later, his ideas established themselves as an international trend of scientific thought and his activity on forming the collections began to be considered as a model. At present, there are more than 1750 gene banks, including the Global Seed Vault (seed depository), which was created in 2008 in permafrost on Svalbard (Spitsbergen) Island, which can reliably preserve more than 5 million plant seed samples.

Scientists of several generations have been collecting the VIR collections, and today the monitoring, collection, preservation, documentation, detailed investigation, and efficient use of the world's PGRs continue and develop based on modern achievements of science and technology with account for new economic and political trends in plant diversity activity. These collections include more than 324000 plant samples (representing 64 botanical families, 376 genera, and 2169 species), occupy the fourth place in the world by the quantity of samples preserved, and are the richest in terms of their botanical, genetic, geographical, and environmental diversity. It is not by chance that the FAO steering council on plant genetic resources included the institute and its collections in

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the list of Future Harvest Centers, which unites the 11 largest PGA-preserving gene banks.

The significance of the collections for domestic selective breeding, food production, and the development of environmentally safe agriculture can hardly be overestimated. Suffice it to say that, in the second half of the 20th century, as a result of studying and using samples from the VIR collections by plant breeders from Russia and the former Soviet republics, unique varieties were created, which made it possible to increase grain crop yields by two-to-five times, boosting considerably gross grain yields. By introducing wild potato species, collected in South and Central Americas by VIR expeditions, into selection alone, this culture was disseminated across Russia and acquired the traits of early maturation, resistance to diseases and pests, and a better storage capacity, and its crop yield increased by three-to-four times by the end of the 20th century. Thanks to the use of the sources of the early maturation and cold endurance of wheat, oats, sunflower, soybean, cotton, rice, corn, and other cultures in selection, their arable areas have moved far northward; in particular, the area of corn for grain has spread almost 2000 km northward and 10000 km eastward.

The country's fields cultivate 80% of the varieties and hybrids of agricultural crops obtained owing to the collections' samples. For example, on the basis of the collections, more than 300 varieties of rye, oats, and barley were bred, more than 120 of which were regionalized. The dominant short-stem gene, found in the rye collection, served as the parent material for a general global trend in winter rye selection—the creation of erect varieties. Short-stem varieties, bred using this gene, now occupy about 80% of the rye-planted area in Russia and the CIS countries, annually yielding an income of billions of rubles.

The institute's collections favored the introduction of new species for food (spelt, amaranth, Chinese cabbage, stevia, cherry plum, sea-buckthorn, actinidia, honeysuckle, etc.), as well as for growing them on acid, desertified, and contaminated soils, including species of phytoremediants, ameliorants, and edificators (a dominant species that plays a determining role in the structure of biocoenosis). New arid forage plants, such as *Krascheninnikovia ceratoides*, prostrate summer cypress, and saxaul were introduced in Precaspian regions.

The collections' essential role in preserving and improving major agricultural crops and reducing the vulnerability of varieties is obvious. Thus, out of 324000 collection samples contained in the VIR gene bank, about 30% are varieties and populations that have already disappeared in nature and have been lost by producers. Often they carry genes that are valuable for selection and production and that come in demand at a certain stage. This is especially true of resistance to pathogens. In particular, the gene pool of wild species that have disappeared in natural conditions but that have been preserved in the collections has made it possible to save a culture from *Phytophthora infestans* and other diseases. The involvement of representatives of remote and rare species, wild relatives of cultured plants, old-local varieties, and varieties with different breeding trees in selection increases the pool of valuable genes (gene pool) that determine agronomic and economically valuable traits and makes it possible to expand the hereditary basis for newly created varieties, reduce their vulnerability, and withstand stressors. The collection samples make it possible to renew the selection and cultivation of crops discontinued long ago, for example, to return to the selection and production of many industrial crops (false flax, kok-saghyz, mole plant, castor oil plant, sea kale, *Eruca*, etc.). Interest in them has reappeared owing to the use of new raw materials, alternative fuels, natural rubber, and nonfreezing lubricant oils, which became possible thanks to the variety of these cultures at the institute.

Annually, the VIR gene pool is replenished by 1000–3000 new samples, which are studied and reliably preserved as seeds, vegetative and generative organs, tissue cultures, test-tube plants, and nucleic acids at controlled low temperatures, in vitro, and in cryogenic storage. Comprehensive studies over the past ten years have allowed us to extract and create by traditional methods more than 20000 genetic sources and 500 donors of selection-crucial gene alleles and polygenes, and to form numerous trait and gene collections of major agricultural crops for their target application in selection programs. New effective and rare gene alleles, previously unused in selection, were identified and mapped to determine their photoperiodic sensitivity and reaction to vernalization (plants' reaction to the effect of low positive temperatures), resistance to pathogens, and other traits. In addition, quantitative trait loci (QTLs) were marked and molecular-genetically mapped in order to reveal, identify, and transfer under control chromosome loci that determine the manifestation of economically valuable traits of major agricultural crops (resistance to biotic and abiotic stressors, quality, and productivity). The genetic diversity of the collection material, studied using traditional technologies and molecular-genetic approaches (including genomics, molecular marking, mapping, and bioinformatics), is a powerful basis for valuable source material and an effective tool for the efficient development of selection.

The revealed potential of valuable genes and polygenes and their identification contribute to the diversification of the genetic base for the creation of new genetically heterogeneous varieties and hybrids (with improved crop yields in combination with quality and resistance to diseases and pests, abiotic and edaphic stressors that can perform habitat-forming and

resource-restoring functions) capable of creating highly productive and environmentally stable agrosystems. The diversity of the collection material (reliably preserved and rationally used) can ensure the development of selection technologies and priority trends in the 21st-century selection, which are aimed at the creation of quality foods; the optimization of feed production; global climate change; the "northering" of crop production; the development of new agro-, bio-, food, chemical, and industrial technologies; agriculture biologization and ecologization; and resource and energy saving.

VIR is the chief holder and keeper of the genetic resources of cultured plants and their wild relatives in Russia. Collections of plant resources totaling approximately 50000 samples are also contained in other organizations, such as research institutes, selection centers, higher education establishments, botanical gardens, commercial selection and seed-breeding firms, and farms. In addition, more than 1600 species of wild relatives of cultured plants, which are the potential carriers of traits valuable for selection, grow on Russian territory. Many of them already now face the danger of extinction, and measures are required to preserve them.

The problems of preserving genetic resources in gene pools, within natural plant communities, and on farms and using them rationally are among the five priorities of the national security policies of most countries. These problems should be solved at both the national and international levels. The joint efforts of specialists from various countries helped develop international documents to steer PGR activities, such as the 1992 Convention on Biological Diversity, the 1996 and 2011 Global Plans of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture, the 2004 International Treaty on Plant Genetic Resources for Food and Agriculture, and the 2011 Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity. An international network was established to deal with the problems of PGR conservation. To solve these problems at the national level with account for the international documents, most sovereign countries have developed and adopted relevant legislation and national strategies and programs on genetic resources, which are directly controlled by the states that allocate the necessary funds for their implementation.

Unfortunately, the issues of PGR conservation and rational use, which require a special policy on the part of the state and which in most countries of the world are under the jurisdiction of their governments, do not have a priority status in Russia. Despite the fact that the importance of the VIR collection and work in solving the objectives of selection and crop production in Russia, as well as their role in solving the food problem, was stressed by former Russian President D.A. Medvedev at the World Grain Forum (St. Petersburg, 2009), as well as by former Russian Minister of Agriculture E.B. Skrynnik at the World Summit on Food Security, held by UN FAO (Rome, 2009), at which she said that Russia was ready to open up opportunities for using the VIR PGR collection in the interests of the world community, taking into account climate changes on the planet and the general interest of the countries of the world in overcoming hunger and poverty. Russia has not yet developed a state strategy or a policy aimed at turning PGR into an effective national resource of renewal of agricultural production and sustainable economic development and has not yet approved or started to implement the national program "The Preservation and Rational Use of Genetic Resources of Cultured Plants," developed by the institute in 2006, with the necessary budget funding for the efficient coordination of actions in the field of plant resources at the national, regional, and international levels. The draft national program and the issue of 100% budgetary funding of a work package to mobilize and reliably preserve the plant genetic resources were considered and approved at a meeting of the Council of the Federation Committee for Agrarian and Food Policy and Environmental Management on December 25, 2006 (no. 26/7); the project was recommended for adoption by the Russian government. Unfortunately, no answer came from the relevant ministries.

Russia has not yet joined the International Treaty on Plant Genetic Resources for Food and Agriculture (2004, 130 member countries), which created a multilateral platform for cooperation and exchange of genetic material for 64 agricultural crops most important for food security.

Efficient preservation and management of the collections, increase in their use, and access to hermoplasma require the development, fortification, and harmonization of the national legislation on PGR. Currently, the Russian Ministry of Agriculture, the Russian Academy of Agricultural Sciences, and VIR have joined their efforts to prepare and agree upon, at the level of the relevant ministries, the draft Federal Law On Plant Genetic Resources for Agricultural Production, which will regulate the collection, reproduction, storage, study, and rational use of plant genetic resources and their collections for agricultural production on the territory of the Russian Federation.

The state budgetary funds that VIR receives for all programs, projects, and grants cover only 30% of the necessary funding for the work with the collection, which are targeted for basic and priority applied PGR research. Thus, all operations related to the monitoring and mobilization of genetic resources, keeping up their germinating capacity and reproduction, and pre-

serving the collection samples in low temperature conditions, in vitro, and in cryogenic storage, as well as preserving the clone collections of perennial fruit crops in the institute's field gene pools, remain without sufficient financial support on the part of the state, although the draft Federal Law On Plant Genetic Resources for Agricultural Production defines the collection as federal property, meaning, respectively, it should be supported by budgetary funds.

The cost of keeping live just one seed sample, taking into account international practices, is \$20–\$60 on average, and that of preserving one sample of perennial fruit crops in a field gene pool is \$80–\$120. Thus, for research and engineering to maintain and preserve the world collection, the institute and its experimental stations require annual budgetary funding of \$14.3 million (425 million rubles), while the annual subsidy to the institute and its experimental network for basic and priority applied research was only 212.8 million rubles in 2013. At the same time, we should note that the Program of Basic Research at the State Academies of Sciences for 2013–2020 envisaged 471 million rubles for PGR mobilization and preservation in 2013 alone. At present, the collections are financed from nonbudgetary funds earned by VIR and its experimental network and thanks to the enthusiasm and efforts of the scientists and support personnel. Chronic underfunding of the collections, which has lasted for more than 20 years, affects the quality of the preserved material and leads to irreplaceable damage to collection samples; the loss of scientific schools, experience, and research continuity; and the aging of personnel.

Understanding the moral and legal liability for the preservation and development of the VIR collections as a unique wealth of Russia and the world community, as well as taking into account the importance of the collections for the sustainable development of environmentally safe agricultural production in the conditions of climate change and economic instability, the associates of the institute addressed more than once their initiatives and proposals to the top government bodies in an attempt to draw attention to the existing problems and to solve them within the government programs shaped.

In 2011 VIR prepared a substantiated measure to preserve and use rationally the PGR collections as the main component of ensuring the sustainable development of agriculture with the allocation of the necessary financial and logistic support. First, it was included into the draft State Program of Agriculture Development for 2013–2020, but then it was excluded from it during the process of approval with the relevant ministries.

On June 9, 2011, the State Duma held a "roundtable" to preserve the Russian collections for the development of the biotechnological industry in the Russian Federation, and its recommendations were taken into account during the development of the Complex Program for the Development of Biotechnologies of the Russian Federation for the Period until 2020. This program was approved by former Chairman of the Russian Government V.V. Putin on April 24, 2012. However, despite the fact that the program assesses the Vavilov collection of world genetic resources as "unprecedented in its scientific and practical purport" and that among the program's top priority measures is the development of the Federal Law On Plant Genetic Resources for Agricultural Production, the VIR collections were not included into the financed priority section "Biological Collections and Bioresource Centers," which proposed to allocate funds exclusively for microbial collections. The exclusion from this program of the Vavilov PGR collection, which is a key link in the preservation and development of Russia's bioresource potential, deprived it once again of state financial support.

We have to state that the situation with financial support for research and engineering associated with genetic collections in Russia is critical, and, if the government does not find without delay the possibility to allocate annually an additional target 425 million rubles from the budget for the reproduction, preservation, and expansion of the global PGR collections, which are federal property, the genetic diversity—a key component of Russia's food and environmental security—will be irretrievably lost.

After the presentation, N.I. Dzyubenko answered questions.

Academician **A.L. Aseev**: You mentioned the Svalbard Global Seed Vault. The same work is done at the Yakutsk Research Center, based at the Mel'nikov Permafrost Institute, RAS Siberian Branch. What do you know about this project and how do you assess its prospects?

N.I. Dzyubenko: In 1976, VIR was the first to lay 12000 collection samples in the Permafrost Institute's shaft. However, despite permafrost, we still need controlled storage conditions. At Svalbard, for example, they have set a constant temperature of –18°C.

Academician **D.S. Pavlov**: What amount of funding does VIR receive compared to international centers?

Dzyubenko: If we compare international centers by the size of their genetic collections (and there are ten in the world), we are second to none of them by any indicator, except for funding. We are allocated about 35 times less on average than our foreign colleagues. Let me give you a few examples. Latin America allocates almost \$2000 a year to maintain one potato sample. The International Center for Agricultural Research in the Dry Areas (ICARDA) is located in the city of Aleppo, Syria, and it is annually funded by

international funds at $500 per sample. Russia allocates about 600 rubles for these purposes.

D.S. Pavlov: How can plant genetic resources ensure a country's environmental safety?

Dzyubenko: Adaptive crop growing is the use of the specific and intraspecific diversity of plants and the absence of monocrops. Competent crop rotation can minimize chemical treatment and reduce mineral fertilizer dosage, thus maintaining soil fertility and preserving the environment. In addition, there exist many phytomeliorant plants that can clean the soil and air and that require a minimum of nutrients, and so on.

Academician **R.I. Nigmatulin**: Alarmist sentiments spread across the world about genetically modified products; people are intimidated, although, in my opinion, all this is absolute nonsense. How do you feel about this issue?

Dzyubenko: For me, it is hard to give an unambiguous answer, because genetically modified varieties differ. Probably, there are safe varieties among them, as well as those that threaten human health as food. I believe that certain evolutionary, environmental, agronomic, and other risks do exist, and the Russian Federation has to pass a law on biosecurity to conduct a full check on GMO products. To date in the world it has been proposed to use two principles of assessing GMO safety: the American and the European. The American principle is identity or substantial identity, where possible risks are assessed only in the end products as goods. The United States asserts that there is no danger for humans. Europe makes assessments at all stages (the choice of a specific variety or hybrid, growing, and processing), taking into account evolutionary, environmental, and agricultural risks.

Academician **R.Z. Sagdeev**: it became known recently that 187 agricultural crops have GMO analogs. Are they also kept in the Russian collections?

Dzyubenko: The issue of possible storage of such varieties and hybrids was considered at the institute and the Academy more than once. Currently, we do not store them; however, a special laboratory exists for genetically modified plant research. Estimation techniques are not yet refined; we use only qualitative assessment.

Academician **V.E. Fortov**: You said that field research should be continued. How many species out of the whole diversity on the planet are stored in the genetic banks?

Dzyubenko: The world now cumulatively stores 7.3 million samples, which is approximately 5200 plant species (with account for tropical and subtropical ones). We, however, keep only species of moderate climate, which are about 2200 plant species. As for the volumes of preservation, no scientist in the world would say accurately how many samples should be collected to provide the future population of the earth with foods and ensure the food security of a sovereign state.

Fortov: How many diverse species are there on the globe?

Dzyubenko: About 400000 plant species, out of which 300000 have been identified. The exact number does not exist; annually botanists discover up to ten new species, especially in the equatorial zone of the Amazon delta. Our main objective is to collect wild relatives of cultured plants and to study and preserve them in gene banks.

Fortov: Is your objective just to preserve these species or also to breed new and more productive varieties on their basis?

Dzyubenko: We try to solve both problems. New storage technologies are developed in order not to lose the integrity of a genetic sample. We also provide the selection centers with identified source material for breeding new varieties and hybrids.

Translated by B. Alekseev