Innovative technologies in agricultural crops breeding and seed farming

A L Zolkin¹, E V Matvienko² and M V Shavanov³

¹ Computer and Information Sciences Department, Povolzhskiy State University of Telecommunications and Informatics, L.Tolstogo Street 23, Samara 443010, Russia
² Laboratory of Breeding and Seed Farming of Cereal and Sorghum Crops, Volga NIISS - branch of the Samara Scientific Center of the Russian Academy of Sciences, Shosseinaya Street 76, Ust-Kinelskiy 446442, Russia
³ Horticultural and winegrowing department, Chechen State University, A. Sheripova Street 32, Grozny 364024, Russia

E-mail: alzolkin@list.ru

Abstract: Plant breeding involves the study of ways of creation of the new varieties of cultivated plants with important traits and improvement of the existing one. The following basic breeding methods are distinguished: selection, hybridization, mutagenesis and polyploidy. In 2019, the share of domestic breeding seeds in the total volume of seeds was 62.7%, for sugar beets - 0.6, sunflower - 26.5, vegetables - 43, corn - 45.8, soybeans - 41.8%. For winter and spring wheat, this indicator was 90.5 and 82.2%, respectively. The food security doctrine for seeds as a whole sets the indicator at no less than 75%. Import dependence on seeds and hybrids of agricultural crops is due to a number of factors: low competitive potential of newly registered varieties and hybrids, low quality of seeds, deficiencies in the system for stimulation of variety renewal, underdeveloped infrastructure, outdated material and technical base, lack of highly qualified specialists in genetics, breeding and seed production.

1. Introduction
The country’s food security is impossible without modern breeding and seed production, which fully applies to both open and protected ground. The production of competitive agricultural products is carried out through the use of advanced methods of genetics, breeding, seed production, diagnosis of pathogens, integrated plant protection products, the latest technologies, etc. The tasks of breeding and seed production of agricultural crops are the reproduction of seeds of varieties and hybrids and the maintenance of their genetic potential in order to preserve the properties and economically valuable traits.

High-quality seeds of the best zoned varieties are the foundation of the future harvest. They carry the complete genetic information of the variety, possess a complex of biological, physicochemical and biochemical properties (the yield and the effectiveness of the technological methods used in the cultivation of crops in production conditions depend on these properties). In recent years, a large number of seeds have been imported into Russia from all over the world, and not always these seeds had a proper quality. In general, breeding establishments are equipped with means of mechanization of breeding, testing and primary seed production works for about 50%. Due to the lack of comprehensive
mechanization of elite seed production, it is impossible to carry out breeding and experimental work at a qualitatively level. Currently, a lot of attention is paid to innovative technologies and issues of mechanization and automation in this industry [1].

The Decree of the President of the Russian Federation No. 350 dated July 21, 2016 refers to the development and solution of a set of measures aimed at the creation and implementation of competitive domestic technologies by 2026. These technologies shall ensure the production of original and elite seeds of agricultural plants in the areas of domestic crop production, which is currently time has a high degree of dependence on imports [2].

There are three areas of technology development that are the key areas for the innovative development of the modern economy: information technology, nanotechnology and biotechnology.

Modern plant breeding uses a whole range of methods based on the latest advances in many biological sciences.

The importance of biotechnological methods in plant breeding is constantly growing.

With the help of biotechnology, the following breeding problems are solved:

- Creating new source material;
- Acceleration of the breeding process;
- Reducing the labour intensity of breeding work.

Successful crop production depends on rapid variety change, variety renewal and stable seed production.

2. Breeding and seed production development strategies until 2020

The main tasks are:

- Modernization of the material and technical base.
- Expansion of the range of plant genetic resources.
- Creation of high-tech centers for breeding, industrial production, preparation and storage of seeds.
- Development of modern biotechnological and breeding methods for creation of varieties and hybrids of agricultural plants.
- Creation of high-yielding, technological, modern varieties and hybrids.
- Development of modern varietal technologies for the cultivation of agricultural crops.
- Development of a system of relationships between participants at the seed market based on the development of self-regulatory organizations of breeders and seed growers.
- Creation of conditions for sustainable development of the domestic seed market and improvement of mechanisms for its regulation.
- Improvement of the regulatory and legal framework for breeding and seed production.

Without the use of biotechnological innovations, agricultural production in Russia will continue to be highly costly and lose in competitiveness to foreign countries [3].

For Russia with a wide geographical and ecological heterogeneity of the soil and climatic environment, there cannot be universal varieties equally suitable for all natural zones, regions and ecological conditions. The types and varieties of agricultural crops must have geographic (climatic) and environmental adaptability. Plant breeding involves the study of ways to create new and improve existing varieties of cultivated plants with practically important traits. There are the following main breeding methods: selection, hybridization, mutagenesis, and polyploidy [4].

3. Plant breeding methods

Table 1 shows the methods of plant breeding, their brief characteristics and scope of application.
In order to objectively show the advantages of the newly developed varieties in terms of yield, product quality, length of the growing season, resistance to diseases, pests, lodging and other indicators in front of the standard variety, it is necessary to pay a great attention to the careful observance of the field experiment methodology throughout all stages of the breeding process. Only the correct experiments with breeding material will allow to obtain varieties that will confirm their high qualities in the state testing and production conditions of a certain soil-climatic zone of their future zoning. To achieve such results, it is necessary, first of all, to ensure the typicality and accuracy of the experience, to observe the principle of single difference [1].

Table 1. Plant breeding methods.

| Method       | Features                                                                 | Application range                                      |
|--------------|---------------------------------------------------------------------------|--------------------------------------------------------|
| Selection    | Selection of the most economically or decoratively valuable plants with desired properties | for economically valuable featured                     |
|              | The process of forming or obtaining hybrids, which is based on the unification of the genetic material of different cells in one. There are closely related (inbreeding) and unrelated (outbreeding) hybridization | Closely related hybridization is used to obtain pure lines with the desired traits, unrelated is used to obtain heterozygous populations and manifestation of heterosis in their representatives |
| Hybridization| Artificial introduction of changes into the nucleotide sequence of DNA    | In plant breeding it is used to get more yielding material |
| Mutagenesis  | Cultivation of individual cells or tissues on nutrient media              | Getting uninfected planting material                   |
| Genetic engineering | Purposeful transfer of the desired genes from one type of living organism to another | Improving the hereditary qualities of organisms, obtaining biologically active substances in an unlimited amount |

4. Molecular markers
The priority task of research in the field of genetic resources is intensification of the work on molecular genetic monitoring of the gene pool in crop production, use of molecular genetics methods to identify new genes, regulatory elements and physiological and biochemical mechanisms. The main direction of development of fundamental biotechnological research in the field of genetic resources is work on molecular selection, including the creation of sources and donors of economically important genes and plant traits, as well as the development of new technologies for their transformation that meet modern biosafety requirements. Large international programs, such as the Generation Challenge Program or the Global Wheat Program program of the International Maize and Wheat Improvement Center (CIMMYT), rely on the latest advances in comparative genomics, bioinformatics, and molecular marker breeding in order to expand the genetic diversity of modern wheat varieties and form the wide nonspecific resistance for these varieties [4].

Molecular markers are widely used by breeders in the USA, the European Union, Australia, Japan, China and other countries. In our country, this technology is in its infancy, it is beginning to be applied, for example, in the Krasnodar agricultural research institute named after P. P. Lukyanenko, now known as FSBSI National Grain Center named after P. P. Lukyanenko in cooperation with the Russian State Agrarian University-Moscow Agricultural Academy named after K. A. Timiryazeva and the Federal Research Center Russian Institute of Plant Genetic Resources named after N. I. Vavilov. The development of this technology is based on the existing cytogenetic collections of common wheat, which were created in the middle of the last century and were used to improve this culture using chromosomal engineering methods.
The first molecular genetic maps of wheat based on DNA markers were constructed for all 21 chromosomes using the analysis of restriction fragment length polymorphism (RFLP markers) resulting from DNA treatment with restriction endonucleases (restriction enzymes). The advantage of RFLP markers is their high conservatism, which makes it possible to use them for comparative mapping of related species, protein analysis allows to investigate polymorphism of only protein-coding sequences and only in expressed genes. At the same time, such functionally significant regions as promoter regions, enhancers, various regulation sites located in introns or untranslated regions of genes, as well as outside genes, often at a considerable distance from the coding sequence, are excluded from the analysis [4].

One of the maps that is richest with DNA markers was created in IPK in collaboration with Trait Genetics (Gatersleben). Molecular linkage map for chromosomes of the second homeologous group, created for the mapping population ITMI (International Triticeae Mapping Initiative). For all other chromosomes of this population, the same marker-rich maps have been created.

The creation of various mapping wheat populations, the development and cheapening of genotyping technologies stimulated the growth of work on the study of the architecture of complex polygenic traits in the wheat genome through the mapping of quantitative trait loci (QTL). QTL analysis is an analysis of associations between phenotypic (measured traits) and genotypic (molecular markers) data, which allows splitting the genetic base of a complex trait into simple components.

Over the past two decades, a large number of genes and QTLs have been mapped using molecular markers on wheat chromosomes. All information on the localization of genes or loci of quantitative traits is placed in the International Catalogue of Wheat Gene Symbols at http://www.shigen.nig.ac.jp/wheat/-komugi GENES/SYMBOL. Information about markers validated (tested) for practical use and recommended protocols are presented at http://maswheat.ucdavis.edu/.

As for today, this site contains functional markers for genes that affect:

- agronomically important traits: plant height (Rht), sensitivity to photoperiod (Ppd), which determine the type of development (Vrn);
- baking quality (activity of lipoxygenase, polyphenol oxidase, loci that control glutenin subunits, etc.);
- resistance to various pathogens.

5. Cellular biotechnology

Currently, cell biotechnology has a number of methods. The main of them are not limited by cultivation of cells and tissues of individual plants and are listed below:

- methods of clonal micropropagation, including the induction of organogenesis and somatic embryogenesis;
- methods of isolating protoplasts and obtaining somatic hybrids;
- methods of obtaining haploid plants and dihaploids derived from them;
- methods of genetic transformation followed by the regeneration of modified plants.

6. Fasciation

Finding new plant forms that meet market needs may involve an innovative approach to terat specimens. Teratos are plant organs changed under the influence of various factors. These include plants with fasciations, in which various parts grow together.

First of all during breeding studies of fasciated plants, the question of hereditary fixation of the mutation with fascia is relevant. On a number of crops, such as kiwi, peas, lilies, cauliflower, cellozia argentea, it was possible to fix and convey this characteristic. On the basis of the obtained hybrid forms, varieties have been developed [4].

A number of authors note the accretion phenomenon in various plants in the following cases:
• fascia occurs due to the non-divergence of the lateral lashes of plants or partial thickening of the stems due to a decrease in the number of branches;
• most often fascia is occurred on plants reproductive organs (flowers and ovaries),
• fasciation occurs by the deposition of a supply of nutrients, which, fill an organ and combine its individual parts into one massive formation.

Probably, selection with fasciated plants will follow the path of searching for unique genotypes with a fixed mutation. In some cases, the creation of a form will solve food problems, that is, a larger size of fruits, more harvest, in other cases it is the creation of decorative forms. Thus, the study of the phenomenon of fasciation in higher plants could give us, on the one hand, a method of selection for large-fruited yield, and on the other hand, to establish the adaptive abilities of newly created genotypes. Areas where plant fasciation is studied: plant breeding, ecology, biotesting, ecological genetics and botany [4].

7. Import dependence on seeds and crop hybrids
In 2019, the share of domestic breeding seeds in the total volume of seeds was 62.7%, for sugar beets - 0.6, sunflower - 26.5, vegetables - 43, corn - 45.8, soybeans - 41.8%. For winter and spring wheat, this indicator was 90.5 and 82.2%, respectively. The food security doctrine for seeds as a whole sets the indicator at no less than 75%. Import dependence on seeds and hybrids of agricultural crops is due to a number of factors: low competitive potential of newly registered varieties and hybrids, low quality of seeds, shortcomings of the system for stimulating variety renewal, underdeveloped infrastructure, outdated material and technical base, lack of highly qualified specialists in genetics, breeding and seed production. Due to ineffective links in the chain of genetics - breeding- seed production - agricultural producers, new varieties and hybrids registered with the State Sort Commission hardly reach the consumer. Compared to state institutions and private domestic companies, foreign seed producers have significant advantages both in genetics, breeding and seed production as well as in marketing. In developed countries, investments from private breeding companies are directed towards equipping with the latest equipment and technology, scientific research in the field of biotechnology, marketing programs, etc. Seed breeding companies operate under state control, which ensures copyright protection for the variety and payment of breeding fees - royalties to finance the activities of breeders. Thus, intellectual property rights to plant varieties, which are valid throughout the EU, are granted in accordance with the TRIPS / WTO agreements and the UPOV convention - the International Union for the Protection of New Varieties of Plants. In the EU, USA, Canada and other countries, the state regulates the registration of varieties (national registries), testing them and protecting the rights of developers. The experience of legal regulation of the development of selection and seed production of foreign countries shall be used in Russian legislative practice.

8. Findings
It is necessary to develop mechanisms to stimulate and support the development of breeding and seed production at all stages - from the creation of a competitive variety to its introduction into production, providing for the distribution of the profit in accordance with the contribution of each link in the chain of its formation [5].

The main measures of state support stimulating the production and use of original and elite seeds of agricultural crops were provided within the framework of state programs at the federal level and regional programs for the development of the agro-industrial complex in the form of co-financing in all areas that operated in crop production: subsidies for providing unrelated support; unitary regional subsidy; subsidy for the reimbursement of a part of the interest rate on investment loans taken before January 1, 2017; compensation for direct costs incurred for the construction and modernization of agricultural facilities; concessional lending; leasing, etc.

Prospective directions of development of breeding and seed production are stipulated by the Nauka (Science) project and federal research and development program (FRDP). As part of the implementation
of the FRDP sub-programs, it is planned to create 87 specialized service centres in the main agricultural zones of the country on the basis of federal innovative scientific and technological centres that have a human potential, bioresource collections, material and technical, land resources and performing genetic research. Nauka project provides for the creation of 35 specialized service centres and social pedagogical centers, 15 scientific and educational centers, 5 agrobiotechnological cluster capable of integrating the capabilities of universities, academic institutions, high-tech companies aimed at the commercialization of R&D results, as well as providing training programs, consulting, exhibition and other activities. The following development institutions shall take part in the implementation of the development of the material and technical base of selection and seed production: Rosagroleasing JSC, Rosselkhozbank JSC, Small and Medium Business Support Corporation, etc. [5].

References
[1] Fedorenko V F, Mishurov N P and Kolchina L M 2017 Innovative technologies in breeding, crop variety testing and seed farming: scientific publication (M.: FSBSI Rosinformagrotekh) p 200
[2] Decree of the President of the Russian Federation No. 350 dated July 21, 2016.
[3] Innovative technologies in breeding and seed production of agricultural crops - the main page of the Central National Agricultural Bank URL: http://www.cnshb.ru/news/vex_sel.shtml (Accessed on: 10.10.2020)
[4] Tsatsenko L V 2020 Innovative technologies in agronomical science: educational medium (Krasnodar: Kuban State Agrarian University) p 88 p.
[5] Korolkova A P, Kuzmin V N, Marichenko T E and Goryacheva A V 2020 Stimulating the development of breeding and seed production of agricultural crops: domestic and foreign experience: an analytical review (M.: FSBSI Rosinformagrotekh) p 124