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SELECTION AND SEED PRODUCTION OF VEGETABLE CROPS IN RUSSIA (the 100th anniversary of the Federal Scientific Vegetable Center)

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FEDERAL SCIENTIFIC VEGETABLE CENTER — 100-YEAR HISTORY AS A BASIS FOR FUTURE DEVELOPMENTS
(review)

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Abstract

The review presents the history of the Gribovskaya Vegetable Breeding Experimental Station, the first in Russia and the USSR for vegetable breeding and seed production, on the basis of which the All-Russian Research Institute of Vegetable Breeding and Seed Production was established, farther reorganized into the Federal Scientific Vegetable Center. The center's activity dates back to 1920, when, under the leadership of Sergei I. Zhegalov, a theoretical and practical basis for the development of domestic breeding was laid. The century-old anniversary of the selection of vegetable crops allows us to trace the way of its formation in Russia, successes and future development. Since 1920, scientists paid much attention to the development and improvement of breeding methods that increase the efficiency of selection, as well as to accelerate the selection process to create targeted varieties and hybrids. With regard to the main vegetable crops, methods have been developed for interspecific hybridization (N.I. Timin et al., 2013; A.F. Agafonov et al., 2018), molecular labeling (T.P. Suprunova et al., 2011; E.A. Domblides et al., 2015), clonal micropropagation and production of doubled haploids successfully used in breeding (M.S. Bunin et al., 2004). Basic protocols have been proposed for in vitro culture of microspore for most cabbage crops (E.A. Domblides et al., 2016) and non-pollinated ovules for *Cucurbitaceae* (N.A. Shmykova et al., 2015). A technology has been developed for the production of doubled haploids in carrots in in vitro cultures of anthers, non-pollinated ovules and microspores (T.S. Vjurtts et al., 2016). The economic benefit of modern biotechnological in vitro methods when creating hybrids has been proven: the time for creating hybrids is reduced from 12 to 6 years, financial costs are reduced 2 times (A. Mineykina et al., 2019; T. Vjurtts et al., 2019). The aggravated situation with plant diseases and the expansion of the areas of new harmful pathogens on vegetable crops are discussed. Based on immunological, molecular and morphophysiological tests at artificial, provocative and natural infections, the sources of resistance to economically significant diseases are identified, in cabbage to *Plasmodiophora brassicae*, in table beet to *Cercospora beticola*, in vegetable beans to viral diseases, in onions to *Peronospora destructor* (I.A. Engalycheva et al., 2019). Physiological and biochemical methods are widely used when creating varieties with a high content of biologically active substances and antioxidants. Technologies have been developed for obtaining functional food products, including new types of teas with a therapeutic and prophylactic effect, soft drinks, food dyes, and confectionery (M.S. Gins et al., 2017). Recipes for gluten-free bakery products have been created using introduced yacon, amaranth and daikon cultures. Technologies for selenium enrichment of vegetable crops for fresh consumption and as raw materials for functional products have been developed (N.A. Golubkina et al., 2018). The intellectual potential accumulated over a hundred-year history is inextricably linked with the traditions laid down at the experimental station. Nowadays the Federal Scientific Vegetable Center coordinates scientific research on the selection, production and processing of vegetable and melon crops in Russia within the framework of state programs for the development of the industry and ensuring food security.

Keywords: history, anniversary, research, varieties, vegetables, breeding, biotechnology, immunity, molecular marking, biochemistry, functional products

The century-old history of the Federal Scientific Vegetable Center began with the Gribovskaya Vegetable Experimental Station, organized on March 1, 1920 at the initiative of the People's Commissariat of Agriculture for the state production of garden seeds and eliminating the deficit resulting from the introduction of sanctions from a number of foreign countries. By 1920, the Russian catalog of zoned crops included 70 varieties of vegetable, of which 50 were registered for foreign companies, which prompted the solution to the problem and the creation of a nursery for varieties of garden plants. By 1970, scientists from the Gribovskaya Vegetable Experimental Station created 240 varieties of vegetables and melons used in practice. In Erfurt (Germany) in 1961 and 1969, varieties of Gribovskaya Vegetable Experimental Station received 18 gold, 13 silver and two bronze medals, 11 varieties of white cabbage (by E.M. Popova) were awarded the Grand Prix. By the decision of the State Committee of the Council of Ministers of the USSR for Science and Technology dated October 28, 1970 and by the order of the USSR Ministry of Agriculture dated November 23, 1970 No. 377, the Gribovskaya Vegetable Experimental Station was turned into the All-Union Research Institute of Vegetable Breeding and Seed Production (VNIISSOK), which became a methodological center of fundamental and applied research in this area, with special attention paid to the organization of seed production and raising a high-quality elite. In 2017, after joining VNIISSOK eight branches, the Federal Scientific Vegetable Center was created as the coordinator of consolidated research on breeding, production and processing of vegetables and melons in Russia within the framework of state programs for the development of the industry and ensuring food security.

The stages of development of domestic selection and seed production of vegetable crops can be traced through the history of the Gribovskaya station, methods of work, the creation of unique varieties.

To start with, foreign varieties were multiplied in order to provide the country with seed material, however, due to the lack of initial samples or their inconsistency with varietal requirements, it became necessary to create new domestic varieties of vegetables. In this, agronomic and morphological features, varietal characteristics and their correlations were studied. A method to reveal early ripening variants by determining the growth rate of cabbage head was developed based on the correlations revealed in white cabbage. Correlations between early maturity and the proximity of female flowers to cotyledon leaves allowed accelerated selection of pumpkin crops. Analysis of trait dominance in vegetable peas provided identification of appropriate parents for crossing and selection of hybrid forms with desired characteristics given trait dominance, expected segregation, and the economic value of the parents. The used selection methods were continuous mass selection, individual selection using the method of halves for pumpkin, family selection with assessment by offspring, pure-linear selection for legumes, group selection for solanaceous, negative selection for flower varieties, clonal selection in vegetatively propagated crops, e.g. tarragon, rhubarb, selection from the population. Refractometers were used in breeding for increased dry matter content in cell sap, calipers were used to measure fruit diameter, and a weight method was applied for determining plant productivity. As worldwide, induced mutagenesis and distant hybridization were conducted in order to enrich the gene pool of cultivated plants [1].

The first interspecific onion hybrids were obtained in the USA in the 1930s [2], and in Russia A.A. Krivenko made the first crosses in 1936 [1]. Crossing *Allium cepa* L. with perennial onion *species A. altaicum* Pall., *A. fistulosum* L., *A. vavilovii* Popov & Vved. generated original interspecific hybrids with high resistance to peronosporosis. For the first time in breeding and genetic investigation of interspecific hybridization in the genus *Allium* L., the fertile hybrids between di- and tetraploid species were created, *A. cepa* L. (×2) × *A. nutans* L. (×4) and *A. cepa* L. (×2) × *A. schoenoprasum* L. (×4) [3]. Interspecific onion hybrids were used to create varieties Sigma, Zolotye Kupola, and Tseparius with low damage caused by downy mildew and a high yield [4]. At present, studies of interspecific onion hybrids continue both in Russia and abroad [5, 6]. The world practice of onion breeding shows that the use of *A. roylei* Stearn, *A. galanthum* Kar. & Kir., *A. vavilovii* Popov & Vved. is advisable to obtain new forms resistant to downy mildew, neck rot [7] and *Fusarium oxysporum* f. sp. *cepae* [8].

The creation and characterization of interspecific hybrids involves cytogenetic studies, which were started in 1931 to obtain cabbage and tomato polyploids [1]. Currently, fluorescent genomic in situ hybridization (GISH) and fluorescence in situ hybridization (FISH) are used to determine the degree of proximity of samples and predict a successful distant hybridization [9, 10].

In addition to distant hybridization, intervarietal crosses were used. Selection of parents from geographically and ecologically remote regions was widely used for breeding pumpkin crops, e.g., the cucumber variety Izyashchnyi, melon variety Gruntovaya Gribovskaya 149, watermelon variety Gribovskiy dlinnopetistyi, pumpkin variety Gribovskaya zimnyaya [1]. In addition to common methods of selection and pair-crosses, complex stepped backcrosses are currently used with an emphasis on the female type of flowering and selection under infectious load. Cucumber (*Cucumis sativus* L.) varieties and hybrids with group resistance to four or five diseases and adaptability to abiotic environmental factors, e.g. the Aquarius, Electron 2, Unity, F_1 Debyut, F_1 Krepysh, F_1 Bryunet, F_1 Krasotka, bush variety Korotyshka, etc., are widely grown in field conditions [11]. Unique varieties and hybrids of large-fruited pumpkin (*Cucurbita maxima* Duchesne) have been created, e.g. ultra-early maturing variety Vesnushka, early maturing varieties Ulybka, Konfetka, Olga with splendid taste quality; mid-season fruitful variety Rossiyanka; late ripening varieties Premiera, Gribovskaya zimnyaya and Moskvichka with a high content of dry matter and sugars. The last three varieties create a continuous consumption conveyor, and even in the conditions of the Moscow region can be grown by sowing seeds in open ground at the end of May [12].

New complex crossbreeding schemes involving varieties of local breeding and geographically distant foreign origin have been successfully used for legumes. In 1949, from the hybrid population of vegetable peas (*Pisum sativum* L.), a form with all leaflets transformed into tendrils was selected for the first time, and cultivar Usatyi 5 was created, which was involved in creation of the initial material and varieties resistant to lodging. Based on the developed methods for the selection of parents, modern pea varieties with an optimal combination of productive parameters were obtained, e.g., with canned green seeds, characterized by high yields, top-positioned beans and a slow transition of sugar into starch (varieties Sovinter 1, Fragment, Izumrud, Darunok, Viking, Barin, Korsar), and sugar peas without a parchment layer in the bean shells for fresh consumption (Neistoshchimyi 195, Sakhaenyi 2, Gigant) [13]. In addition, high-quality varieties of *Phaseolus vulgaris* L. Zolushka, Pagoda, Lika, Mriya, Antoshka, Svetlyachok have been created, as well as *Vicia faba* L. var. *major* Harz variety Russkie belye with light seeds, high protein content, resistance to diseases, and suitable for mechanized cultivation technologies have been created [15].

Back in the 1930s, breeders were tasked with creating annual onion varieties throw sowing seeds in the ground. This task remains relevant nowadays. For growing from seeds, high-yielding varieties have been created that can form a harvest of marketable bulbs not only in the southern regions, but also in the Non-Black Earth Zone of Russia. These varieties are Chernyi Prints, Globus, Zolotnichok, Zolotye Kupola, Kolobok, Patryda, and Vermeles [16]. Intensive breeding is underway to create heterotic hybrids based on cytoplasmic male sterility (CMS). Using sterile lines, a number of heterotic hybrids have been created, including F_1 Vizit possessing high marketability, maturity, bulb yield, and disease resistance [17].

Hybridization method were also used to create cosmopolitan cabbage varieties Iyun'skaya 3200, Podarok 2500, Zimnyaya Gribovskaya 2176, Slava Gribovskaya 231, Slava 1305, Nomer pervyi Gribovskiy 147, Stakhanovka 1315, Amager 611 [1]. Almost the entire assortment of *Brassica oleracea* L. convar. *capitata* (L.) Alef. var. *alba* DC from the Gribovskaya station and the All-Russian Research Institute of vegetable breeding and seed production (VNIISSOK), zoned more than half a century ago, comprises a unique gene pool for creation of new heterotic hybrids and varieties. Thus, heterotic hybrids F_1 Aurora, F_1 Snezhinka, F_1 Zarnitsa, F_1 Mechta, F_1 Severyanka were obtained, which make a conveyor of fresh products for consumers [18].

At the dawn of the selection of table root crops, free pollination was the main method of hybridization. Using polycross-pollination of a group of samples, varieties of table beet (*Beta vulgaris* L. ssp. *vulgaris* var. *conditiva* Alef.) Bordo 237, carrots (*Daucus carota* L.) Nantes 4, radish (*Raphanus sativus* L. var. *sativus*) Teplichnyi Gribovsky and Soffit were produced [1]. By the method of paired crosses, i.e. a kind of free pollination of two parents, direct and reverse, the carrot variety Moscovskaya zimnyaya A-515 was obtained. Intra-family crossing and crossbreeding within groups were used to obtain monogerm forms of table beet (Bordo odnosemyannaya, Lyubava, Gaspadynya). In recent years, inbreeding, backcrossing and crossbreeding have become the main methods for creating lines. The sib cross method is used to overcome inbred depression [19].

Over time, the requirements for the varieties have changed. The need arose to obtain varieties and hybrids with modified biological properties. The scope of the study was biochemical features and chemical composition of plants, e.g. concentration of carbohydrates in green peas, protein in vegetable beans, ascorbic acid in large-leaved sorrel *Rumex acetosa* L., watercress *Lepidium sativum* L., in the leaves of Brussel cabbage *Brassica oleracea* L. var. *gemmifera* Zenker and Savoy cabbage *Brassica oleracea* L. convar. *capitata* (L.) Alef. var. *sabauda* L. [20]. Adverse conditions due to technogenic factors create a special need for these products, since vegetables are considered as a necessary product for normal human life. In recent years, functional food products containing components that have a positive effect on the physiological functions of a person have become widespread in Japan and the EU countries [21-23].

The world market of functional products is intensively developing, annually increasing by 15-20%, which reflects the modern trend to healthy and balanced nutrition. Japan remains the leader in the functional food market with about 40% of the global product, the second place is occupied by the United States with slightly more than 30%, and the share of European countries is less than 30% [24, 25]. The creation of functional food products is focused on obtaining varieties with an increased content of carotenoids, flavonoids and other bioactive components [26-28].

In Russia, breeding for a high content of biologically active compounds, including antioxidants and micronutrients, is also being successfully carried out. The required product quality is achieved through regular assessment of biochemical parameters during breeding [29]. These studies result in functional products aimed to boost immunity and to increase human life expectancy. Technologies have been developed for the production of new types of tea with therapeutic and prophylactic properties, soft drinks, food dyes and confectionery products, including for diabetics. Formulations of gluten-free bakery products have been created using yacon, amaranth and daikon varieties [30]. Technologies for enriching vegetable crops with selenium for fresh consumption and use as raw materials for functional products have been developed [31-34].

Research on immunity and plant protection has always been a priority. The study began with the most harmful pathogens and the methodology of the assessment of plant resistance [1]. Nowadays, the plant immunity and protection are acquiring special relevance. In the world, millions of tons of vegetable products are annually lost due to various epiphytoties [35]. Monitoring of the pathogenic complex on agricultural crops over the past 10-15 years indicates an expansion of the areas of new harmful pathogens, a change in abundance populations of plant pathogens, the nature and size of the ecological niches they occupy, a change in dominant species in communities, an increase in virulence. and aggressiveness of previously low-pathogenic organisms [36, 37].

The population changes are largely associated with environmental factors that affect relationships in the pathogen—plant system [38, 39]. Fungal pathogens *Sclerotinia nivalis*, *Gleocladium roseum*, *Trichotecium roseum*, *Chaetomium* spp., *Typhula ishikariensis* were for the first time discovered on the roots of canteen carrots during storage. An increase in the prevalence and aggressiveness of *Pectobacterium carotovora* was detected. In recent years, the species composition of micromycetes of the genus *Fusarium* has expanded on vegetable crops in the Moscow region. Many of these causative agents of fusarium rot and wilting are thermophilic species and have not previously been found in this region. *F. oxysporum*, *F. avenacium*, *F. nivale*, *F. chlamidosporum*, *F. solani*, *F. culmorum*, and *F. semitectum* have been identified on winter garlic; *F. chlamidosporum*, *F. equiseti*, *F. proliferatum* were found on dining carrots [40]. *Aspergillus niger*, a new pathogen for the Central Russia identified on onions causes black mold by the end of the growing season and during storage [41, 42]. *Typhula ishikariensis* was isolated from beet roots, and *Drechslera* Bondartseva from radish seeds [43].

Recently, the epiphytoties of phytoviruses are mainly due to more aggressive new strains, the cultivation of varieties with poor resistance, uncontrolled trade in planting and seed material, the emergence of new vectors and insufficient combating them [44, 45]. In recent years, the harmfulness of phytoviruses for vegetable crops has been increasing, which leads to a decrease in the productivity and quality of vegetable crops. Therefore, the identification and study of viruses and viral diseases on vegetable crops remain relevant in immunological research.

On lettuce plants (*Lactuca sativa* L.), harmful infections of *Lettuce mosaic virus* (LMV, *Potyvirus*, *Potyviridae*) and *Tomato aspermy virus* (AsTV, *Cucumovirus*, *Bromoviridae*) was identified [46]. In the Moscow region, *Bean common mosaic virus* (BCMV, *Potyvirus*, *Potyviridae*), *Bean yellow mosaic virus* (BYMV, *Potyvirus*, *Potyviridae*), and *Pea mosaic virus* (PMV, *Potyvirus*, *Potyviridae*) cause great damage to *Fabaceae* crops (beans, sweet peas) [47]. Immunodiagnostic methods detected the most harmful and economically important *Tobacco mosaic virus* (TMV, *Tobamovirus*, *Virgaviridae*), *Tomato spotted wilt virus* (TSWV, *Tospovirus*, *Bunyaviridae*), *Cucumber mosaic virus* (CMV, *Cucumovirus*, *Bromoviridae*), *Potato virus X* (PVX, *Potexvirus*, *Alphaflexiviridae*), *Potato virus Y* (PVY, *Potyvirus*, *Potyviridae*), and *Alfalfa mosaic virus* (AMV, *Alfamovirus*, *Bromoviridae*) infecting *Solanaceae* plants (sweet pepper and tomato) [48, 49]. The methods used to isolate and select disease-resistant forms are constantly being modified depending on the biological characteristics of host plants and phytopathogens within the framework of targeted breeding. Particular attention is paid to the development of express methods of detection at early stages of plant development, in seeds and seedlings. The use of etiolated and photosynthetic seedlings allows screening of a wide range of genetically diverse samples [40, 50, 51]. A methodical approach is suggested to assessing the resistance of white cabbage to *Xanthomonas campestris* pv. *campestris* using etiolated and photosynthetic seedlings. The influence of this pathogen on plant growth were studied depending on the race composition of the pathogen and the cultivar resistance [52].

Immunological, molecular, and morphophysiological assessments of the collection and breeding material upon artificial infection, provocative conditions and natural infection revealed the sources of resistance to economically significant diseases, e.g., in cabbage to keel [53], in beetroot to cercosporosis [54], in vegetable beans to viral diseases [47], and onions to downy mildew [4].

Wide experimental network in various geographic zones (Russia, Ukraine, Turkmenistan, Uzbekistan, Azerbaijan) provide conditions to reproduce high-quality elite seeds in various soil and climatic conditions. Since the 1970s, ecological studies have been aimed at increasing the role of the variety in the genotype-environment system, which has become the main method for obtaining plastic and high adaptive varieties [55]. Mechanized technologies for seed production, small-scale mechanization, methods of economic evaluation in seed production and plant breeding were developed. The range of crops expanded to involve green, spicy-flavoring and less widespread crops (110 items in total).

Nowadays, the expansion of the spectrum of genetic resources and the enhancement of the morphogenesis are the most important to obtain a fundamentally new source material. At the Federal Scientific Vegetable Center (FSVC), a rich indicative collection has been created, numbering more than 16 thousand accessions of 120 cultures. In 2017, the collection was registered as USI (unique scientific installation) Genetic collection of plant resources VNIISSOK. In the collection, there are varieties of vegetables, melons and flowers, breeding forms used as genetic sources and donors of selectively valuable traits, as well as folk varieties.

To speed up the breeding, the development and application of innovative methods is of no small importance. Since the late 1980s, in vitro tissue and cell culture technologies has been actively using by the FRCVG researchers. First studies were aimed at obtaining a virus-free planting material for garlic in a meristem culture. A.V. Polyakov and colleagues found that the use of air bulbs isolated from unopened inflorescences up to 25 mm in diameter to produce winter garlic in vitro culture makes it possible to obtain plants free from internal infection [56]. The technology of clonal micropropagation of white cabbage was developed to unlimitedly obtain plants with male sterility [57]. The developed technology of clonal micropropagation of eggplant (*Solanum melongena* L.) and pepper (*Capsicum annuum* L.) [58] formed the basis of embryoculture for the rescue of embryos during interspecific hybridization [59].

Since the discovery of the first haploids in 1922 [60], many geneticists and plant breeders have become interested in using such haploids to obtain homozygous lines. To date, almost 300 varieties of agricultural crops have been created in world practice via haploid biotechnology. The list of species in which haploids and doubled haploids (DH) are obtained is constantly lengthening, new review publications on haploidy appear, genetic and fundamental studies are carried out on DH lines, new varieties and hybrids are created based on lines of doubled haploids, including vegetable crops [61-65]. At VNIISSOK, the methods of haploidy began to develop in the 1990s on carrots and white-headed cabbage. As a result, doubled haploids of carrot varieties of various origins were obtained, e.g. NIIOH 336, Vitaminnaya, Moskovskaya Zimnyaya A-515, Losinoostrovskaya 13, Leandr, Shantane 2461, Nape, Rondo, hybrids F_1 Karatan, F_1 Calisto [66].

The developed innovative biotechnologies make it possible to significantly accelerate breeding for most vegetable crops. The basic protocol for doubled haploid technology based on the in vitro culture of isolated microspores was developed in the early 1980s [67] for rapeseed and adapted for genus *Brassica* [68, 69]. A success of the protocol is reported by scientists from India [70], Canada [71], Czech Republic [72]. A basic protocol for in vitro microspore culture for cabbage crops has been developed at the FRCVG [73], and doubled haploids have been obtained, including white cabbage [74, 75], broccoli cabbage *Brassica oleracea* L. convar. *botrytis* (L.) Alef. var. *cymosa* Duch. [76, 77], turnip [78], purple cabbage *Brassica rapa* L. ssp. *chinensis* (L.) Hanelt var. *purpuraria* (L.H. Bailey) Hanelt [79], Sarepta mustard *Brassica juncea* (L.) Czern., Indau *Eruca sativa* Mil. [80], and even the most unresponsive culture in this family, the European radish [81].

Research on generating carrot doubled haploids has been going on for a long time, but the first successes have been achieved recently. Back in 1995, the formation of multinucleated structures in the culture of isolated carrot microspores was reported for the first time, but no plants were obtained [82]. There are publications on the use of this approach by Polish [83] and Chinese [84] researchers. At the FRCVG, a technology was developed for the production of doubled haploids of table carrots in in vitro cultures of anther, non-pollinated ovules and microspores, resulting in doubled haploids for eight varieties [85]. Calculation of the cost for pure lines of white cabbage [86] and table carrots [87] proved the economic benefit of the method of isolated microspores in vitro when creating hybrids. The time to obtain hybrids is reduced from 12 to 6 years, and financial costs are halved.

Experiments are underway to optimize production of doubled haploids in in vitro culture of non-pollinated ovules for pumpkin crops. DH plants of large-fruited pumpkin have been obtained [88]. Considerable progress has been achieved for homozygous zucchini [89] and cucumber [90] lines. The basic protocol for production of doubled haploids of pumpkin crops via in vitro culture of non-pollinated ovules was developed in the second half of the 20th century but patented only in 2017 [91]. Over time, it was adapted for various members of *Cucurbitaceae* family [92, 93], in particular for squash (*Cucurbita pepo* L.), large-fruited and hard pumpkin [94], and cucumber [95]. It was shown that the in vitro non-pollinated ovule-based doubled haploid technologies for pumpkin crops developed at the FRCVG are more effective compared to foreign analogues, since the number of regenerants per ovary was greater than indicated in foreign publications. For the first time, the formation of ugly abnormal flowers was discovered in the progeny of DH lines derived from in vitro culture of non-pollinated ovules [96], which is of interest for genetic studies of sex determinants in *Cucurbita pepo* L. Cytological analysis of R_0 regenerant plants showed that 7% were haploids, about 20% were mixoploids, and the rest were doubled haploids ($2n = 2\times = 40$). For the first time, micrographs were obtained of the chromosomes of the squash *C. pepo* subsp. *brevicaulis* var. *giraumons* Duch, its distant hybrid with *C. pepo* subsp. *pepo* var. *pepo*, and their doubled haploids [97].

At the FRCVG, the molecular marker technologies have been actively developing since the 1990s [98]. At present, molecular markers are the main method to produce CMS-based hybrids of vegetable crops. A system has been developed for DNA identification of all types of cytoplasm in cabbage crops with a new allelic variant of the *orf138* locus responsible for sterile cytoplasm of the Ogura type in white cabbage [99].

The mitochondrial genes *coxII* and a*tp6* responsible for the CMS, have been identified in sweet pepper and interspecific hybrids of *Capsicum frutescens* and *C. chinense*, which makes it possible to identify samples with sterile and fertile cytoplasm [100]. Samples of onions with mitochondrial genes *orfA501* and *cob* were identified, and the type of sterile cytoplasm (S- or T-plasmotype) was determined [101]. Additional markers were used for detection of cytoplasmic gene *orf725* and nuclear genes to more fully assess the initial material of onion, which revealed the samples suitable for hybridization [102].

Using modern breeding methods, heterosis hybrids of pepper F_1 Natali, F_1 Gusar [100], medium late cabbage F_1 Natali [74], large-fruited pumpkin F_1 Vega [103], and broccoli cabbage F_1 Sparta [104] were created.

Thus, the breeding of vegetable crops in Russia went through several stages: introduction, the use of various methods of selection among local and foreign populations, the production of new varieties by crossing species and genera, the use of biotechnology and molecular markers to quickly achieve the final result. A century after its founding, the Federal Scientific Vegetable Center remains the leader in the Russian Federation in creating vegetable varieties and hybrids for open ground and greenhouses, hydroponic and aeroponic installations in combination with growing technologies, fertilization and plant protection protocols in line with the world trends. Innovative solutions are being developed for obtaining functional food products. The Federal Scientific Vegetable Center coordinates research on the breeding, production and processing of vegetable and melon crops in Russia within the framework of state programs for the development of the industry and ensuring food security.

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