Forefront of Crop Science Research in Krasnodar: All-Russian Research Institute of Oil Crops by the name of V.S. Pustovoit (FGBNU VNIIMK), Russian Academy of Agricultural Sciences

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Summary

All-Russian Research Institute of Oil Crops by the name of V.S. Pustovoit is the leading oil crop research State Scientific Institution and one of the longest-running agricultural research institutions of the Russian Federation. It has been at the forefront of crop science for more than 105 years and made a significant impact on the global breeding science. This paper presented a research network, organizational structure, an overview of scientific activity and practical work of the Institute. Special attention was paid to the soybean breeding research of the Institute in the context of soybean production development in Krasnodar region and Russia in general.

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Key words : Krasnodar, oil crops, crop science research, soybean breeding, seed production

Introduction

Soybeans (*Glycine max*) serve not only as an oil seed crop, valuable feed for livestock and aquaculture but also as a good source of protein for the human diet. Therefore it is one of the most globalized, traded and processed crop commodities and demand for it is expected to grow instantly. USA, Argentina and Brazil continue to be the top three producers and exporters of soybean and soymeal (USDA, 2017).

Russian soy-industry is yet on its way to make a mark in the national and global arena. Russian agricultural crop production has undergone unprecedented changes both in the intensification of technologies and expansion of cultivated area. As a result, second-year through total grain crops brake historical maximum and are reported to reach 134.1 million tons. Soybean production also hits record of 3.6 million tons (plus 14.1% to 2016 year) (IKAR, 2018).

The Russian government has made it a priority to ensure food security for the nation by increasing the number of agricultural products produced in Russia. Domestic demand for soybeans continues to grow with Russia's focus on development of the livestock, poultry and aquaculture sectors. Rapidly evolving soybean-processing facilities excess short domestic supply. APK Inform estimates soybean import for the season 2017/18 to be 1,8 million tons (APK Inform, 2017). While production of such soybean products as protein isolates, soymeal, oil and some other derivatives is promoted by the industry demand, the use of soy for health and nutrition purposes requires stimulating (Petibskaya, 2012). Conditions of soybean farming and soy-related industry could be further improved.

Today in Russia there is an informational deficit in the field of soybean production. Therefore, it is necessary to address the problem in order to fulfill the need for knowledge, skills, and technologies, as well as for the quality seeds of the Russian agricultural producers and of the foreign stakeholders, potential investors and researchers. Present paper aims at informing prospective producers about the research carried out in the field of oil crops and specificly soybean-related production, and the network of the scientific organizations for possible cooperation.

Since the international and domestic demand for high-quality protein, both for people and livestock is growing unprecedentedly, it is essential for the Russian scientific institutions to be able to provide the expanding soybean and soyfood production industry with high-quality materials (seeds) and appropriate agrotechnological know-how. North Caucasus region of the Russian Federation has tremendous comparative advantages in agricultural production, with some of the world's best land for arable farming and long agricultural traditions. We found it necessary to present All-Russian Research Institute of Oil Crops by the name of V.S. Pustovoit (FGBNU VNIIMK) - the main oil crop state

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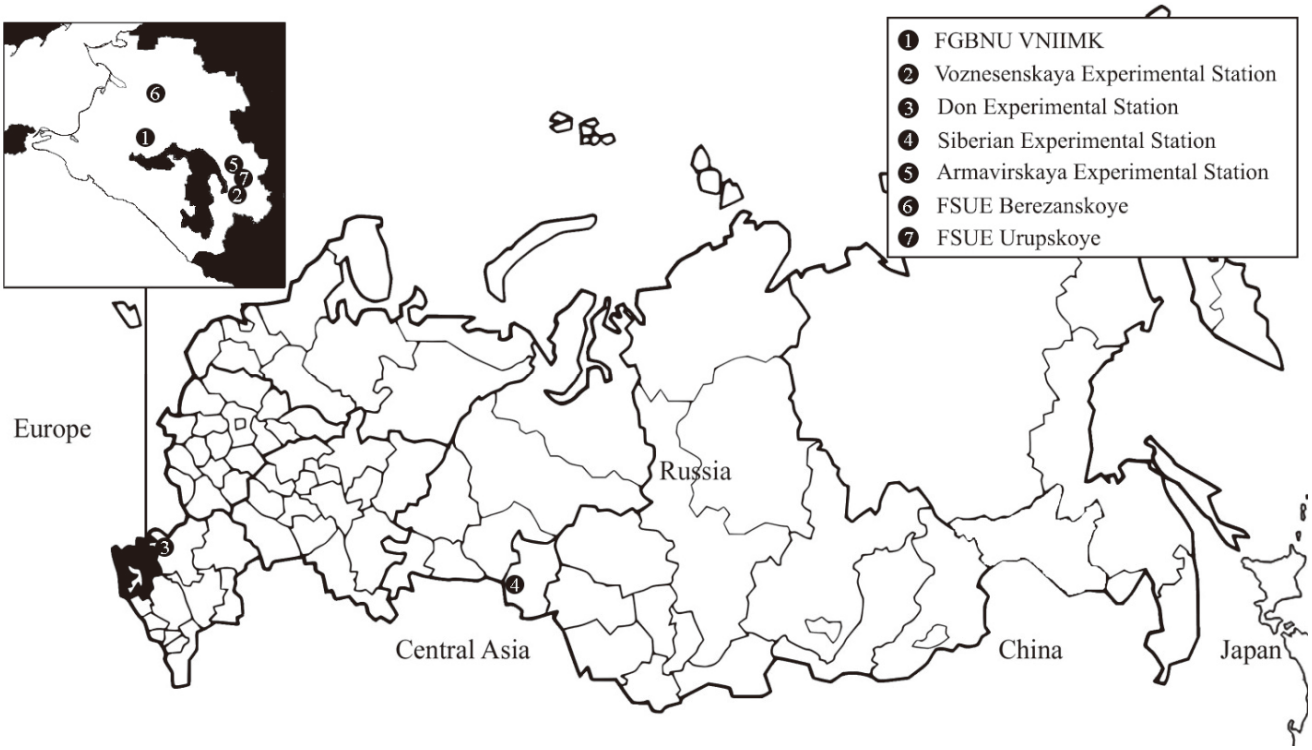

Fig 1. Organizational-Scientific Network of FGBNU VNIIMK

scientific institution of Russian Federation.

Information basis for the article was constituted by the official data of Federal State Statistics Service of the Russian Federation and The State Register of Breeding Achievements Approved for Utilization; official site and publications of FGBNU VNIIMK, interview with the head of the VNIIMK Soybean department, Dr. Sergey Zelentsov; and study of relevant literature.

History, structure and research outline of VNIIMK

VNIIMK was founded in 1912 in Krasnodar. The history of the Institute started when "Kruglik," an experimental breeding field was established under the Kuban military and agricultural school. VNIIMK became one of the first experimental organizations specializing in field crops in the south of Russia with sunflower (*Helianthus annuus L.*) being the primary scientific focus.

Vasily Stepanovich Pustovoit after whom the Insitute took its name was a prominent scientist and an outstanding breeder of oil crops. Academician V.S. Pustovoit headed the Department of Selective Breeding and Seed Growing of Oil Crops, and the laboratory of Sunflower Breeding from 1935 until his death in 1972 (VNIIMK, 2018). It was on account of his work that sunflower became an essential technical crop, at first in the USSR, and later in the countries around the world. V. S. Pustovoit made a significant contribution to the development of fundamentally new methods of sunflower breeding and seed production (Vear, 2016). For example, the technique of multiple individual selection from strains and intervarietal hybrids assessed for their offspring quality with the subsequent induced and regulated transpollination of the best numbers helped to create sunflower varieties resistant to pests and diseases, rich in oil content and able to give high yields (ISA, 2018). Pustovoit succeeded in increasing oil content in sunflower seeds from 28-32% to 50-53% (VNIIMK, 2018).

At present, the All-Russian Research Institute of Oil Crops includes a central experimental station, two federal state unitary enterprises (FSUE) "Berezanskoe" and "Urupskoe", a "Voznesenskaya" branch, and three experimental stations: Armavirskaya, Don, and Siberian (Figure 1). The Institute has an area of 35.0 thousand ha, 33.8 thousand ha of which is arable land.

The staff of VNIIMK and its subordinate organizations consists of 929 people, with 350 specialists working in the scientific sphere, including 22 Doctors of Sciences and 66 Candidates of Sciences.

The priority areas of research are oil crops breeding and seed growing, increasing the efficiency of management practices and production equipment production, development of machinery for cultivation, harvesting and post-harvest processing of oil crops and their seeds.

170 varieties and hybrids of oil seed crops bred by scientists of VNIIMK are registered in The State Register of Breeding Achievements Approved for Utilization (2016); the varieties are adapted to climatic conditions from the North Caucasus to the East Siberian region.

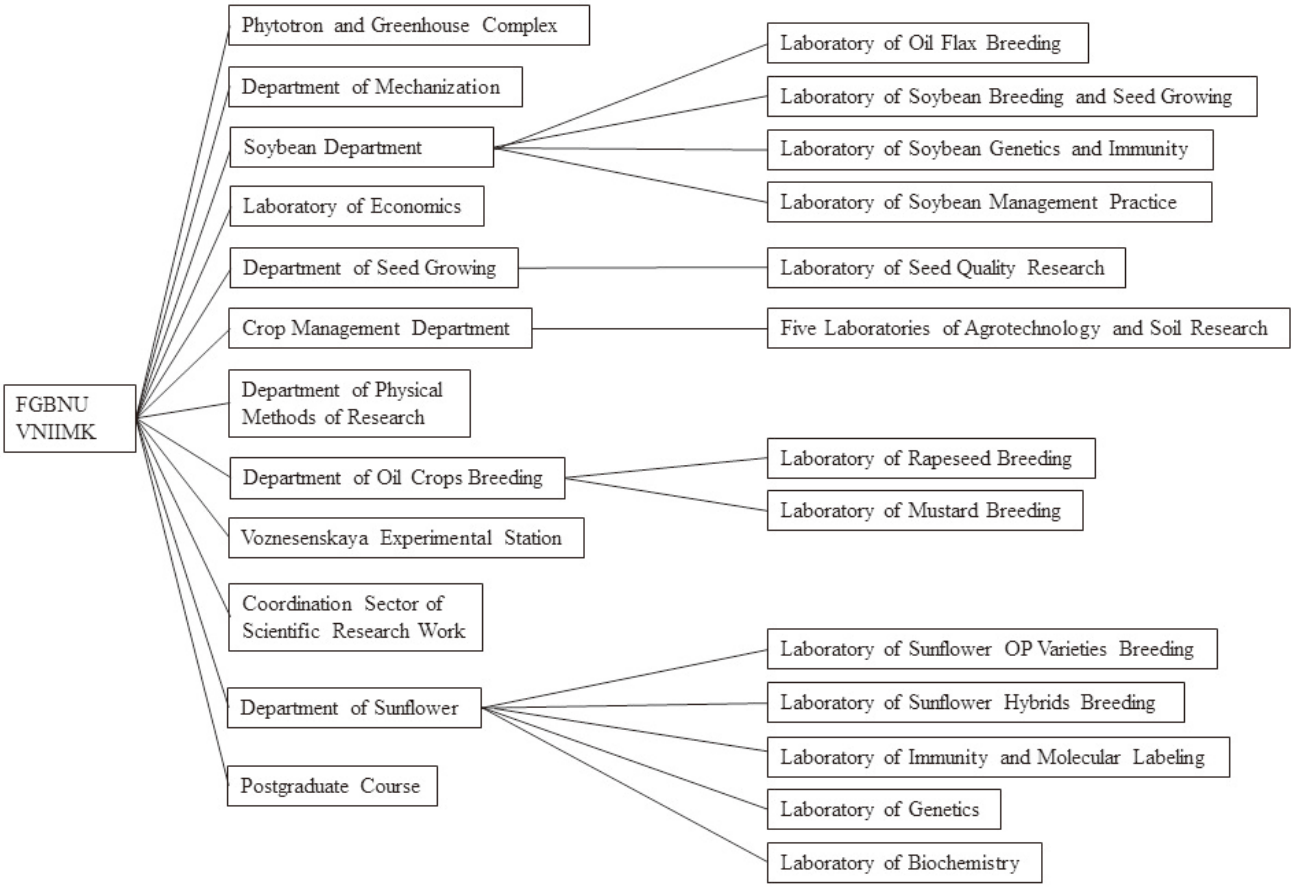

Fig 2. Structure of FGBNU VNIIMK

Organizational structure and scientific network of FGBNU VNIIMK

Complex scientific network and organizational structure of VNIIMK reflects the long history of the institution. (Figure 2).

Department of Sunflower

Department of sunflower was established in 2014 and consists of five laboratories: laboratory of sunflower selective breeding, laboratory of sunflower hybrids breeding, laboratory of immunity and molecular labeling, laboratory of genetics and laboratory of biochemistry.

In 1976, a prominent scientist, Soldatov bred Pervenets, a sunflower variety with the fatty acid composition of oil, similar to the olive oil. The creation of Pervenets stimulated a shift from quantity and originated breeding of varieties for oil quality in all foreign countries that were cultivating sunflower (Vear, 2016). One of the latest achievements of the Institute is a sunflower hybrid Oxy with an increased level of oleic acid in oil - up to 90%, with the content of natural antioxidants gamma and delta-tocopherols. The seed oil of Oxy is 14 times more resistant to oxidation, which makes it an essential product for the food industry (Demurin et al., 1996 and Kochegura, 2012).

Department of Oil Crops Breeding

The Department was formed in April, 2002. It consists of two laboratories specializing in rapeseed and mustard breeding. The work of the Department is focused on breeding and seed growing of such varieties as winter and spring rapeseed (*Brassica napus*), turnip rapeseed, mustard (*Brassica juncea*), and white mustard and black mustard. More than 90% of total Russia's mustard area is covered by cultivars of VNIIMK breeding (VNIIMK, 2017).

Department of Seed Growing

The Seed Growing Department was established in 1960 at the initiative of V.S. Pustovoit. The work of the Department is concentrated on the seed growing of all oil crops, and developing technical requirements for the Russian Federation State Standards.

The laboratory of seed quality research is a subdivision of the Department, which controls and ensures high quality of produced seeds.

The Institute produces about 100 varieties of commercial seeds, among which are 53 sunflower hybrid varieties. The total volume of certified seed production amounts to 10-13 thousand tons per year (VNIIMK, 2017).

Table 1. Postgraduate Training in the All-Russian Research Institute of Oil Crops

Code	Field	Specialization
35.06.01	Agriculture	General Agriculture, plant growing; Agricultural chemistry; Plant breeding and seed growing; Phytopathology and plant protection
35.06.04	Technologies and methodology of agricultural mechanization; Power equipment for agriculture, forestry and fishery	Technologies and methodology of agricultural mechanization
38.06.01	Economics	Economics and national economy management

(Source: VNIIMK, 2018)

Crop Management Department

When first established the main focus of studies conducted by the Department was different factors influencing sunflower yield, e.g., sowing dates and plant density. Since 1930, the research expanded to cover such subjects as soil moisture, fertilizers, their forms and doses for sunflower, castor, and peanut, inoculation of soybean on crops yield, as well as mechanization of sowing, treatment and harvesting of oil crops.

Another principal activity of the Department includes training agrarian specialists; consulting and providing agricultural enterprises with scientific and practical help on the proper usage of management practices of oil crops.

Department of Physical Methods of Research

The Department carries out research on the methods and tools for nondestructive quality control of oil crop seeds and their processing products, on the means of metrological supplying, and on the development of express instrumental methods and devices for protein content determination.

Scientific research on the creation of nuclear magnetic resonance express-analyzer (NMR-analyzer) of oil and moisture content in oil crop seeds has been conducted since the beginning of 1973. The specialists of the Department of Physical Methods of Research released several generations of prototypes, which were approved by the state standardization committee and put to production.

In 1998, a modernized model of an analyzer AMV-1006M, was developed in collaboration with the Ural Scientific Research Institute of Metrology. At present, more than 85% of the oil produced in Russia is evaluated and quality-controlled on the NMR-analyzers AMV-1006M (Prudnikov, 2015).

Postgraduate Course

VNIIMK has a long tradition of providing postgraduate education and offers Ph.D. training in three scientific areas (Table 1).

Department of Soybean

Scientific research on soybeans in the Institute started with a soybean breeding laboratory establishing in 1957. Department of Soybean, an integrated scientific division, was organized in 1977. At present, it consists of the laboratory of soybean breeding and seed growing, the laboratory of soybean genetics and immunity, and the laboratory of soybean management practice (Figure 2). In 2001 research on cytogenetics, classical and evolutionary genetics of soybean started by the laboratory of genetics and immunity. Research is developed by traditional breeding methods (non-transgenic) on a base of the best domestic and foreign breeding achievements. The effectiveness of conducted scientific research resulted in the attachment of the oil flax breeding laboratory to the Department of Soybean in 2011.

At present, the staff of the Department of Soybean comprises 18 specialists, including one doctor of agricultural sciences and six candidates of biological and agricultural sciences.

Productive work enabled the Department to take one of the leading positions in the European part of Russia and the CIS countries. While in 2015, 47 varieties of soybean by domestic and foreign originators were cultivated in Krasnodar region, 51% of the total sowing area of 167.7 thousand hectares under soybean were occupied by cultivars of VNIIMK breeding (Zaitsev et al., 2016).

VNIIMK self-estimates its position as similar to the role of All-Russian Scientific Research Institute of Soybean located in the city of Blagoveshchensk (Amur Region) in the Asian part of Russia (VNIIMK, 2018).

The Department of Soybean has been actively engaged in international activities. Scientists from various scientific institutions of the Republic of Belarus, Kazakhstan, Uzbekistan, and Ukraine have completed internships in the Soybean Department. The staff of the Department has contributed to the development and increase of the economic efficiency of the national soybean production in Iran (Zaitsev et al., 2016). They successfully adapted technologies to the semi-desert conditions of the country, trained dozens of

Iranian specialists and graduates of Iranian agricultural universities using Kuban methods of soybean breeding. The Soybean Department has also interacted with specialists from China, South Korea, Qatar, Algeria and Sudan in the field of soybean breeding.

Soybean Breeding Challenges and Achievements

Russia's agriculture depends on climatic fluctuations and changes to the maximum extent. Despite the fact Krasnodar region is supposed to provide the most favorable climatic conditions in Russian Federation, very often they are not optimal for soybean cultivation (Kochegura A., 2007). In the majority of the Southern and the North Caucasian regions, moistening conditions are optimal until the end of June, with July and August bringing late summer droughts. Cracks, up to one-meter depth can be seen on Kuban region fields (Figure 3).

Fields of industrial soybean in Russia can be found at latitudes 54-56 ° in the Tula, Ryazan, and Penza regions, in Chuvashia, Tatarstan and Mordovia. There is a successful experience of growing soybeans at a latitude of 60 ° in the Leningrad region, and also in conditions of partially permafrost soils of the Irkutsk and Tomsk regions (Petibskaya, 2012). Therefore, approach to the soybean cultivation in Russia is radically different from the western one (Zaitsev et al., 2016). While in the West breeders pursue a goal of maximizing the possible harvests of soybean varieties, in Russia, soybean crops are sought to be, above all, profitable even in unfavorable climatic conditions. This is explained by the fact that in Russia the climatic zones which can provide optimal heat and water resources to the agricultural crops similar to the North American or Western European occupy only about 0.7% of the total territory of the country (Zaitsev et al., 2016). Hence, one of the aims of the Russian selective breeding, as well as the Department of Soybean is to breed soybean varieties capable of withstanding prolonged droughts and low temperatures, rather than maximize crop yields.

Another goal established by the staff of the Soybean Department is to create a day-neutral (with reduced photoperiodic sensitivity) variety of soy (Kochegura et al., 2011). The classical approach to solving the problem is growing soybean at different latitudes. The Institute, for instance, studied a large number of the same soybean samples, in Krasnodar region (45 ° N), in Belgorod (50 ° N) and in Vologda (59 ° N) regions of Russia, as well as in Iran, from the northern coast of the Persian Gulf to the southern coast of the Caspian Sea at latitudes 29, 35 and 37 ° N. Although this method was very complicated and expensive to be carried out, it allowed to collect experimental data on soybean samples grown at different lengths of the day (Zaitsev et al., 2016).

Fig 3. Experimental field of VNIIMK on August 25, 2017.

Using computer technologies, specialists of the Department initially developed a mathematical algorithm, which enabled researchers to analyze formation patterns of certain commercially valuable traits, as well as to predict the reaction of new varieties to different environmental and geographical conditions. In particular, using specific biometric plant parameters from the extensive empirical data, this technology made possible to forecast the reaction of soybean varieties to the duration of the day, one of the most important factors directly affecting the crop yield. It allowed the researchers to increase the breeding efficiency of soybean varieties with a reduced photoperiodic sensitivity. For example, modern varieties of soy can be successfully cultivated at geographical latitudes from 38 to 52 °, in a wider range of ± 7 degrees, compared to the previous ± 3 degrees (Zaitsev et al., 2016).

Working on soybean stress resistance and adaptivity to the low level of precipitation (Kochegura and Miroshnichenko, 2007), researchers of VNIIMK showed that between the height of soybean plants and the depth of the central root there is a high positive correlation. This correlation predetermines the shallow root system undersized the determinant types of the bush, which is usual for the vast majority of foreign soybean varieties. It was concluded that the height of soybean plants for arid conditions of Kuban ideally should be up to one or more meters (Zelentsov et al., 2016). The ratio of the stem length to the length of the central root of soybeans is approximately 1/2.2, which means that at one meter of plant height the central root can penetrate the soil to a depth of 2.2 meters. Deep root allows a plant to access scarce moisture resources during summer droughts (Zaitsev et al., 2016). This valuable trait has been further implemented in the breeding activity (Figure 4).

Breeding for stable and high yields is also one of the essential activities of the Department. For example, the idea of fixing heterosis on the mulberry silkworm developed half a century ago by a famous Russian geneticist and breeder V. A. Strunnikov was implemented for the first time in the world practice for the breeding of soybean. It made possible to create varieties yielding up to 7 tons per hectare in experimental fields, and up to 5.7-6 tons per hectare in production conditions of Kuban farms (Lukomets et al., 2012).

One of the significant scientific achievements of the Department of Soybean of the All-Russian Institute of Oil

Fig 4. Dr. Zelentsov, Head of Soybean Department, with a high stem soybean variety sample.

Crops is the theory of polyploid recombination of the genome (Zelentsov, 2007). The discovery enabled the scientists independently reproduce mechanisms of the evolutionary morphogenesis in soybeans (Zelentsov et al., 2014) and purposefully widen a pool of valuable traits for selective breeding. New varieties have an increased sucking force of the roots, stronger drought resistance, and in addition, are more pathogen resistant (Kochegura, 2012). They are suitable for direct propagation in brief-field crop rotation (2–4-field) and even in monoculture. Maturing periods are divided to the extra early (90-100 days), early (102-110 days), mid-early (104-106 days) and mid-maturing (112-118 days) (VNIIMK, 2017).

The most famous varieties at present include Vilana and Slavia (Zelentsov et al., 2012).Vilana is a mid-maturing variety, bred using the technology of fixed heterosis. The variety combines drought resistance and sensitivity to moistening conditions and is a leader in Eurasia regarding productivity with the ability to yield up to 6 tons per hectare. Slavia, a highly productive early maturing soybean cultivar with a weak response to the day length, is the only plant in the world that can withstand low temperatures up to minus 5 ℃ during the seedling stage. At present, another high-yielding soybean cultivar Irbis is passing the State Variety Testing. Irbis can accumulate up to 45.8% of the protein in its seeds (Zaitsev et al., 2016).

Oil flax breeding

Oil flax breeding is a new, however promising area of research in the Department of Soybean. The strategic goal of including new culture in the department's work was to adapt and transfer theoretical developments of soybean to the practical breeding of oil flax. This strategy has confirmed its effectiveness in the form of creating unique varieties of oil flax (Zelentsov et al., 2017). In 2016 the Department handed over to the State Variety Testing the first flax seed variety in Russia and in the world, which has a reduced sensitivity to the length of the day.

Simultaneously, a huge unsolved problem of flax sickness of soil is addressed successfully. New flax lines resistant to flax sickness of soil were created. They are suitable for direct propagation and introduction into production as self-tolerant varieties for cultivation; both in brief-field (3–4 fields) crop rotations, and even in monoculture. These lines can also be used as sources of complex resistance to flax sickness of soil and Fusariosis in the breeding of oil and fiber flax varieties (Zelentsov et al., 2017). At present, 16 of total 33 flax seed varieties approved for utilization in Russian Federation, belong to VNIIMK breeding (Gossort, 2018).

Soybean varieties for food industry

VNIIMK works on the further improvement of soybean farming conditions and soy-related industries, and on promoting a positive role of the soy foods in human health and nutrition.

Since 1990, when Krasnodar region faced a soybean boom, marked by a rapid increase in soymilk and meal, tofu, okara, and other soyfood production, the Department has developed a new direction - breeding varieties with better organoleptic and biochemical characteristics (Petibskaya, 2012).

The dependence of variability of soybean chemical composition from biological characteristics of variety, natural and climatic conditions, and management practices of production have been reported. VNIIMK extensively studied and presented results on the chemical composition of soybean seeds from wild forms to the varieties of domestic and foreign breeding (Petibskaya, 2012). Depending on the chemical composition of seeds researchers distinguished three different purposes of soybeans use: oil production, livestock and poultry feed production and functional food production for the humans (Kochegura et al., 2005).

First in Russia, series of high-protein, low trypsin inhibitors food industry-oriented varieties including Fora, Delta, Vesta, Renta, Lakta and Valenta were registered by the State Register for the State Commission of the Russian Federation for Selection Achievements Test and Protection. This research allowed to distinguish lines of soybean with protein content up to 50% (Petibskaya, 2012). Since then these lines have been used in the purposeful breeding of high-yielding, high-protein food soybean varieties.

When pursuing food varieties the importance of such factors as seed color (yellow, with yellow hilum), the absence

of pigmentation and shell defects; size and good shape of every individual grain, high protein content, improved fractional and amino acid composition of the protein has been stressed by VNIIMK (Petibskaya, 2012). When selecting soybean varieties for animal feed, the primary attention is paid to plant height, resistance to lodging, tenderness of stems, high yield of seeds and green mass (Didorenko, 2013).

The main goals of the selective breeding work of the Department are to increase yield and ensure stable profit-safe harvests in various climatic conditions, by applying different methods and varying factors, e.g., resistance to drought and lower temperatures, decrease of the vegetation period, lowering photoperiodic sensitivity, resistance to dangerous pathogens, etc. The research on improving biochemical and technological characteristics of soybean include increasing protein content (protein fractions and amino acid balance), lowering of trypsin inhibitors content in seeds, overcoming the negative correlation between yield and protein content in the seeds, combining two and more characteristics within one variety (Zelentsov et al., 2016).

Implications

Soybean is a unique crop with high production plasticity. Profit-maximizing has never been a focus for soybean production in Russia, and soybean significant advantages is profitability even at a minimum yield of 0.8-1.0 ton per hectare (Petibskaya, 2012). However, market prices for soybean can significantly differ depending on the protein content, the intensity of cultivation technologies, uniformity of seeds, and other factors (USDA, 2017). Therefore, soybean producers are free to choose whether to continue an older extensive strategy or seek for a margin-oriented intensive one.

Over a very short period, a regional distribution map of soybean production changed drastically. Traditionally, most soybeans in Russia were produced in the Far East federal district, but over the past several years, the Central federal district has increased production up to 30% of Russia's total. For instance, Belgorod region rocketed production by 48.3% in a year and with 17.4% of the total production ranked second after the traditional leader, Amur region. All About Feed analytics (2017) point at low levels of crude protein content (around 30%) of the soybean cultivated in Central Region.

These soybeans are grown extensively; their quality cannot meet international standards. However, it has been a quick and timely response to the animal feed industry demand, and an increase in processing facilities. Therefore for a while, any quality will be accepted and welcomed by the market.

At the same time, a constant tendency of pursuing higher margins through orientation on more expensive high-protein soy cultivation can be seen. Those agrarians who chose narrower but more profitable niche are facing a necessity to shift to intensive agricultural technologies; use seeds of the highest propagation, apply proper agrochemicals. They face challenges of post-harvest storage and transportation. Agrarians are striving for innovative knowledge, practical experience, scientific advice and detailed recommendation both on appropriate variety choice, proper cultivation technologies, and mechanization.

We are sure that VNIIMK is precisely the institution which is capable of providing the market with expertise and safe, high-quality, high-yielding seeds. The first wave of purposeful breeding of high protein varieties in VNIIMK in 90th years found little support from just emerging soy food market and was gradually forced to lose its intensity. Both international and domestic demand for food soybean nowadays let us optimistic on the prospect of the soy-related industry.

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クラスノダール市における作物科学研究の最前線
―ロシア農業科学アカデミー全ロシアプストボイト油糧作物研究所―

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（平成30年１月19日受付）

要　約

全ロシアプストボイト油糧作物研究所は油糧作物研究における主要な国家科学機関であり、ロシア連邦で最も長い歴史を持つ農業研究機関の一つである。105年以上にわたり作物科学の最前線で活動を続け、品種改良・育種学に大きな貢献を果たしてきた。本稿では、まず研究所の研究ネットワーク、組織構造、学術活動の概要を紹介した。次いでクラスノダール地域とロシア連邦における大豆関連産業の発展という観点から、大豆育種・種子生産に係る研究の現状と課題について詳述した。

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