Key challenges and opportunities of scientific and technological development of Russia’s crop industry

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Abstract. The global challenges that many countries will face in the near future, including Russia, require transforming their economies, searching for windows of opportunities, and adapting to new conditions. The plant growing industry is one of the main sectors for the country’s economy, as it ensures its food security. Therefore, it is extremely important to identify the key global trends, i.e. the direction in which the world market for crop production is moving, as well as how demand and supply for it could change in the future. The purpose of this work is to identify key challenges and “windows of opportunity” for the plant industry, including seed production and organic farming, which will be divided into several groups: economic, social, technological, and environmental, as well as in the following areas: technology and market conditions. To achieve this goal, the following aspects are reviewed in the paper: global trends, challenges and threats in the crop industry, windows of opportunities for Russia, and promising markets for crop technology. The study reveals that the main trends in the scientific and technological development of the industry are the following: biologization, informatization, urbanization, and robotization. Moreover, due to population growth, the shift in demand for organic products, the unevenness of people living in the city and rural areas, etc. are also the emerging challenges to be addressed.

1. Introduction

Despite the existing potential and competitive advantages of the domestic crop industry, negative factors and trends (expansion of agricultural production mainly due to extensive factors) lead Russia to lag behind the countries which are the world technological leaders and reduce the efficiency of investments in technical and technological modernization, increase the dependence on imports of domestic breeding and seed production, and reduce the competitiveness of Russian crop production in the world, endangering the food security of the country.

Technological modernization of production, together with the transition to an innovative model of economic growth, are the key and interrelated objectives of the sustainable development of the agro-industrial complex of the Russian Federation in the medium and long term. Scientific and technological development is the transformation of science and technology into a key factor in the development of Russia and ensuring its ability to respond effectively to global challenges. This process should be carried out according to the priorities of the country’s scientific and technological development, i.e. the most important areas of research and development in which technologies are created and used, solutions are being implemented, ensuring the most effectively response to global
challenges. The identification of priorities for scientific and technological development is carried out by means of strategic planning methods [7].

State authorities need to have a clear vision of the future, a clear understanding of likely development trajectories, key technological, economic and social trends. Without these factors, any effective management and sectoral strategic planning are impossible. Long-term forecasting is particularly important for the full integration of Russia into global value chains, effective international cooperation in the field of science and technology.

Scientific and technological forecasting is considered as the basis of modern strategic planning for the development of the economy, and the agro-industrial complex is one of the first sectors of the Russian economy in which a sectoral technological forecasting system is created [8].

Scientific and technological forecasting of the crop production industry in Russia should be carried out in accordance with global trends – large-scale economic, technological, environmental, and social changes in people's lives affecting each country. Such trends create challenges and threats for Russia and open “windows of opportunities.” As a result of the latter, the country can enter new markets for the technology industry, which would allow to move to a new, sixth technological order. All this has a significant impact on the development of the domestic crop industry.

Such an analysis of trends, challenges, threats, and “windows of opportunities” is important for the timely identification of problems in the industry that threaten every country, without exception, in the medium and long term, and their prevention. Such problems in the modern world include an increase in population and insufficient food, a decrease in natural soil fertility, the spread of genetically modified products in developing countries and an increase in demand for organic farming products in developed countries, robotization, and urbanization of agricultural production, etc. At the same time, new resource-saving and information technologies are being introduced very slowly into the industry and inhibit its scientific and technological development.

2. Problem Statement

The purpose of this study is to identify key challenges and windows of opportunity for the crop industry, including seed production and organic farming. The following tasks were solved by us to achieve this goal:

− Global trends, challenges and threats identified in the plant industry of Russia;
− “Windows of opportunities” are defined for Russia;
− Crop technology markets identified that are likely to appear in the medium term.

3. Research Results and Discussion

Technological modernization is a fundamental response to the long-term challenges of the development of the domestic plant industry. As a result, it is necessary to determine the nature of specific challenges by projecting global trends on the internal situation. The most relevant and common in the literature call groups include: economic, environmental, technological, and social. Their comparison with the conditions of development of the domestic branch of the plant growing industry will allow to highlight global challenges and windows of opportunities that are generated by global trends in the studied industry [10].

Over the next 10–15 years, the main global trends in crop production, seed production and organic farming will be the improvement of technologies for pre-sowing protection of planting material, increasing fertility and preventing soil depletion by reducing chemical stress, and improving the soil microbiota. All promising technologies in crop production will be aimed at ecologizing production and reducing waste. The magnitude of the demand for food does not change almost in developed countries. The changes will affect its structure and quality in the direction of fresh vegetables and fruits, as well as products of organic farming [3, 4].
All global trends in plant growing, seed production and organic farming can be divided into the following groups:

**According to the technologies used:**

1. **Biologization of planting.** Biotechnologies in crop production are able to compete in yield and cost with chemical fertilizers in the modern world. The ceiling will be reached by China, the USA, and the EU in the use of agro-chemicals and synthetic fertilizers. Their increasing use does not lead to an increase in the gross collection, but only to environmental problems that adversely affect agricultural production. The world’s largest production of biotechnology belongs to the United States – almost 50% of the global market for the global market for environmentally friendly products [5];

2. **The spread of biofuels.** The processing of grain to produce biofuel has become more profitable than its processing for food, in developed countries in recent times. Already today, the USA, Germany, France are not only vigorously expanding their “biofuel wedge”, but also importing biofuel (so far from Brazil). The demand for biofuels can lead to the fact that even in those countries where there is a shortage of food, grain would be used for the production of more expensive energy and not bread for the starving population, because the traditional energy sources are exhausted. Growth of consumption is planned for cereals for biofuel by 12%, sugar cane – by 30%, vegetable oils – by 15%, in the medium term;

3. Genetic engineering of agricultural crops, for example, the creation of perennial grain crops, which reduces the need for resources such as land, water, energy, fertilizers, herbicides, and, at the same time, increases crop yields. This makes it attractive for sustainable and productive crop production. This technology, which has already been called the “second green revolution”, is capable of increasing the productivity of corn, soybeans, and wheat by 50%, including in the long term;

4. The widespread spread of precision farming, which is based on the idea of the heterogeneity of the cultivated areas. Limiting the area of arable land and its depletion requires new, more efficient ways to manage resources, optimize the use of machinery and equipment, fertilizers, seeds. The use of precision farming technology leads to minimization of the unit cost of production. The main tools of this technology: satellite, aerial photography by means of drones, sensors for tracking the state of the soil, air, crops [11];

5. One of the most promising technological trends in agriculture is the cultivation of plants without the use of soil (robotic plant growing). According to forecasts, in the next 10-15 years, almost three-quarters of the world’s population will live in cities, which would be an incentive to use vertical farms, hydroponics, aeroponics, and aquaponic. Synthetic nutrient solutions will be used instead of soil. At present, these technologies are gradually spreading, for example, hydroponic installations and artificial beds with rice, vegetables and fruits are available in the Japanese company “Pasona.” And the company Mitsubishi Heavy Industries produces vegetables: the farm is built on one of the plants that runs on solar batteries. Staff meals and supplies to Tokyo restaurants are provided with vegetables. The use of vertical farms simultaneously solves many problems: economy of territories; independence of the crop from external conditions: temperature, solar lighting, pests, and bad weather; growing season shortening;

6. Technologies in vegetable growing in protected and open ground will be based on the automation of technological processes with minimal use of manual labor and on high-precision phytomonitoring;

7. Lack of arable land, reaching the limit of crop yields, rising food prices in most countries of the world can lead to the spread of synthetic crop products, a variety of vitamin cocktails, which will replace conventional fruits and vegetables.
According to market conditions:

1. *The shift in demand for crop production in the Asian markets.* In the next 10-20 years, the main consumer of food is the East Asian market: China, Japan, Mongolia, Taiwan, and North Korea.
2. *Projected growth in demand for soybeans and their products.* In 2016, the record soybean harvest was collected (about 331 million tons), but still its consumption volumes exceed the gross harvest. The main importer of soybeans is China. Also, at present, soybean is the basis of biodiesel fuel, the demand for which is growing annually.
3. *Stable decline in wheat prices, due to the growth of its supply on the world market from the USA, Argentina, Russia.* At the same time, the growth of grain demand will come from livestock breeders for fodder purposes, and it will be reduced for food purposes.
4. *Growing demand for corn, in particular for feed purposes.* In the United States in the medium term, it is planned that the volume of corn production over wheat will be predominant (corn is more profitable than wheat), which will reduce its exports to the world market by 15%. This fact will allow Russia to become the main exporter of wheat.
5. *By 2021, the shift is projected for global consumer demand for agricultural crops in the direction of rice, vegetable oil, and sugar;* in particular, this concerns developing countries.
6. *Growth in demand for functional and personalized nutrition.* Socio-cultural changes and trends in other industries have led to an increase in the personalization of product offerings. Such segments of the crop production market began to appear as personalized nutrition (individual and group). In the future, the population of developed countries will pay much more attention to the quality of crop production consumed and will strive to build their diet with the greatest health benefits, which will make the personalized food segments attractive [1, 2].
7. *The increase in the organic crop segment will be a consequence of the growing demand for personalized nutrition.* Increasingly, the world community is paying attention to the issues of maintaining and enhancing the viability of ecosystems, the issues of sustainable rural development. Increasing attention is paid to the “environmentally friendly” products when choosing food.

In the future, until 2030, we can expect the following global socio-economic and scientific-technological challenges to be preserved (Table 1).

| Table 1. Global challenges affecting the development of the crop industry. |
|-------------------------------------------------------------|
| **Challenges** |
| Economic | – The growing global demand for environmentally friendly and organic crop production; |
| | – The growth rates of the global gross crop production being ahead of the growth rate of population; |
| | – In developed countries, subsidies for crop production inhibit the growth of the agro-industrial complex of developing countries and lead to distortion of raw materials prices on world markets. |
| Technological | – Reduction of acreage of grain crops in the USA, Canada, China; |
| | – Exhausution of the potential of the “green revolution”; |
| | – Reduction of natural species and varietal biodiversity in crop production. |
| Ecological | – Global warming; |
| | – Reduction of natural soil fertility, erosion; |
An increase in the frequency of extreme weather events (floods, droughts, etc.);
The growing threat of bioterrorism;
Massive deforestation;
An annual increase in livestock waste.

Social

Differentiation of incomes of rural and urban population;
The growing rate of urbanization.

However, the response may be slowed down to the global challenges listed in Table 1 for the crop sector, including seed production and organic farming, under the influence of various threats in the economic, technological, environmental, and social spheres (Table 2).

Table 2. Threats for the Russian crop industry.

| Threats          | Economic                                                                                                     | Technological                                                                                     | Ecological                                                                                                   | Social                                                                                          |
|------------------|---------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
|                  | – A high level of dependence of vegetable crops on imported seeds;                                             | – Extensive development dominated by crop production;                                              | – Poor development of land reclamation;                                                                       | – An unattractiveness of rural infrastructure for highly qualified specialists; a lack of an effective consulting services system. |
|                  | – A low level of development of the material and technical base of crop production, seed production, and breeding; | – Insufficient use of new methods of breeding and seed research based on the innovative achievements of molecular genetics; | – The threat of illegal distribution of the cultivation of GMO plants in the border regions (with China, Ukraine); |                                                                                |
|                  | – Conservatism and unreadiness of Russian agricultural producers to introduce innovations;                    | – Insufficient mineral and organic fertilizer application;                                         | – The problem of waste disposal of livestock farms; insufficient distribution of agricultural technologies for growing bioenergy crops. |                                                                                |
|                  | – Large losses of crop production at the stages of storage, processing, logistics;                             | – A lack of a modern system for monitoring the phytosanitary situation;                            |                                                                                |                                                                                |
|                  | – An insufficiently effective government support for the industry;                                             | – A lack of infrastructure for the transfer, promotion, and commercialization of new promising varieties of plants of domestic breeding; |                                                                                |                                                                                |
|                  | – A disparity in prices for crop production and industry.                                                    | – A low level of mass training and retraining of personnel possessing modern knowledge and technologies in the field of genetics, selection and seed production. |                                                                                |                                                                                |

In addition, the following threats are noted by experts for Russia in this area: a low productivity of crop production; the critical lag of research and production and technological base in the field of crop production, including seed production and organic farming; low demand for practical development; insufficient business investment in the development of the industry; high barriers to entry into the crop production market of the Asia-Pacific region [6].

Figure 1. “Windows of opportunity” for the Russian crop industry.
1. The development of organic farming and export of high-margin organic products to Europe and Southeast Asia.

2. Attracting domestic companies to knowledge-intensive links in the value chains, capacity modernization, optimization of production processes.

3. Improving the quality and standard of living in rural areas through the creation of innovative industries and infrastructure development.

4. Securing the country in new markets and market niches.

5. Providing import substitution of vegetables by creating automated climate-independent greenhouses for their year-round cultivation.

6. Creating fundamentally new breakthroughs due to the implementation of accumulated scientific and technological reserves.

Thus, the main trends in the world crop production include the processes of biologization, robotization and informatization, and urbanization (a transfer of agricultural production to cities) of production. They open up new “windows of opportunity” for Russia (Figure 1).

The identified challenges and “windows of opportunity” predetermine promising directions for the development of the crop industry and open up new markets for Russian agricultural producers, which become an incentive for research and development. The list of technology markets is defined, which are likely to appear before 2030, based on the research and taking into account expert opinion. In Fig. 2, the formation is represented by these markets [9]:

1. The market for technologies of accelerated breeding, seed production, production of new varieties and hybrids, where methods for creating highly productive varieties of agricultural plants will develop. They cannot be created in the traditional way, and they consist in using the latest technologies for obtaining the initial homozygous and recombinant material. New ways to manage the development and adaptive functions of crops will be developed in environmentally sustainable agroecosystems using signaling molecules; molecular genetics mechanisms will be studied that determine the economically valuable traits of plants (resistance to stress factors, including phytopathogens, improved quality of the crop), as well as the identification of genes. Advanced post-genomic and biotechnological methods will be developed in crop production (databases of carriers of valuable varietal properties) [5].

2. The market of energy-saving technologies for environmentally safe production of crop production, the main features of which are the economic efficiency and minimal negative impact on the environment. Technologies for tillage, sowing and harvesting grain, fodder with
a high content of exchangeable energy belong to this market and ensure a reduction in the cost of diesel fuel several times [11].

3. The high-quality feed for livestock will be sold on the market of intensive industrial technologies in fodder crops. These technologies will allow to reduce losses in the production of feed, as well as introduce new crops into the crop with increased yield and resistance to extreme weather conditions.

4. The market for wide tillage machines, sprayers, sowing, and harvesting machines is based on precision farming systems using geoinformation systems and optical sensors. Precision farming is a management strategy that uses information technology, extracting data from multiple sources in order to make the right decisions for managing an agricultural organization. Ideas about the existence of heterogeneities within the same field: local characteristics of the soil and climatic conditions underlie this concept. Using maps of agrophysical and chemical indicators of the soil, obtained using geographic information systems (GIS), it is possible to implement a strategy for managing the development of crops at the field level and optimizing costs [12]. The advantages of this technology are the emergence of the possibility of carrying out field work around the clock, an increase in labor productivity due to the rapid movement of the machine and a decrease in machine operator fatigue.

5. The market of industrial technologies of urbanized agriculture, which, first of all, is represented by highly automated agro-industrial complexes and differs from traditional greenhouses primarily through an intensive approach to the use of space, through vertical multi-tiered planting. This market is represented by the following technologies: vertical farms (they solve the problem of space saving in megacities); hydroponics (by means of which plants are grown in nutrient water solution and seedling cassettes - one of the most progressive and modern methods of growing planting material). The technologies of urbanized agriculture make it possible to get rid of the seasonality of production, increase crop yields, as well as restore agricultural land affected by aggressive farming and return them to the natural cycle.

6. The market of aeroponic technologies for food supply of autonomous objects. Aeroponika is the technology of growing plants in a nutrient solution without the use of substrates. The main component of plant growth and development is oxygen, aeroponics is based on this. All the necessary nutrients are delivered to the roots of plants in the form of an aerosol. Transferring agriculture to roofs, terraces, empty buildings, etc. is possible through aeroponics. Its main advantages are in obtaining safe and environmentally friendly products that consume much less water and fertilizers than in traditional cultivation and reduce the cost of its production.

7. Market of plant growth biostimulants. The deterioration of climatic conditions in many countries around the world, the reduction of soil fertility led to the need to use growth biostimulants. Growth biostimulants are an extensive group of natural and synthetic organic compounds that in small doses affect the metabolism of plants. They are used to change the life processes or structure of plants, improve quality, facilitate harvesting and increase yield, protect plants from extreme environmental conditions. All potential in the plant genome is revealed through such substances.

8. The market for technologies of biological reclamation. Biological reclamation is a set of measures to improve the conditions of the natural environment through the cultivation and maintenance of natural plant communities. Such activities include the creation of forest belts, kulishnyh plantings, and grass sowing. The principle of their action is to enrich the soil with organic substances (when grown on the field for 4-5 years). As a result, the soil structure improves, the content of humus increases in it, the flow decreases, and the effects of erosion processes decrease.

9. The market of modern technologies for the use of organic composts based on biologically active substances. One of the main problems facing the modern world is the increasing volumes of products of vital activity of farm animals. Technologies for industrial processing
of these products can be its solution for the creation of biological fertilizers and plant growth biostimulants.

10. The market of technologies for the use of vermicultures. The technology of breeding earthworms or “vermiculture” is one of the most promising methods for solving the problem of recycling organic waste. Negative changes in ecology contribute to the development of this technology, they are caused by human activity in industry and agriculture, aimed at the rapid intensification of production. The use of vermiculture with the use of produced biohumus to fertilize crops solves the problem of utilization of organic residues, restoration and improvement of soil properties, to a large extent.

Currently, many markets for crop technology are in a “rudimentary” state, are small and unevenly distributed across all countries. If, for example, in Singapore, Japan, and Sweden, the market for urbanized crop technology is developed at a high level, then for Russia vertical farms, aeroponics, and bioponics are new technologies. However, there are markets that are developing simultaneously in most countries of the world; for example, the market of wide tillage machines, sprayers, sowing and harvesting machines [16].

**Figure 2.** Formation of markets for crop technology, including seed production and organic farming.

4. Conclusions

The scientific and technological development of the crop production industry in Russia is influenced by global trends that affect all countries of the world and lead to significant changes in the structure of the economy and the life of the population. Global trends were divided into two areas:

1. **According to the technologies used:** the biologization of crop production (abandonment of pesticides and mineral fertilizers and the transition to organic farming), processing of grain into biofuels, genetic engineering of crops, precision farming and robotization of production, the universal development of year-round vegetable farming in protected ground;
2. **According to market conditions:** the growing demand for crop production from Asian countries, including soybeans, corn, rice, as a result of which wheat prices fell; growing demand for personalized nutrition and organic products.
3. Global trends form challenges for countries affecting all walks of life: (a) **economic:** outpacing the world population growth rates over growth rates of gross crop production, distorting prices...
for agricultural raw materials on world markets due to unequal subsidies for agricultural production in developed and developing countries; (b) technological: reducing the area under crops in the world and its fertility; (c) ecological: soil erosion, an increase in the frequency of extreme natural phenomena, an increase in animal waste; (d) social: urbanization and strong income differentiation of urban and rural populations.

4. Accordingly, the following threats to the scientific and technological development of the crop industry of Russia can be identified: a high dependence on imported seed material, a low level of material and technical base of most agricultural producers, mainly extensive development of the industry, insufficient fertilization, poor development of melioration, a threat of the spreading GMO products in border areas and underdeveloped rural infrastructure.

5. Global trends, challenges, and threats open up “windows of opportunities” for our country, which include the following: the development of organic farming and the export of high-margin organic products to Europe and South-East Asia; attraction of domestic companies to high-tech links in the value chains, capacity modernization, optimization of production processes; improving the quality and standard of living in rural areas through the creation of innovative industries and infrastructure development; consolidation of the country in new markets and market niches; provision of import substitution of vegetables by creating automated climate-independent greenhouses for their year-round cultivation; the creation of fundamentally new breakthroughs through the implementation of accumulated scientific and technological reserves.

6. In the course of the study, we identified the promising markets for Russia, where there is the potential to implement critical plant growing technologies. The following markets can be attributed to them: technologies of accelerated breeding, seed production, production of new varieties and hybrids, energy-saving, environmentally safe production of crop production, intensive industrial technologies in fodder crops, wide-spread tillage machines, sprayers, sowing and harvesting machines, industrial technologies of urbanized agriculture, aeroponics for food supply of autonomous objects, plant growth biostimulants, technologies of biological reclamation, technologies of applying organic composts based on biologically active substances, technologies of applying vermiculure.

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