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SOCIO-ECONOMIC EFFICIENCY OF THE APPLICATION OF NEW TECHNOLOGIES FOR THE PRODUCTION OF ORGANIC PRODUCTS

SUMMARY

The article presents the results of scientific research on the effectiveness of new technologies for the production of organic food products, in particular biotechnologies, scientifically based crop rotation, the use of entomophages in biological plant protection, mechanical soil treatments in organic farming. The transition to organic agriculture is due to the negative consequences of global intensification for the environment, public health, and consumers of food products. The high nutritional value of organic agricultural products is shown. The efficiency of organic production is considered from the standpoint of a socio –ecological and economic approach. In the context of innovative development of organic agricultural and food production processes, points of economic growth are noted due to the introduction of biologization of agricultural production technologies, as a large-scale system program of the digital and technological generation, the development of which requires improvement of work with environmental resources, is a necessary condition for the development of organic production in agriculture. It is proved that the production of organic products in the regions improves the quality and standard of living of the population. The article substantiates the one-digit prospects for the production of organic agricultural products based on the use of agrobiological technologies, which combine the concept of AgroTech or high agro-industrial technologies and "Agriculture 4.0".

Keywords: organic products, agrotechnologies, biologization, efficiency of application

INTRODUCTION

The concept of organic agriculture originated at the beginning of the twentieth century, when the need for food supply to the population in the countries of the world increased, which required solving the problem of soil depletion, insufficiency of crop varieties and the quality of agricultural and food

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products. At that time, the intensification of agriculture developed rapidly, which dramatically increased yields and made agriculture much more productive, intensive farming based on chemicalization, as a rule, yields higher yields (by about 5-34%) compared with organic farming (Seufert and Verena, 2012; Mazurova, 2022). However, the resulting negative consequences for the environment and public health stimulated the birth of the organic farming movement (Mazurova, 2022). The founder of organic agriculture abroad is Walter James, who in the 1940s first used this term in the book "Look at the Earth", and justified an ecological, natural approach to agriculture (Tarasov, 2007). Research in the field of farming without the use of chemicals was conducted by Rodale J., English botanist Albert Howard. In 1939, farmer Yves Belfort, influenced by the work of Albert Howard, sets up the world's first scientific experiment on agricultural land in Great Britain in order to compare organic and intensive agriculture (Lord Northbourne Walter James, 1939). Long before the global intensification, Russian scientists turned to organic agriculture. The founder of Russian agronomic science, A.T. Bolotov (1738-1833), formulated the basic principles of agroecology in 1771 in his work "On the division of fields" - farming in harmony with nature. His ideas and practical recommendations are actively used abroad in the production of organic products. Later, the issues of ecologization were developed in their writings by I.M. Komova (1750-1792), A.V. Sovetov (1826-1901), A.N. Engelhardt (1832-1893), P.A. Kostycheva (1845-1842), V.V. Dokuchaeva (1846-1903), I.A. Stebuta (1833-1923) and others (Tarasov, 2007).

Currently, the latest available data on organic agriculture worldwide shows that 2021 has been another good year for global organic agriculture (World Organic Market, 2021). According to the latest published FiBL study on organic agriculture worldwide, organic farmland and retail sales of organic products continued to grow and reached a new record high, as evidenced by data from (Willer *et al*., 2023). The area of organic farmland in the world has reached 72.3 million ha, increasing annually by an average of 10%. At the same time, the largest share of land for the production of organic products is in Oceania and Europe, the leader is Australia (35.69 million ha). The regions with the largest areas of organic agricultural land are Oceania (36.0 million ha – almost half of the world's organic agricultural land, i.e. 47 percent) and Europe (17.8 million ha, 23 percent) (data for the end of 2021). Globally, 1.6 percent of agricultural land is organic (Willer *et al*, 2023).The global organic food market is one of the fastest growing. Experts from various reputable organizations agree that it will continue to develop at a high pace. It is projected to increase sales of organic products to $ 212-230 billion by 2025 and replace 3-5% of the market for all agricultural products in the world. Already, almost 700 million people actively consume organic products. However, the concept itself is deeper than just safe nutrition (Willer *et al*, 2023).

The production of organic agricultural products, in the technological processes of which biomaterials, natural fauna, and agrotechnical techniques are used instead of chemical fertilizers, pesticides and fungicides (Federal Law, 2018), is being developed in the countries of the world as a segment and direction for improving modern agricultural production.

The negative consequences of global intensification over the decades have led to the need to change the theories of economic growth, when growth problems are considered inseparably from the concepts of "responsible consumption" in relation to nature and society. At the same time, qualitative indicators are more focused on the social component, assessment of health, active longevity, quality of life of the population, and food security. However, the decrease in crop yields with the abandonment of the use of mineral fertilizers, chemical plant protection products, and the underdevelopment of the organic market raise doubts among commodity producers and farmers about the expediency of switching to organic farming methods. At the same time, the problems of the development of organic agriculture are becoming urgent. Scientific research shows real opportunities to increase the efficiency of organic agriculture and its unambiguous prospects based on the use of biotechnologies, scientifically based crop rotations, agrotechnical techniques, organization of production and labor, cooperation and agro-industrial integration. In modern science and practice, agrobiotechnology is classified as a section of new technologies that combine the concept of AgroTech or high agro-industrial technologies and "Agriculture 4.0". In practice, it has been proven that agrobiotechnology increases the efficiency of agricultural production by 10 to 40 percent, reduces climatic stresses by 10 to 30 percent, increases soil fertility, and improves the quality characteristics of products (The Strategy, 2023).

Agriculture 4.0 represents a new evolution in the agricultural industry, combining advanced technolgies, innovative methods and sustainable resource management practices, including precision farming digitalization, automation and robotization of production processes, smart technologies in mechanization and electrification of production, artificial intelligence in agriculture, management of agricultural waste and climate change, sustainable rural development, the quality and safety of food products based on the production of organic products and the transition to a circular economy in the branches of the agro-industrial complex (Anishchenko and Shutkov, 2019; Panova, 2024). This concept provides not only an increase in production, an in-crease in resource productivity, but also environmental protection, which is of critical importance for ensuring food security in the face of a growing population and climate change, provides socio–ecological and economic benefits for the development of agriculture and rural areas.

In order to support the strategic development of organic agriculture, in order to meet the increasing demand for organic food products in the domestic and global markets, the Federal Law of the Russian Federation "On the Development of Agriculture" in Article 7 defines "The main directions of state support in the field of agricultural development", including "the development of organic agriculture and support for producers of organic products" (Federal Law, 2006).

The purpose of the scientific work, the results of which are presented in this article, is to generalize the theory and practice of replenishing soil fertility, the use of plant protection products and others, mechanisms for the development of modern organic agriculture based on the principles of responsible consumption. The scientific novelty of the work lies not only in substantiating the

expediency, but also the effectiveness of the development of organic agriculture, the factors of its improvement from the standpoint of a socio–ecological and economic approach.

MATERIAL AND METHODS

The research process uses a systematic approach, general scientific and empirical methods, including dialectical, review-theoretical, economic-statistical, computational-constructive, comparative and factor analysis, system-functional. In order to identify trends and problems in the development of organic agriculture, the positive experience of organic producers through review and theoretical methods, the materials of scientific research by Russian and foreign scientists on the forms and methods of organization and development of organic agricultural production in the Altai Territory were studied, tabular and graphical methods were used to visually present the results obtained, generalize and formulate conclusions about efficiency, methods of economic and statistical modeling and competitive analysis. With the help of an economic and statistical model, the forecast of grain yield and factors affecting it was carried out. The economic and statistical multifactorial model is represented by factors:

Y–grain yield, kg/ha;

X_1–applied to 1 hectare of mineral fertilizers, kg of active substance;

X_2–applied to 1 ha of organic fertilizers, tons.

It was assumed that the values of the resulting variable Y act as a function, the values of which are determined by the values of the explanatory variables acting as arguments to this function, so:

$Y = f(X1,\ldots,Xk)$

Among all possible functions f(X1,...,Xk), a multiple linear regression model with a free term is selected (Shorokhova *et al.*, 2015).

The regression equation is obtained, which has the following form:

$Y = \beta_1 X_1 + \beta X_2 + \varepsilon$

Based on the obtained regression equation, it is possible to make a forecast of yield per hectare of acreage, while there was no close relationship between the yield of grain crops and the amount of mineral and organic fertilizers applied to cereals in the Altai Territory, therefore, this factor may be a prerequisite for the development of agriculture focused on the production of organic products.

RESULTS AND DISCUSSION

It is based on the principles of the "green economy", which implies a responsible human attitude to the natural resources of the planet and a compromise between increasing production and preserving their potential. Organic products are food products grown or manufactured without the use of synthetic pesticides, synthetic fertilizers, biological and chemical (again synthetic) additives (antibiotics, growth hormones and others), as well as genetically modified organisms of plants or animals. These requirements are valid for both agricultural products and food industry products. Studies have shown that there are no big differences in the content of minerals and vitamins in conventional and organic products. “Organic” meat contains more

polyunsaturated fatty acids and omega-3 compared to regular meat, although these comparisons are not entirely correct due to the heterogeneity of the samples studied.

The nutritional composition of milk and dairy products may vary depending on the components of the feed, the time of year, etc. However, milk produced both “organically” and traditionally raised cows has the same amount of protein, vitamins, lipids and trace elements. A study conducted in England demonstrated that “organic” milk has significantly higher levels of polyunsaturated fatty acids (including conjugated linoleic acid and alpha-linolenic acid), alpha-tocopherol and iron than conventional, but lower levels of iodine and selenium (“Organic” products. Nutritional value, 2023). The contribution of organic agriculture to comprehensive sustainable development strategies such as the Sustainable Development Goals and the European Un-ion's Farm-to-Fork Strategy. In Russia, a modern approach to the production of organic products is being formed in accordance with the application of Federal Law No. 280-FZ from January 1, 2020, as well as a strategy for the development of organic production until 2030. In the coming years, the Russian organic market will continue to grow at an average rate of 10-12% per year, and its volume by the end of 2022 may amount to more than 14 billion rubles (Organic market, 2023).

In the Altai Territory, as our research has shown, there is sufficient potential for the production of organic products, but only 7 producers of agricultural and food products have passed certification procedures to con-firm the status of "Organic". The most significant of them is Stepnoy LLC of Biysk district, which has been operating using organic technologies since 2008 without applying fertilizers, without using chemical plant protection products against weeds, pests and diseases. The farm specializes in the cultivation of cereals and legumes (buckwheat, rye, oats, spring and winter wheat, peas, rapeseed). The cultivated area is more than 6,000 hectares. Half of the fields are occupied by buckwheat, the rest by oats, peas and wheat. The agricultural enterprise works in cooperation with the certified processor of organic products LLC Kurai Agro Plus, LLC Predgorye, which sells organic products, a specialized organic food store has been opened in Biysk and others. As follows from the data in Table 1, the yield of cereals and buckwheat is not much lower in the farm compared to the average in the Biysk region, oats are 1-2 hundredweight higher per 1 hectare.

A comparison of the costs of grain and leguminous production using organic technologies in Stepnoy LLC and industrial methods in Prigorodnoye Educational and Experimental Farm JSC of the Altai Territory shows that with significant costs for the application of mineral fertilizers and the use of chemical plant protection products, the yield of cereals and leguminous crops in Prigorodnoye Educational and Experimental Farm JSC" 1.4 – 1.5 times higher, the cost of a unit of production is 1.2 -1.05 times lower. In order to assess the economic efficiency of intensive and organic crop cultivation technologies, economists have calculated technological maps (Vinnichek and Zaruk, 2022).

Table 1. Yield of main crops, kg/ha in LLC "Stepnoy" (household) Biysk district in comparison with the average indicators for the Biysk district (district) of the Altai Territory

	2017	2018	2019	2020		2021		2022	2023
The indicators	"Stepnoy"	"Stepnoy"	"Stepnoy"	"Stepnoy"	Biysk district	"Stepnoy	Biysk district	"Stepnoy"	"Stepnoy"
Winter wheat	10,3	27,1	32,2	19,3	23,1	26,5	26,9	22,2	14,8
Spring wheat	24,0	-	14,5	13,7	20,9	21,0	25,3	28,3	25,9
Barley	27,5	21,0	20,9	18,4	19,8	13,0	26,6	15,0	9,1
Oats	27,1	31,1	30,7	17,5	15,0	21,0	18,8	20,9	26,1
Buckwheat	10,2	10,0	7,9	10,1	11,6	8,3	10,2	9,5	13,4

The technology assessment was carried out based on the condition that agricultural crops are placed on soils of the first group (PH - 5.6 and above, P_2O_5 - 100 and above, K_2O - 80 and above) for a more objective comparison of the economic results of each of the three technologies (Table 2).

Table 2. Efficiency of various technologies of spring grain crops cultivation

Indicators	Spring cereals with sowing of perennial grasses		
	Intensive technology	Organic technology (Model - 2)	Organic technology (Model - 1)
Yield, centner /ha			
basic production	28	25,2	22,4
by-products (related)	22,4	20,16	17,92
The total cost of production, thousand rubles/ha.	19,22	19,89	21,53
Expences per 1 ha, thousand rubles, cost price 1 centner, rubles	12,69	10,03	9,37
basic production	407,99	358,10	376,34
by-products (related)	56,67	49,74	52,27
Conditional net income, thousand rubles/ha.	6,53	9,86	12,16
Profitability, %	51,41	98,38	129,81

Thus, the economic benefits of organic agriculture have also been proven. Modern scientific research by agricultural scientists is aimed at developing agrotechnologies that make it possible to replenish soil fertility, protect plants from pests, and animals from diseases. In a discussion organized by the Union of Organic Farming, scientists and practitioners noted that Russia needs to stop and not go into a dead end of chemicalization. Russian science is ready to replace 40-50% of imported agro-pesticides with environmentally friendly biological products (National Organic Union, 2023). The economic agro-industrial policy is aimed at ensuring stable growth in the production of agricultural ecological products, protection and technological use of land, and increasing the effectiveness of the introduction of biologization.

Our research on the effectiveness of the use of expensive mineral fertilizers in agricultural organizations of the Altai Territory showed a low dependence of increasing the yield of grain and leguminous crops on the amount of fertilizers applied based on the construction of a multifactorial economic and statistical model reflecting the dependence of grain yields on the level of application of mineral and organic fertilizers and solving an economic and mathematical problem. The economic and statistical multifactorial model is represented by factors:

y – grain yield, kg/ha;

x_1 – applied to 1 hectare of mineral fertilizers, kg of active substance;

x_2 – applied to 1 ha of organic fertilizers, t

Data analysis in the period 1966-2021 (Table.3) showed that there is a weak direct relationship be-tween grain yield and the volume of application of mineral fertilizers per 1 hectare in the Altai Territory, the correlation coefficient r=0.29.

There is a weak direct relationship between grain yield and the application of organic fertilizers per 1 ha of crops, since the correlation coefficient r=0.23, with an increase in the dose of organic fertilizers per 1 ha of sowing, the yield of grain crops will increase.

The regression equation has the following form:

$y= 12{,}199 + 0{,}1738x_1 – 3{,}321x_2$

Based on the obtained regression equation, a yield forecast can be made, which will amount to 1.52 tons/hectare. The actual yield of grain crops in the Altai Territory was, respectively, 1.69 and 1.38 tons /hectare in 2022 and 2023 (Altai Territory, 2024). In general, as a result of the study, there was no close relationship between the yield of grain crops and the amount of mineral and organic fertilizers applied in agriculture in the Altai Territory, therefore, this factor may be a prerequisite for the development of agriculture focused on the production of organic products and the abandonment of the use of mineral fertilizers in agriculture. Due to their low efficiency in the conditions of agricultural production in the Altai Territory.

In general, it should be noted that there is no close relationship between the yield of grain crops and the amount of mineral and organic fertilizers applied in agriculture in the Altai Territory, therefore, this factor may be a prerequisite for the development of agriculture focused on the production of organic products and the abandonment of the use of mineral fertilizers due to their low efficiency in agricultural production Altai Territory. To create an effective system for using the region's resources until 2035, the Altai Territory adopted the law "On Approval of the strategy for socio-economic development of the Altai Territory", which creates conditions for the development of measures to support the production of eco-products.

The Altai Territory has absolute competitive advantages for the development of this area, including land, human resources and technological resources. Technologies for the production of organic crop production using biological products have been developed.

Table 3. Yield and availability of crops of grain crops with organic and mineral fertilizers in the Altai Terri-tory for the period 1966-2021.

Years	Per 1 ha of crops		Yield, kg/ha
	mineral kg D.V.	Organic, t	
1966-1970	5,7	0,4	10,5
1971-1975	10,0	0,8	13,3
1976-1980	18,2	1,2	11,4
1981-1985	27,7	1,6	11,0
1986-1990	38,0	1,7	13,4
1991-1995	11,2	0,8	10,2
1996-2000	2,1	0,2	9,1
2001-2005	1,6	0,2	11,8
2006-2010	2,9	0,2	12,6
2015	6,8	0,3	14,3
2018	11,9	0,3	15,6
2019	15,3	0,2	14,6
2020	23,4	0,2	12,6
2021	23,6	0,2	17,3

The branch of the Federal State Budgetary Institution "Rosselkhoznadzor for the Altai Territory and the Altai Republic" is increasing the production of biological products such as "Humate +7B", "Pseudobacterin -2, Zh", Rizoplan, Rizotorphin (Fig. 1) due to the increase in their demand. In 2020 - 2021, the branch expanded its range with new drugs, such as Pseudobacterin-2, Zh, Azolene.The profitability of the branch in 2022 amounted to 21%. It is proved that the use of biological products in agriculture contributes to an increase in productivity and product quality against the background of cost reduction and increased profitability of production. The heads of organizations producing organic products point to a number of constraining factors, the main one is the high cost of certification of farm lands and products. Therefore, the process of entering organic agriculture is lengthy and requires government support and preferences (Official website of the Altai Territory, 2024).

In order to make better and more effective use of internal capabilities in solving the problems of biologization of production, we have proposed the activation of marketing activities in this direction, the expansion of the network of consulting points to provide advice to rural enterprises, entrepreneurs, and individuals.In the activity of the Rosselkhoznadzor, it is important to take into account the uniqueness of the conditions of each region and understand that there are no universal solutions in the biologization of organic production.

Therefore, the popularization of biological methods of plant protection occupies an important place in the activities of the Federal State Budgetary Institution "Rosselkhoznadzor" (Bulletin of the Rosselkhoznadzor, 2022), which is especially important in conditions of high demand for organic products.

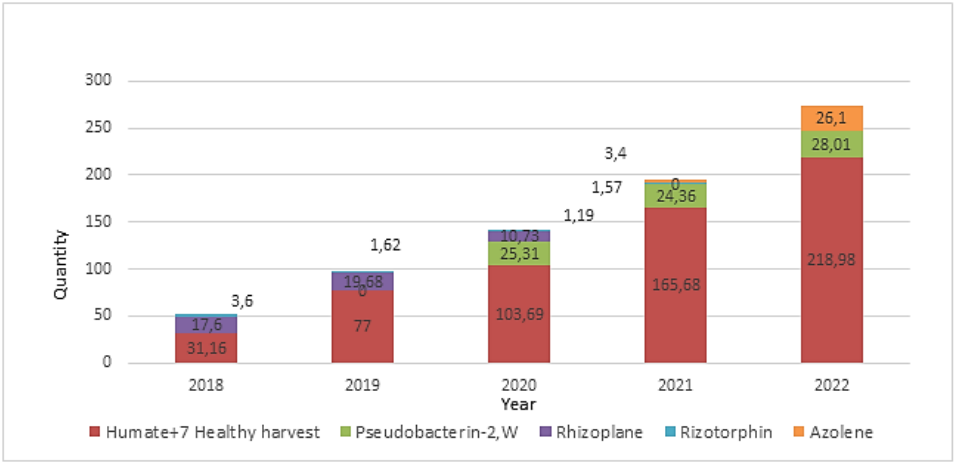

Figure 1. Dynamics of the production of biological products of the branch of the Federal State Budg-etary Institution "Rossel-Khozcenter" in the Altai Territory and the Altai Republic 2018-2022.

According to various authors, application of natural compounds, such as plant extracts and oils, use of antagonistic microorganisms can be used in crop protection practices, and facilitate high levels of disease control and production yield (Golijan-Pantović *et al.* 2022). Joint research and development of organic farming technologies have shown that as a result of the introduction of rhizobacterial fertilizers developed by scientists in Mongolia, the harvest of spring wheat increased by 11.3-46.9%, seed potatoes - by 20-65%, various vegetables such as cabbage, carrots, cucumbers and turnips - by 22.2- 83.6%. The use of Azophos biofertilizer in Seleng Aimag allows to increase the yield of all types of agricultural crops by 1.5-2.0 times. The use of microorganisms and biostimulants can increase crop yields by 20-30%, and also compensates for about 30% of nutrient losses from the soil. 1 liter of the new biological product Mongol EM replaces 20-40 kg of mineral fertilizers. A new type of biopreparation Mongol EM turned out to be safe for food, harmless to human health, it can be used to clean polluted lands and waters, production and introduction of biopreparations for plant protection (Kundius *et al.*, 2020).

According to scientists, agriculture is approaching the threshold moment when a new wave of technologies will provoke a revolution comparable to the mechanization of industry in the 20th century, which will inevitably lead to an increase in labor productivity (Anishchenko and Shutkov, 2019; Panova, 2024). Scientific developments of Altai scientists (FGBNU FANTSA) offer new, locally adapted, high-yielding (6.0-9.0 tons/hectare), diseaseresistant varieties of cereals, fruit and berry crops, and antiparasitic drugs for animals, applicable in organic agriculture. ASAU conducts scientific research on replenishing and increasing soil fertility using siderates, legumes and other useful crops in crop rotations, mechanical treatments, the use of entomophages for plant protection, effective feed additives, medicinal preparations for organic livestock and others. Research

has shown that for small businesses, the production of organic products can be a window of opportunity that allows them not just to survive, but to fully compete due to high product quality (Kundius, 2020; Kundius and Bayarsukh, 2023; Kundius *et al.*, 2024).

In the context of the transition to the next evolutionary stage of technical and technological development – "Agriculture 4.0", new precision farming technologies are being developed and applied in the agriculture of the region. Precision agriculture works by using data from various sensor technologies to improve the efficiency of all types of work. Intelligent sensors of agricultural crops analyze parameters such as humidity, soil electrical conductivity, humus height, and the content of organic substances in the soil. Unmanned aerial vehicles in agriculture equipped with appropriate sensors (video cameras, infrared, multispectral, hyper-spectral cameras and others) allow for the assessment of the condition of crops; identify pests; to determine the lack of moisture; to analyze the condition of the soil; to map; to treat crops with appropriate biological products; to check irrigation systems and much more. Artificial intelligence is being used in organic agriculture, which can process and analyze images from drones or stationary cameras and, on this basis, detect plant diseases, the presence of pests or nutrient deficiencies in the early stages; It can also analyze data on soil moisture, weather conditions and plant needs and optimize the irrigation regime, thereby reducing re-source consumption, increasing the efficiency of organic technologies.

CONCLUSIONS

Thus, taking into account the social, environmental and economic effects, organic agriculture is undoubtedly more efficient. Efficiency is achieved and increased through the use of agrobiotechnologies, techniques for improving agricultural landscapes, and biologization of the technological cycle, which scientists from many countries and regions of Russia are working on creating and improving (Russian Agricultural Biotechnologies, 2024). In the context of international sanctions, the tasks of reducing the level of import dependence and, accordingly, regional problems of organic production in agriculture remain relevant in Russia. At the same time, there is a need to develop regional development strategies that will contribute to increasing the efficiency of the use of biologization of production and economic transformations in the agricultural sector of the region, including through the effective use of organic production technologies.Research has shown that for small businesses, the production of organic products can be a window of opportunity, allowing them not just to survive, but to fully compete due to the high quality of products. State support is important for organic producers, especially at the stage of formation. The adoption of appropriate legislative and regulatory acts will allow the Russian market of organic products to successfully grow and develop.

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