

## **ECOLOGIZATION OF AGRICULTURAL PRODUCTION: DEVELOPMENT OF INTRODUCTION OF INNOVATIVE TECHNOLOGIES IN UKRAINE AT THE BEGINNING OF THE 21<sup>st</sup> CENTURY**

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### **INTRODUCTION**

At the beginning of the 21<sup>st</sup> century, Ukraine became one of the most polluted and ecologically troubled countries in the world. The level of environmental load in Ukraine has several times exceeded the similar indicators of other countries<sup>1</sup>. The state of land resources in Ukraine is nearing a critical point: land degradation processes, significant manifestations of wind and water erosion and soil pollution are noted throughout its territory<sup>2</sup>.

Therefore, an important measure was the ecologization of agricultural production, which envisages the practical application of a scientifically sound set of interrelated agrotechnical, reclamation, soil protection and organizational and economic measures<sup>3</sup>. They aimed at efficient use of soil, climatic resources, biological potential of plants in order to obtain stable crops under conditions of increasing soil fertility and maintaining ecological safety of the environment and grown products<sup>4</sup>. To solve this

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<sup>1</sup> Orekhivskiy, V. D. (2017) *Evolutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druga polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 7. (in Ukrainian).

<sup>2</sup> Kovalenko, N. P. (2014) *Stanovlennia ta rozvytok naukovo-orhanizatsiinykh osnov zastosuvannia vitchyzniannykh sivozmin u systemakh zemlerobstva (druga polovyna XIX – pochatok XXI st.): monohrafiia* [Becoming and development of scientifically-organizational bases of application of home crop rotations in the systems of agriculture (the second half of XIX is beginning of XXI of century): monograph]. Kyiv: TOV «Nilan-LTD», p. 342. (in Ukrainian).

<sup>3</sup> Kovalenko, N. P. (2017) *Naukovi osnovy stanovlennia ta rozvytku zemlerobstva v Ukraini* [Scientific bases of becoming and development of agriculture are in Ukraine]. *Visnyk ahrarnoi nauky*, no. 5, p. 63. (in Ukrainian).

<sup>4</sup> Bahorka, M. O. (2017) *Osnovni napriamy ta mekhanizmy ekolohizatsii ahrarnoho vyrobnytstva* [Main directions and mechanisms of greening of agricultural production]. *Naukovyi visnyk Uzhhorodskoho natsionalnoho universytetu*, vol. 16, p. 14. (in Ukrainian).

problem, great importance was attached to the introduction of ecological innovations with the aim of restoring quality components of the environment due to the process of self-renewal based on the use of the latest ecologically friendly innovative technologies<sup>5</sup>.

In the 2000<sup>s</sup>, ecologization of agriculture was a complex, objectively natural process, driven by changes in the modern paradigm of development of the world economic complex in the direction of ensuring the sustainable functioning of the global economic system, taking into account ecology challenges and threats<sup>6</sup>. The effectiveness of systemic sectoral transformations depended on a set of measures of national, regional and international focus, designed to create an ecology sound basis for the development of each component of the agrarian complex<sup>7</sup>. The ecology orientation of agricultural production in Ukraine involved the search for such methods of organization economic activity that ensured the demand for the products of the industry, while reducing the negative impact on the environment and promoting sustainable rural development<sup>8</sup>.

Solving the problem of ecologization agricultural production with the introduction of innovative technologies has contributed to solving important societal goals. In particular, the formation of a positive image of the state, the promotion of sustainable development of the agricultural sector, the creation of a favorable environment for future generations<sup>9</sup>.

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<sup>5</sup> Kovalova, O. V. (2008) *Prohramno-tsiloyvi pidkhid do upravlinnia ekolohospriamovanyh silskohospodarskym vyrobnytstvom* [A programmatic approach to the management of environmentally-oriented agricultural production]. *Ekonomika APK*. no. 2. p. 105. (in Ukrainian).

<sup>6</sup> Tsybuliak, A. H. (2016) *Ekolohizatsiia silskoho hospodarstva v umovakh hlobalizatsii* [Ecologization of agriculture in the conditions of globalization]. *Ahrosvit*, no. 9, p. 37. (in Ukrainian).

<sup>7</sup> Polehenka, M. A. (2017) *Osoblyvosti innovatsiinoi diialnosti v ahropromyslovykh pidpriemstvakh* [Features of innovative activity in agro-industrial enterprises]. *Ahrosvit*, no. 6, p. 49. (in Ukrainian).

<sup>8</sup> Bahorka, M. O. (2017) *Osnovni napriamy ta mekhanizmy ekolohizatsii ahrarynoho vyrobnytstva* [Main directions and mechanisms of greening of agricultural production]. *Naukovi visnyk Uzhhorodskoho natsionalnoho universytetu*, vol. 16, p. 16. (in Ukrainian).

<sup>9</sup> Kovalenko, N. P. (2017) *Naukovi osnovy stanovlennia ta rozvytku zemlerobstva v Ukraini* [Scientific bases of becoming and development of agriculture are in Ukraine]. *Visnyk ahrarynoi nauky*, no. 5, p. 66. (in Ukrainian).

## 1. Development of theoretical-methodological foundations of ecological innovations in agricultural production of Ukraine

At the beginning of the 21<sup>st</sup> century, ecologization of agricultural production in Ukraine was linked to innovation and was considered an integral part of its development<sup>10</sup>. In an environment of limited and significant depletion of Ukraine's natural resource potential, ecological innovations based on resource-saving and energy-saving technologies, ensuring rational use of the environment with minimizing the negative impact on the environment, and the production of ecologically friendly products, played an important role<sup>11</sup>.

Innovation is understood as a newly created or improved competitive technology, product or service, as well as organizational-technical solutions of a production nature, which significantly improved the quality of agricultural production<sup>12</sup>. Innovative technology was technology developed on the basis of the latest scientific knowledge, which by their technological characteristics corresponded to the level of the best world standards in agricultural production and were able to secure leading positions in the world market of knowledge-intensive products<sup>13</sup>.

The essence of innovation in the agricultural sector was to develop and implement in the agrarian production of new progressive management methods. They differed in the variety of regional, sectoral, functional,

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<sup>10</sup> Tsybuliak, A. H. (2016) *Ekolohizatsiia silskoho hospodarstva v umovakh hlobalizatsii* [Ecologization of agriculture in the conditions of globalization]. *Ahrosvit*, no. 9, p. 35. (in Ukrainian).

<sup>11</sup> Kovalenko, N. P. (2014) *Stanovlennia ta rozvytok naukovo-orhanizatsiinykh osnov zastosuvannia vitchyzniannykh sivozmin u systemakh zemlerobstva (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Becoming and development of scientifically-organizational bases of application of home crop rotations in the systems of agriculture (the second half of XIX is beginning of XXI of century): monograph]. Kyiv: TOV «Nilan-LTD», p. 357. (in Ukrainian).

<sup>12</sup> Sotnyk, I. M. & Chumakova, M. M. (2013) *Rynok ekolohichnykh innovatsii ta problemy yoho rozvytku* [The eco-innovation market and its development problems]. *Mekhanizm rehuliuвання ekonomiky*, no. 3, p. 45. (in Ukrainian).

<sup>13</sup> Bahorka, M. O. (2017) *Osnovni napriamy ta mekhanizmy ekolohizatsii ahromoho vyrobnytstva* [Main directions and mechanisms of greening of agricultural production]. *Naukovi visnyk Uzhhorodskoho natsionalnoho universytetu*, vol. 16, p. 16. (in Ukrainian).

technological and organizational features. In particular, the long duration of the development process and the highly efficient nature of innovation, the key role of research institutions in the process of innovation development, and the consideration of soil and climatic conditions<sup>14</sup>.

Agrarian innovation was an innovation implemented in the agricultural sector to ensure a stable and expanded reproduction of agricultural production. Important was the implementation in the practice of research and development results in the form of new agrarian technologies in agriculture, crop production, soil science, seed production, mechanization and animal husbandry. In particular, disease-resistant, pests and adverse soil and climatic conditions of plant varieties, productive breeds and species of animals and poultry, types of fertilizers and plant and animal protection products, methods of prevention and treatment animals and poultry, biotechnologies that have provided high quality, useful products that had a health and preventive effect<sup>15</sup>. Agrarian innovations included new technical means and technologies of soil cultivation, purification and storage of raw materials; resource-saving and energy-saving technologies and ecological innovations, which ensured increasing the productivity of agricultural production, minimizing costs and guaranteeing ecological safety of the environment<sup>16</sup>.

Innovative technologies in agrarian production underwent four stages of development: development of innovations, as a framed result of basic or applied research in the form of development or experimental works, their testing and verification, reproduction, and introduction into production<sup>17</sup>. At the beginning of the 21<sup>st</sup> century, the main producer of

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<sup>14</sup> Polehenka, M. A. (2017) *Osoblyvosti innovatsiinoi diialnosti v ahropromyslovykh pidpriemstvakh* [Features of innovative activity in agro-industrial enterprises]. *Ahrosvit*, no. 6, p. 51. (in Ukrainian).

<sup>15</sup> Demydenko, L. M. (2016) *Orhanizatsiino-ekonomichni napriamy innovatsiinoho rozvytku silskohospodarskykh pidpriemstv* [Organizational and economic directions of innovative development of agricultural enterprises]. *Naukovyi visnyk Khersonskoho derzhavnoho universytetu*, vol. 20, p. 73. (in Ukrainian).

<sup>16</sup> Polehenka, M. A. (2017) *Osoblyvosti innovatsiinoi diialnosti v ahropromyslovykh pidpriemstvakh* [Features of innovative activity in agro-industrial enterprises]. *Ahrosvit*, no. 6, p. 50. (in Ukrainian).

<sup>17</sup> Demydenko, L. M. (2016) *Orhanizatsiino-ekonomichni napriamy innovatsiinoho rozvytku silskohospodarskykh pidpriemstv* [Organizational and economic directions of innovative development of agricultural enterprises]. *Naukovyi visnyk Khersonskoho derzhavnoho universytetu*, vol. 20, p. 72. (in Ukrainian).

innovations in the agricultural sector was the network of research institutions of the National Academy of Agricultural Sciences of Ukraine and the Ministry of Agrarian Policy and Food of Ukraine. The most common innovations included: new plant varieties and hybrids and animal breeds; strains of microorganisms; brands and modifications of agricultural machinery; technology; chemical and biological preparations, vaccines; economic developments – documented methodologies, recommendations, etc.<sup>18</sup> Testing and checking of innovations were carried out by special state scientific institutions. Reproduction of innovations in the agricultural industry was carried out as follows: seed farms grew elite and reproductive seeds of new varieties and hybrids of crops; breeding plants bred pure breeds of animals; machine-building enterprises carried out serial production of new equipment; biological factories produced vaccines and the like. The introduction of development into production, or the transformation of innovation into innovation, was undertaken at the initiative of business entities for the purpose of commercial gain.

Ecological innovations were the final product of ecology-innovation activity in the creation, use and introduction into production of ecology-oriented innovation, which was realized in the form of ecologically friendly goods, products and services, technologies of their production, management methods at all stages of production and marketing<sup>19</sup>. They ensured the development and improvement of the socio-economic efficiency of the functioning of economic entities, promoted resource and ecological security, and minimized the negative impact on the environment<sup>20</sup>. The main criteria for ecological innovation were scientific and technological progress, practical

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<sup>18</sup> Serediuk, Yu. I. & Shmatkovska, T. O. (2015) *Osoblyvosti innovatsii v silskomu hospodarstvi* [Features of innovation in agriculture]. *Problemy formuvannia ta rozvytku innovatsiinoi infrastruktury: yevropeiskyi vektor – novi vyklyky ta mozhlyvosti: tezy dopovidei III Mizhnarodnoi naukovo-praktychnoi konferentsii* (Ukraine, Lviv, May 14–16, 2015). Lviv: Vydavnytstvo Lvivskoi politekhniki, p. 305. (in Ukrainian).

<sup>19</sup> Tsybuliak, A. H. (2016) *Ekolohizatsiia silskoho hospodarstva v umovakh hlobalizatsii* [Ecologization of agriculture in the conditions of globalization]. *Ahrosvit*, no. 9, p. 37. (in Ukrainian).

<sup>20</sup> Kovalenko, N. P. (2012) *Ekolohichno zbalansovani sivozminy v systemi alternatyvnoho zemlerobstva: istorychni aspekty* [Ecologically balanced crop rotations in the system of alternative agriculture: historical aspects]. *Ahroekolohichnyy zhurnal*, no. 4, p. 96. (in Ukrainian).

implementation and the ability to meet the needs through their implementation in the market<sup>21</sup>.

Environmental innovations were divided into: environmental technologies – means of control, elimination and prevention of pollution, compliance with sanitary boundaries. In addition, there were ecological efficient innovations – fundamentally new or modified products, processes and services that generate profit for the manufacturer and the consumer while contributing to the reduction of environmental pollution. There have also systemic innovations – large-scale changes in production and consumption systems, as well as waste management systems within a country or region<sup>22</sup>.

At the beginning of the 21<sup>st</sup> century, the development of state programs aimed at the creation of ecological technologies in developed countries of the world was actively developing. In particular, Japan has created a public-private and private sector research center for innovative technologies for the Earth. Its main focus is on global warming and the development of alternative energy sources. In Germany, the Ministry of Research and Technology's Environmental Technology Program operated. A technology and technology transfer organization has been set up in the Netherlands, with ecological technology accounting for about 10% of its activities. A Technology Innovation Fund was set up in Italy, where 5% of the money was used for ecological technologies. The Environmental Technology Solutions Program was operating in Canada. In many countries, the task of developing ecological technologies has been part of existing scientific and technical programs in research institutions<sup>23</sup>.

Great importance for the development of ecologization of domestic agricultural production is attached to the draft Law of Ukraine

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<sup>21</sup> Khodakivska, O. V. (2015) *Ekolohizatsiia ahromoho vyrobnytstva: monohrafiia* [Ecologization of agricultural production: monograph]. Kyiv: NNTs IAE, p. 259. (in Ukrainian).

<sup>22</sup> Sotnyk, I. M. & Chumakova, M. M. (2013) *Rynok ekolohichnykh innovatsii ta problemy yoho rozvytku* [The eco-innovation market and its development problems]. *Mekhanizm rehuliuвання ekonomiky*, no. 3, pp. 39–40. (in Ukrainian).

<sup>23</sup> Bahorka, M. O. (2017) *Osnovni napriamy ta mekhanizmy ekolohizatsii ahromoho vyrobnytstva* [Main directions and mechanisms of greening of agricultural production]. *Naukovi visnyk Uzhhorodskoho natsionalnoho universytetu*, vol. 16, p. 15. (in Ukrainian).

“On Agriculture”. It states that ecologization of agriculture was a system of national, sectoral and regional measures. They were aimed at introducing into the practice of agricultural production qualitatively new, ecologically safe types of machinery, technologies and organization of material production, methods and methods of functioning of agrarian and agro-industrial complexes. For the rational use of natural resources, their conservation, reproduction and maintenance of dynamic ecological balance in the environment<sup>24</sup>.

Innovation processes were regulated by the Law of Ukraine “On Innovative Activity”, which defined the legal, economic and organizational principles of state regulation of innovation activity in the country<sup>25</sup>. Its main purpose was to create socio-economic, organizational and legal conditions for the effective reproduction, development and use of scientific and technical potential of the country, ensuring the introduction of modern ecologically friendly, safe, energy-saving and resource-saving technologies, production and sale of new types of competitive products.

Important was the Law of Ukraine “On the Fundamental Principles (Strategy) of the State Environmental Policy of Ukraine for the Period until 2030”, which established the factors of ecological problems and main directions of development of the country’s ecological policy<sup>26</sup>. Factors of ecological problems were: the subordination of ecological priorities to economic feasibility and the neglect of environmental consequences in the legislative and regulatory decisions of executive authorities. Ecological problems were exacerbated by the predominance of resource-intensive and energy-intensive industries with a negative impact on the environment, which was exacerbated by the lack of regulation in the transition to market conditions; unsatisfactory state of

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<sup>24</sup> Sotnyk, I. M. & Chumakova, M. M. (2013) *Rynok ekolohichnykh innovatsii ta problemy yoho rozvytku* [The eco-innovation market and its development problems]. *Mekhanizm rehuliuvannia ekonomiky*, no. 3, p. 42. (in Ukrainian).

<sup>25</sup> *Zakon Ukrainy № 40-IV «Pro innovatsiinu diialnist» vid 5 hrudnia 2012 r.* [Law of Ukraine no. 40-IV «On Innovative Activity» of December 5, 2012]. Retrieved from: <https://zakon.rada.gov.ua/laws/show/40-15> (accessed 30 September 2019). (in Ukrainian).

<sup>26</sup> *Zakon Ukrainy № 2697-VIII «Pro Osnovni zasady (stratehiiu) derzhavnoi ekolohichnoi polityky Ukrainy na period do 2030 roku» vid 28 liutogo 2019 r.* [«On the Fundamental Principles (Strategy) of the State Environmental Policy of Ukraine for the Period up to 2030» of February 28, 2019]. Retrieved from: <https://zakon.rada.gov.ua/laws/show/2697-19> (accessed 30 September 2019). (in Ukrainian).

the system of state monitoring of the environment. The development of ecological problems has led to: a low level of understanding in society of the priorities of environmental protection and the benefits of balanced (sustainable) development, the imperfection of the system of ecological education. Unsatisfactory level of compliance with environmental legislation and ecological rights and obligations of citizens; insufficient funding from state and local budgets for environmental measures. At the same time, the main directions of development of Ukraine's ecological policy were: stabilization and improvement of the environment, guaranteeing an ecological safe environment for the life and health of the population, as well as introduction of an ecologically balanced system of nature use and conservation of the country's natural ecosystems.

At the beginning of the 21<sup>st</sup> century, there were a number of unresolved problems at the domestic enterprises regarding the effective implementation of ecological innovations. These negative tendencies were accompanied by the loss of competitiveness of agricultural enterprises not only internationally but also locally. In recent years, innovation activity in agriculture has slowed down substantially, reducing both the number and quality of scientific developments performed and the number of scientists, which has resulted in a decrease in the state funding of their scientific activity<sup>27</sup>. The economic relations between science and production were not well established, and scientific developments were slowly being introduced into production. The renewal of agricultural production with new varieties, machinery and technologies was hampered by the lack of financial support for agricultural producers and their lack of awareness of the latest achievements of domestic agrarian science.

Agrarian enterprises of Ukraine needed an ecologically friendly restructuring of production activities, which included: rational use of land, which was accompanied by conservation and increase of soil fertility. In addition, there were ensuring the optimal level of plowed land, which prevented the development of water and wind erosion of the soil; compliance with the requirements to prevent exceeding the

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<sup>27</sup> Polehenka, M. A. (2017) *Osoblyvosti innovatsiinoi diialnosti v ahropromyslovykh pidpriemstvakh* [Features of innovative activity in agro-industrial enterprises]. *Ahrosvit*, no. 6, p. 51. (in Ukrainian).



maximum permissible standards of contamination of agricultural production, ensuring its ecologically friendliness<sup>28</sup>. It was important to follow the established rules for the transportation, storage and application of mineral fertilizers, plant and animal protection; prevention of pollution by chemical means of environment and food; compliance with ecological requirements during the design, construction, reconstruction and commissioning of new buildings and structures, reclamation systems, etc.<sup>29</sup>

In order to stimulate the innovation activity of enterprises, an important trend was the creation of innovative programs, which included the coordination of organizational objectives for the development and implementation of innovative products. An innovative strategy for long-term growth based on sustainable development has become widespread, which has become a common concept on the need to strike a balance between meeting contemporary needs and protecting the interest of future generations, including their need for an ecologically friendly environment<sup>30</sup>. This concept led to the expansion of the introduction of ecological innovations, which included the production of ecologically friendly products, the use of ecologically friendly resource-saving and energy-saving technologies of production, which provided a sustainable improvement of the ecological situation and increased efficiency of agricultural production, saving jobs and improving living standards.

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<sup>28</sup> Kovalenko, N. P. (2014) *Stanovlennia ta rozvytok naukovo-orhanizatsiinykh osnov zastosuvannia vitchyzniannykh sivozmin u systemakh zemlerobstva (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Becoming and development of scientifically-organizational bases of application of home crop rotations in the systems of agriculture (the second half of XIX is beginning of XXI of century): monograph]. Kyiv: TOV «Nilan-LTD», p. 348. (in Ukrainian).

<sup>29</sup> Orekhivskiy, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 186. (in Ukrainian).

<sup>30</sup> Polehenka, M. A. (2017) *Osoblyvosti innovatsiinoi diialnosti v ahropromyslovykh pidpriemstvakh* [Features of innovative activity in agro-industrial enterprises]. *Ahrosvit*, no. 6, p. 53. (in Ukrainian).

## 2. Improvement of practical implementation of ecological innovations in organic agriculture of Ukraine

At the beginning of the 21<sup>st</sup> century, innovations in organic agriculture became a component of ecologization of agricultural production in Ukraine<sup>31</sup>. Examples of such ecological innovations include the production of organic agricultural products using organic seeds and scientifically based alternation of crops, organic fertilizers, soil protection, biological plant protection products and more. The introduction of ecological innovations in agricultural enterprises was carried out simultaneously with traditional production, as it was aimed at improving or creating new products and significantly updating production technologies. At the same time, the transition to renewed production required additional costs of finance, time, energy, etc., which could only be ensured by the effective management of agricultural production<sup>32</sup>.

During the 2000<sup>s</sup>, Ukraine, with significant potential for its own production of organic agricultural products, its export and consumption in the domestic market, achieved certain results in its development. This was facilitated by the adopted Law of Ukraine “On Basic Principles and Requirements for Organic Production, Circulation and Labeling of Organic Products”, which was implemented on August 2, 2019<sup>33</sup>. This Law of Ukraine defines the basic principles and requirements for organic production, circulation and labeling of organic products. The principles of legal regulation of the production and functioning of the organic produce market, legal bases of activity of the central executive bodies and directions of state policy in the specified sphere are established.

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<sup>31</sup> Khodakivska, O. V. (2015) *Ekolohizatsiia aharnoho vyrobnytstva: monohrafiia* [Ecologization of agricultural production: monograph]. Kyiv: NNTs IAE, p. 5. (in Ukrainian).

<sup>32</sup> Orekhivskiy, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druga polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 229. (in Ukrainian).

<sup>33</sup> *Zakon Ukrainy № 2496-VIII «Pro osnovni pryntsyipy ta vymohy do orhanichnoho vyrobnytstva, obihu ta markuvannya orhanichnoi produktsii» vid 10 lypnia 2018 r.* [Law of Ukraine no. 2496-VIII «On the basic principles and requirements for organic production, circulation and labeling of organic products» of July 10, 2018]. Retrieved from: <https://zakon.rada.gov.ua/laws/show/2496-19> (accessed 30 September 2019). (in Ukrainian).

According to the Federation of Organic Movement of Ukraine, the domestic consumer market for organic products in the country began to develop from the early 2000<sup>s</sup>. Most of the agricultural enterprises producing organic products were located in Western Ukraine, Vinnytsia, Dnipropetrovsk, Zhytomyr, Kyiv, Odesa, Poltava, Kherson, Chernihiv regions<sup>34</sup>. They specialized mainly in the cultivation of cereals, legumes and oilseeds, some combining the use of organic technologies in plant and animal husbandry<sup>35</sup>.

The development and implementation of innovative technologies for the ecologization of agricultural production in different soil and climatic conditions of Ukraine was carried out by scientists of the National Scientific Center “Institute of Agriculture of NAAS”. They have developed the optimal structure of sown areas and scientifically substantiated crop rotations on the basis of a point evaluation of precursors and periods of return to the previous place of cultivation<sup>36</sup>. In the early 2000<sup>s</sup>, these technologies were introduced in the farms of Rivne<sup>37,38</sup> and Poltava region<sup>39,40</sup>. The farms used a system of

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<sup>34</sup> Orekhivskiy, V. D. (2018) *Osoblyvosti rozvytku ahrarykh pidpriemstv z vyrobnytstva orhanichnoi produktsii v Ukraini (1990-ti – 2000-ni roky)* [Features of development of agricultural enterprises for organic production in Ukraine (1990<sup>s</sup>–2000<sup>s</sup>)]. *Hileia*, vol. 133, p. 67. (in Ukrainian).

<sup>35</sup> Orekhivskiy, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 303. (in Ukrainian).

<sup>36</sup> Kovalenko, N. P. (2014) *Stanovlennia ta rozvytok naukovo-orhanizatsiinykh osnov zastosuvannia vitchyzniannykh sivozmin u systemakh zemlerobstva (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Becoming and development of scientifically-organizational bases of application of home crop rotations in the systems of agriculture (the second half of XIX is beginning of XXI of century): monograph]. Kyiv: TOV «Nilan-LTD», p. 226. (in Ukrainian).

<sup>37</sup> Boiko, P., Kovalenko, N., Poliovyi, V. & Panasiuk, M. (2002) *Dosvid i praktyka «Zorianskoi akademii»* [Experience and practice of «Zorianska of academy»]. *Propozycja*, no. 11, pp. 26–28. (in Ukrainian).

<sup>38</sup> Boiko, P., Kovalenko, N., Poliovyi, V. & Panasiuk, M. (2002) *Dosvid i praktyka «Zorianskoi akademii»* [Experience and practice of «Zorianska of academy»]. *Propozycja*, no. 12, pp. 36–38. (in Ukrainian).

<sup>39</sup> Boiko, P. I. & Kovalenko, N. P. (2005) *Naukovo obgruntovani sivozminy i systema rilnytva u velykotovarному ghospodarstvi* [Scientifically reasonable crop rotations and system of field-crop cultivation in large commodity economy]. *Propozycja*, no. 6, pp. 38–42. (in Ukrainian).

specialized rotary crop rotations for growing cattle, pigs and poultry using post-harvest and sidereal crops<sup>41</sup>, by-products, tillage, local organic fertilizers – manure, slurry, compost, peat; agrotechnical, biological and organizational measures of plant protection<sup>42</sup>; soil erosion changes were introduced on hazardous erosion crop rotations<sup>43</sup>.

Scientists of the Odessa State Agricultural Experimental Station of NAAS for the arid conditions of the Southern Steppe of Ukraine scientifically substantiated and practically tested innovative technology of preparation of a sidereal steam, which was effectively used in the farms of the Odessa region<sup>44</sup>. With this technology, the aboveground biomass was not plowed up, but crushed with disk implements and partially mixed with the surface layer of soil, which reliably protected it from wind and water erosion and partly from physical evaporation of moisture.

Scientists of the National University of Life and Environmental Sciences of Ukraine have developed a method of preparation and application of EM-technologies in organic agriculture with the use of effective microorganisms. Such technologies have included the use of EM-preparations: liquids that have a high concentration of effective microorganisms, fermented grains and cereals, as well as fermented

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<sup>40</sup> Boiko, P. I. & Kovalenko, N. P. (2008) *Vysokotovarnye khoziaistva kak model racyonalnogo zemleypol'zovaniia* [Highly commodity economies as model of the rational use of earth]. *Aghrovisnyk Ukrainiia*, no. 1(24), pp. 24–27. (in Russian).

<sup>41</sup> Boiko, P. I. & Kovalenko, N. P. (2003) *Problemy ekologichno vrvnovazhenykh sivozmin* [Problems of the ecologically balanced crop rotations]. *Visnyk ahrarnoi nauky*, no. 8, p. 10. (in Ukrainian).

<sup>42</sup> Boiko, P. I., Borodan, V. O. & Kovalenko, N. P. (2005) *Ekolohichno zbalansovani sivozminy – osnova biolohichnoho zemlerobstva* [The Ecologically balanced crop rotations are basis of biological agriculture]. *Visnyk ahrarnoi nauky*, no. 2, p. 11. (in Ukrainian).

<sup>43</sup> Kovalenko, N. P. (2014) *Stanovlennia ta rozvytok naukovo-orhanizatsiinykh osnov zastosuvannia vitchyzniianyykh sivozmin u systemakh zemlerobstva (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Becoming and development of scientifically-organizational bases of application of home crop rotations in the systems of agriculture (the second half of XIX is beginning of XXI of century): monograph]. Kyiv: TOV «Nilan-LTD», p. 230. (in Ukrainian).

<sup>44</sup> Orehivskyi, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», pp. 231–232. (in Ukrainian).

organic residues<sup>45</sup>. In particular, EM-preparations used to protect plants from harmful organisms in farms of different soil and climatic conditions of Ukraine.

In 2010, scientists of the National Scientific Center “Institute of Agriculture of the NAAS” started the implementation of the scientific-technical program “Scientific bases for the development of organic production of agricultural products and mechanisms of its functioning in Ukraine”. In particular, the zones of organic production of agricultural products were formed, taking into account the soil and climatic conditions, the optimal area of farms for organic farming was established, organic fertilizers from by-products of crop production and animal husbandry were obtained<sup>46</sup>. The enhancement of the functionality of such organic fertilizers was due to the addition of enzyme and microbiological agents at various stages of composting with the active surface<sup>47</sup>.

Scientists of the Institute of Engineering and Technology “Biotechnics” of the National Academy of Sciences of Ukraine started the implementation of the program “Scientific and engineering-technological principles of creation of ecologically safe industrial biotechnologies and equipment for the production and use in agrobiocenoses of biological plant protection products”. In particular, they formed an innovative technology for the application of biological plant protection products and determined the main characteristics of vermicultures, adapted to different soil and climatic conditions of Ukraine<sup>48</sup>. These technologies are widely used in farms of different soil and climatic conditions of Ukraine.

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<sup>45</sup> Stetsyshyn, P. O., Pyndus, V. V. & Rekunenko, V. V. (2011) *Osnovy orhanichnoho vyrobnytstva* [Fundamentals of organic production]. Vinnytsia: Nova knyha, p. 43. (in Ukrainian).

<sup>46</sup> Orekhivskiy, V. D. (2017) *Evolutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», pp. 289–290. (in Ukrainian).

<sup>47</sup> Demydenko, O. V., Boiko, P. I., Blashchuk, M. I., Shapoval, I. S. & Kovalenko N. P. (2019) *Sivozminy ta rodiuchist chornozemu Livoberezhnoho Lisostepu: monohrafiia* [Crop rotations and fertility of black earth of Left-bank Forest-steppe: monograph]. Smila: Chornobaivske KPP, p. 374. (in Ukrainian).

<sup>48</sup> Shuvar, I. A., Sendetskyi, V. M. & Bunchak, O. M. (2015) *Vyrobnytstvo ta vykorystannia orhanichnykh dobryv: monohrafiia* [Production and use of organic fertilizers: monograph]. Ivano-Frankivsk: Symfonia forte, p. 4. (in Ukrainian).

The Association “Bioconversion” has developed new types of ecologically friendly organic fertilizers, which were used in the production of agricultural enterprises of Vinnitsa, Volyn, Ivano-Frankivsk, Kyiv, Lviv, Khmelnytsky regions of Ukraine<sup>49</sup>. In particular, the production and use of biohumus by the method of vermiculture; microorganisms obtained from organic wastes of poultry farms, livestock complexes, leather production by aerobic biological fermentation, microbial associations by composting, liquid fertilizer biostimulators – by cavitation, destruction of straw and other plant residues together with sowing.

The Association “Bioconversion”, based on the improvement of biohumus production technologies for organic waste by vermiculture method, developed and implemented in the farms of the above regions of Ukraine complex humic preparations from vermicompost: aqueous suspensions and vermicompost teas<sup>50</sup>. The technologies of industrial vermiculture of various kinds of organic waste and production of biohumus were of great importance. In particular, technology of production of organic-mineral fertilizers based on biohumus, technology of vermifiltration – utilization of organic waste with the help of heterotrophic organisms, processing of organic waste with higher edible mushrooms, microbiological transformation of organic waste into biogas. The ways of improvement of initial uterine populations of worms and their adaptation to various organic substrates, of obtaining biologically active preparations from the tissues of the organism of vermiculture were determined<sup>51</sup>.

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<sup>49</sup> Orekhivskiy, V. D. (2017) *Evolutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 292. (in Ukrainian).

<sup>50</sup> Shuvar, I. A., Sendetskiy, V. M. & Bunchak, O. M. (2015) *Vyrobnytstvo ta vykorystannia orhanichnykh dobryv: monohrafiia* [Production and use of organic fertilizers: monograph]. Ivano-Frankivsk: Symfonia forte, p. 103. (in Ukrainian).

<sup>51</sup> Orekhivskiy, V. D. (2017) *Evolutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 228. (in Ukrainian).

An example of the introduction of innovative technologies for the ecologization of agricultural production was the long-standing practice of the Private enterprise “Agroecology” in Poltava region under the guidance of NAAS academician S. S. Antonets. In particular, the complex of innovative ecological technologies developed and implemented in the economy included: system of dynamic crop rotations with perennial or annual legumes, post-harvest, after-season and sidereal crops with application of local organic fertilizers and by-products of agricultural crops<sup>52</sup>. This complex provided a permanent vegetation of the soil, which helped to increase the amount of organic matter, ensuring the balance of humus and preventing erosion processes. Dynamic crop rotations provided, if necessary, the replacement of one crop with another, close in biological features, without violating the recommended alternation of crops and the timing of their return to their previous place of cultivation<sup>53</sup>.

The complex of innovative ecological technologies developed and implemented in the economy included the use of soil-protective shallow tillage of soil with mulching, which provided cutting of the root system of plants to a depth of 4–5 cm without its removal from the soil<sup>54</sup>. For this purpose, special cultivators with rigid attachment of stable paws were used to provide adequate depth of cultivation and sufficient pruning of plants<sup>55</sup>. They were equipped with sickle-shaped rods with

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<sup>52</sup> Khodakivska, O. V. (2015) *Ekolohizatsiia ahrarnoho vyrobnytstva: monohrafiia* [Ecologization of agricultural production: monograph]. Kyiv: NNTs IAE, p. 221. (in Ukrainian).

<sup>53</sup> Kovalenko, N. P. (2014) *Stanovlennia ta rozvytok naukovo-orhanizatsiinykh osnov zastosuvannia vitchyzniannykh sivozmin u systemakh zemlerobstva (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Becoming and development of scientifically-organizational bases of application of home crop rotations in the systems of agriculture (the second half of XIX is beginning of XXI of century): monograph]. Kyiv: TOV «Nilan-LTD», p. 343. (in Ukrainian).

<sup>54</sup> Pysarenko, V. M., Antonets, A. S. & Pysarenko, P. V. (2017) *Systema orhanichnoho zemlerobstva ahroekoloha Semena Antontsia [Organic farming system of agroecologist Semen Antonets]*. Poltava: FOP Myron, I. A., p. 20. (in Ukrainian).

<sup>55</sup> Orekhivskiy, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 337. (in Ukrainian).

rigid mounts for better flooding of plant residues into the fields, as well as paws with a self-sharpening effect in the soil<sup>56</sup>. In 2013, these cultivators were patented and introduced into mass production<sup>57</sup>.

The characteristic feature was the introduction of innovative technology for the introduction of organic fertilizers. In particular, together with siderates and plant residues, organic fertilizers of plant and animal origin were used, which underwent certain transformations under the action of organisms<sup>58</sup>. These included: manure, humus, slurry, bird droppings, sawdust, peat, sapropel and composts and more. In order to obtain manure daily on the litter, the animals were daily strawed for better absorption of the liquid fractions. This helped to increase the amount of nitrogen, slower leaching of nutrients, as well as faster development of bacteria needed for its processing. According to the innovative technology, the manure was not plowed and deep wrapped, only mixed with the surface layer of soil. Thanks to the above technology, they reached the most complete nutrient conservation: the humus remained on the surface for a few hours, so it did not dry out, the nitrogen from it did not evaporate and was not washed out<sup>59</sup>.

The farm has developed innovative technology for storing manure in field cages, which provided mineralization of organic matter by soil microorganisms and earthworms. The technology was to form cords with parallel strips of solid straw manure, where a more liquid fraction

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<sup>56</sup> Kovalenko, N. P. (2016) *Evoliutsiia vykorystannia znariad obrobitku gruntu u vitchyznianomu zemlerobstvi* [Evolution of the use of soil tillage tools in domestic agriculture]. *History of science and technique*, vol. 8, p. 136. (in Ukrainian).

<sup>57</sup> Orekhivskiy, V. D. (2018) *Evoliutsiia vprovadzhenia systemy orhanichnoho zemlerobstva v Pryvatnomu Pidpriemstvi «Ahroekolohiia» u druhiu polovyni XX – na pochatku XXI stolit* [Evolution of the organic farming system implementation in PE «Agroecology» in the second half of XX – at the beginning XXI of centuries]. *Hileia*, vol. 130, p. 116. (in Ukrainian).

<sup>58</sup> Stetsyshyn, P. O., Pyndus, V. V. & Rekunenko, V. V. (2011) *Osnovy orhanichnoho vyrobnytstva* [Fundamentals of organic production]. Vinnytsia: Nova knyha, p. 206. (in Ukrainian).

<sup>59</sup> Orekhivskiy, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 340. (in Ukrainian).



was placed between them<sup>60</sup>. A few months later, a strip of straw and liquid manure was rolled up, and a few months later, the bulldozers rolled up the next two cahates to free space. Due to this overturning, the mass was mixed, enriched with oxygen, which stimulated the powerful development of bacteria. The finished baguettes were covered with straw, which protected the manure from drying out and absorbed the vapors of valuable nitrogen. In the midst of the cagata, the activity of microorganisms that mineralized fresh manure organic matter into a plant-accessible form did not cease<sup>61</sup>. Such a substrate became a good environment for the development of earthworms that multiplied and humus were introduced into the fields.

A unique innovative technology was the double fertilization of the soil due to the application of manure after the siderates, the advantage of which was its balance. Manure enriched the soil with macroelements, and mushrooms and microorganisms began to decompose the green mass of the siderates, which acted as a catalyst, and then proceeded to decompose manure<sup>62</sup>. The technology of wrapping the siderates was to simultaneously grind the siderates and loosen the soil<sup>63</sup>. Due to the use of innovative dual fertilizer technology, soil fertility has been significantly improved and product quality has been improved.

An innovative technology of soil protection against erosion was developed in the farm, which consisted of the presence of dense stubble

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<sup>60</sup> Antonets, S. S., Antonets, A. S. & Pysarenko, V. M. (2010) *Orhanichne zemlerobstvo: z dosvidu PP «Ahroekolohiia» Shyshatskoho raionu Poltavskoi oblasti* [Organic farming: from the experience of the PE «Agroecology» of Shishatsky district of Poltava region]. Poltava: RVV PDAA, p. 303. (in Ukrainian).

<sup>61</sup> Orekhivskiy, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 341. (in Ukrainian).

<sup>62</sup> Pysarenko, V. M., Antonets, A. S. & Pysarenko, P. V. (2017) *Systema orhanichnoho zemlerobstva ahroekoloha Semena Antontsia* [Organic farming system of agroecologist Semen Antonets]. Poltava: FOP Myron, I. A., p. 19. (in Ukrainian).

<sup>63</sup> Orekhivskiy, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druha polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 335. (in Ukrainian).

and leaving across the slope of straw rolls, which prevented the washing away of the soil and retained moisture on steep slopes<sup>64</sup>. In winter, stubble delayed the snow, and the snow covered the rolls and strengthened the erosion strips, making the field more secure. To optimize the phytosanitary condition, a set of agro-technical and organizational-economic measures, microbiological preparations were used, economic thresholds of weed, disease and pest control were monitored<sup>65</sup>.

At the beginning of the 21<sup>st</sup> century, these innovative ecological technologies were tested in many years of scientific research by scientists of the agronomic faculty of the Poltava State Agrarian Academy. During the years of their application in Private enterprise “Agroecology”, according to the Poltava Branch of the State Institution “Soil Conservation institut of Ukraine”, humus content – the main indicator of soil fertility and efficiency of innovative ecological technologies – increased by 0.53–1.57%<sup>66</sup>. The soils of the farm were characterized by a sufficient content of the basic trace elements: nitrogen, phosphorus, and potassium. None of the fields in the farm was found to have an excess of heavy metals<sup>67</sup>. Thus, the systematic application of these innovative ecological technologies in the agricultural holdings of Ukraine practically provided the recommended regime of mineral nutrition of the main crops without the introduction of chemicals, contributed to the improvement of the natural environment, increase of soil fertility and growth of production of high-quality ecologically friendly products.

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<sup>64</sup> Khodakivska, O. V. (2015) *Ekolohizatsiia aharnoho vyrobnytstva: monohrafiia* [Ecologization of agricultural production: monograph]. Kyiv: NNTs IAE, pp. 251–252. (in Ukrainian).

<sup>65</sup> Pysarenko, V. M., Antonets, A. S. & Pysarenko, P. V. (2017) *Systema orhanichnoho zemlerobstva ahroekoloha Semena Antontsia* [Organic farming system of agroecologist Semen Antonets]. Poltava: FOP Myron, I. A., p. 73. (in Ukrainian).

<sup>66</sup> Orekhivskiy, V. D. (2017) *Evoliutsiia naukovykh osnov orhanichnoho zemlerobstva v Ukraini (druga polovyna XIX – pochatok XXI st.): monohrafiia* [Evolution of the scientific basis of organic agriculture in Ukraine (the second half of XIX is beginning of XXI of century): monograph]. Vinnytsia: TOV «Nilan-LTD», p. 346. (in Ukrainian).

<sup>67</sup> Pysarenko, V. M., Pysarenko, P. V. & Ponomarenko, S. V. (2017) *Orhanichne zemlerobstvo dlya pryvatnogo sektora* [Organic agriculture is for a private sector]. Poltava: FOP Myron, I. A., p. 12. (in Ukrainian).

## **CONCLUSION**

It can be concluded that in the beginning of 21<sup>st</sup> century, in Ukraine the solution of the problem of development of innovative activity of agricultural enterprises on the basis of using the achievements of scientific and technological progress in ecologically safe production was complex and multifaceted. The introduction of innovative technologies has become an important task for agricultural enterprises and was defined as a promising direction of development, which created a favorable environment for efficient use of resource potential and formation of their competitiveness. In general, the ecological orientation of agricultural production in Ukraine involved the search for such methods of organization of economic activity that provided satisfaction of demand for products of the industry, while simultaneously reducing the negative impact on the environment and promoting sustainable development of rural territories of the country.

Innovative technologies in agrarian production went through four stages: development of innovations, as a framed result of basic or applied research in the form of development or experimental works, their testing and verification, reproduction, and introduction into production. Ecological innovation was the final product of ecologically-innovation activity in the creation, use and implementation of ecologically friendly innovation, which was implemented in the form of ecologically friendly goods, products and services, production technologies, management methods at all stages of production and marketing.

At the beginning of the 21<sup>st</sup> century, innovations in organic agriculture became a component of greening agricultural production. In particular, the production of organic agricultural products using organic seeds and scientifically sound alternation of crops, organic fertilizers, soil protection, biological plant protection products and more. Their systematic application in the agricultural farms of Ukraine practically provided the recommended regime of mineral nutrition of the basic crops without introducing chemicals, helped to improve the environment and to increase the production of high-quality ecologically friendly products.

## **SUMMARY**

The article describes the process of development of theoretical and methodological foundations of ecological innovations in agricultural

production of Ukraine at the beginning of the 21<sup>st</sup> century. It was found that ecological innovations based on resource-saving and energy-saving technologies ensured rational use of the environment while minimizing the negative impact on the environment, as well as the production of ecologically friendly products. The effectiveness of new ecological technologies in agriculture, crop production, soil science, seed production, mechanization and animal husbandry has been determined. Their use has ensured the increase of agricultural production productivity, cost minimization and guaranteed ecology safety of the country's environment.

The effectiveness of practical implementation of ecological innovations in organic agriculture of Ukraine at the beginning of the 21<sup>st</sup> century has been established. Examples of the development of innovative ecological technologies by scientists of research institutions and their effective implementation in certified organic farms of Ukraine are given. In particular, the optimal structure of the acreage and scientifically sound crop rotations based on the point evaluation of the precursors and the periods of return to the previous place of cultivation. The technologies of biohumus production by vermiculture, preparations based on effective microorganisms, and biological plant protection products were important. The efficiency of soil-free shallow tillage of soil with mulching, preparation of sidereal steam, double fertilization due to manure and sideration, protection of soil from erosion has been established. It was found out that their systematic practical application in the agrarian farms of Ukraine provided the recommended regime of mineral nutrition of the basic crops without introduction of chemicals, contributed to increase of soil fertility, improvement of the environment and increase of production of high-quality ecologically friendly products.

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