The Market of Agricultural Biological Products in Ukraine During Martial Law

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神戸学院経済学論集
第56巻　第１・２号　抜刷
令和６年９月発行

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Abstract. *Bionitrogen, biophosphorus, biostimulants, bio-fungicides, bio-insecticides, biorhodenticides and other substances of microbial origin（biological products）are environmentally friendly compared to chemical fertilizers and plant protection products. The use of biological products allows to preserve the ecological state of agro-ecosystems and, accordingly, the environment, including soil, and to produce environmentally safe agricultural products. In Ukraine, the use of biological products in crop cultivation technologies has long been integrated by Ukraine's largest holdings - Kernel, Myronivsky Hliboproduct, UkrLandFarming（Continental Farmers Group）, Epicenter Agro, Astarta-Kyiv, TAS Agro, VITAGRO, and many others.*

After the outbreak of war in 2022, Ukraine saw a significant decline in the biologicals market by an average of 20–30%, but in 2023 it grew by up to 50%. According to the State Register of Pesticides and Agrochemicals Approved for Use in Ukraine, as of May 2022, 126 biological plant protection products from 38 do-

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mestic manufacturers and 117 foreign products from manufacturers in 28 countries were licensed.

The largest domestic producers of biological products are BTU-Center（21 products）, Enzyme（15 products）, BIONASERVICE PLUS（11 products）, and BIONORM（6 products）, "Cherkasy Research and Production Center for Biological Plant Protection（6 preparations）, Institute of Agricultural Microbiology and Agroindustrial Production of the National Academy of Agrarian Sciences of Ukraine（5 preparations）, Institute of Agroecology and Environmental Management of NAAS（3 preparations）. Institute of Microbiology and Virology named after Zabolotnyi of the National Academy of Sciences（3 preparations）. It should be noted that the market of biological products in Ukraine is undergoing significant changes, especially in the category of prescription. As of 2020, the use of inoculants（nitrogen fixers）decreased from 65 to 27.2%, while the demand for biofungicides increased from 27 to 63.5%. This trend is also typical for 2022–2023.

Keywords : *soil, microorganisms, biological products, bacteria, plant protection, biopesticides, bioinsecticides, plants, biofertilizers.*

Biological products in agricultural production are a trend that is gaining popularity in Ukraine and around the world. After the outbreak of the war in Ukraine, the cost of mineral fertilizers, their logistics and use, the loss of some fertile land in the south and east of the country, the environmental disaster with the Kakhovka reservoir and many other environmental disasters became more acute. According to the State Statistics Service of Ukraine, in 2016, the biologics market grew by more than 13%. In 2018, this figure exceeded 38%, and with the outbreak of war in 2022, it fell by 20–30%. However, in 2023, the biologics market is expected to recover by 50%. It is worth noting that in Ukraine, the use of biological products in crop cultivation technologies has long been integrated by the largest holdings in Ukraine - Kernel（390 thousand hectares of land）, Myronivsky Hliboproduct, UkrLandFarming of Continental Farmers Group, Epicenter Agro, Astarta-Kyiv, TAS Agro, VITAGRO and many others.

European Union（EU）programs and international initiatives, such as The European Green Deal and the EU Soil Strategy, also play an important role in popularizing biological products. In particular, the Green Deal is the European Commission's program to combat climate change and build an ecosystem that balances greenhouse gas emissions by 2030. In practice, this means that farmers are required to reduce the use of mineral fertilizers. For example, in Germany, there is a federal law（Düngemittelverordnung, abbreviated as DüMV）on soil pollution protection that prohibits the application of nitrogen fertilizers in the fall. As a result, German farmers are in high demand for nitrogen fixers. In addition, 60–70% of European soils are recognized as being in poor condition. Studies of the agro-ecological state of Ukraine's agro-ecosystems have shown that the soil loses more than 20 million tons of humus formed over thousands of years every year. Thus, the intensification of agriculture and the method of chemicalization disrupts the balance of chains in the ecosystem - in conditions of limited resources for chemicals, there is a negative balance of humus, which is why there is a constant decline in the productivity of arable land. Increasing gross grain production while reducing the chemical burden on the ecosystem was identified as a global problem after summarizing the achievements of twentieth-century agricultural production.

Scientific research shows that only when organic and organomineral fertilization systems are used, the ecological condition of the soil approaches its natural virgin counterparts. The application of organic fertilizers, not only manure, but also green manure, straw and other types of crop by-products, activates soil microbiota, which has a positive impact on the preservation and restoration of soil fertility. It is known that the diversity and physiological and metabolic activity of soil microbiocenosis determine fertility indicators, affect crop yields, participate in the cycles of carbon, nitrogen, phosphorus, sulfur, iron, trace elements, and

soil formation processes, and are the first to respond to changes in weather and anthropogenic factors. Biological products based on different groups of microorganisms have a complex and clearly targeted effect. The most common microorganisms used to produce biological products on an industrial scale are strains of bacteria of the genera *Bacillus, Pseudomonas, Streptomyces, Azotobacter*, and fungi of the genus *Trichoderma*. For example, nitrogen fixation and growth stimulation; fungicidal action combined with growth stimulation and plant protection; improvement of plant immune status and protection; nutrient accumulation, fungicidal action and destruction of substances; nitrogen fixation with phosphate mobilization [1, 2].

The introduction of microbial strains selected for high activity of agronomically useful traits into the rhizosphere and phyllosphere depends on their competitive ability, in particular, undemanding environmental conditions, growth rate and nutrient utilization, and production of biologically active substances. These properties make it possible to replace soil microorganisms that are less active in terms of the desired trait with related but more active ones in terms of plant interaction. It is also possible to replace phytopathogenic microorganisms in their ecological niche, and thus improve plant nutrition and sanitary conditions [3]. A significant positive effect of plant-microbe interactions is the production of phytohormones, vitamins, antibiotics, rhodenticidal and entomocidal toxins by microorganisms that stimulate plant growth and protect them from soil infection, harmful insects, helminths and rodents, thereby significantly reducing the level of chemical pressure on agroecosystems.

By developing a strategy for soil quality, the EU declares that it will strengthen measures to protect soil fertility, reduce erosion, and improve biodiversity. In Europe, in particular, organic farming will account for 25% of all areas by 2030 [4].

Food security and more conscious consumption are driving companies and governments to support sustainable agriculture. The global market for agricultural biologicals is projected to grow at a CAGR of 13.6%, reaching USD 18.9 billion by 2025, with Europe, Australia, and the Americas accounting for the lion's share. Markets in Asia and Africa are also increasing the use of biocontrol products in agricultural practices［5］. The global market for biologics is as follows: the United States produces more than 40% of biologics; China - 35%; and the EU - 25%.［4, 6］.

The United States has the largest sales volume and a wide range of commercially available products. The United States is an example of large-scale commercialization of biological products, and the country has mechanisms to stimulate market entry: a simplified registration system, a system to support the creation of new biomethod agents and the development of commercial forms of drugs and, on their basis, the expansion of the spectrum of action of ready-made forms already on the market. Experts of the DunhamTrimmer consulting company predict the value of the global biocontrol market to exceed USD 10 billion by 2025. The Chinese market of biological products is the fastest growing in the world, with an annual growth rate of 22.4%［6, 7］. This area is also developing intensively in Latin America and Asia.

The global market for biological products has developed more dynamically than predicted and according to "RESEARCH AND MARKETS", the global biopesticides market was estimated at USD 4,550.83 million in 2021, USD 5,311.57 million in 2022, and is projected to grow at a CAGR of 16.89% to reach USD 11,610.10 million by 2027. The global biopesticide market will reach USD 19.85 billion by 2030, growing at a CAGR of 15.6% during 2020–2030. In terms of sales volume, the market will grow at a CAGR of 10.4% in 2020–2030［8］. International organizations are actively working: The Association of Manufacturers of Natural

Biocontrol Products and the Association of Biopesticide Manufacturers. The largest companies Valent Bioscience (USA), Certis (USA), Koppert Biological Systems (Netherlands), Pasteuria Bioscience (USA), Isagro (Italy), Terra Nostra Technology (Canada) produce biological protection products worth more than USD 100 million annually. In recent years, there has been a process of companies merging into associations that strictly divide the markets for biopesticides. The Association of Natural Biocontrol Producers (ANBP), which unites more than 40 companies that produce biocontrol agents, is active in the United States. The Association controls the production and sale of biocontrol agents. Biopesticide Industry Alliance (BPIA) in the United States - unites 22 companies that control the production and sale of biopesticides. In the EU, the most significant is the International Biocontrol Manufactures Association (France), which unites 57 companies that produce biocontrol agents, biopesticides, and pheromones. This association is closely related to ANBP, VIA, and the Japanese Biocontrol Association.

By 1990, there were more than 268 bioprocessing plants and biolaboratories in Ukraine. The use of the biomethod reached 27%. After 1991, about 160 of them ceased operations [6]. According to the State Service of Ukraine on Food Safety and Consumer Protection, as of June 2019, there were 24 bioprocessing plants and biolaboratories in Ukraine [9]. There are no biologics production facilities in Rivne, Zhytomyr, Khmelnytsky, Zaporizhzhia, Dnipro, Luhansk, and Donetsk regions.

It should be noted that the Ukrainian biologics market is undergoing significant changes, especially in the prescription category. The share of inoculants (nitrogen fixers) decreased from 65% to 27.2%. However, the share of biofungicides increased significantly from 27% to 63.5% [6, 9]. Since 2015, Ukraine has been actively producing biological products, and the share of exports has increased accordingly. The increase in Ukrainian production allows to reduce the

share of imports. The National Economic Strategy［10］predicts an increase in the area of land with organic status to at least 3% of the total area of agricultural land by 2030 and an increase in exports of organic products to USD 1 billion.

As of May 2022, the State Register of Pesticides and Agrochemicals Authorized for Use in Ukraine with a valid license contains 126 biological plant protection products from 38 domestic producers and 117 foreign products from producers in 28 countries.［11］. In terms of product range, the largest domestic producers of biological products are BTU-Center PE（21 products）, Enzym SE（15 products）, BIONA SERVICE PLUS LLC（15 products）, BIONORMA LLC, Cherkasy Research and Production Center for Biological Plant Protection LLC（6 products）, and the Institute of Agricultural Microbiology and Agroindustrial Production of the National Academy of Agrarian Sciences of Ukraine（5 products）. Imported biological products are most numerously represented by companies from the USA（ZO preparations）, Argentina（12 preparations）, Hungary（10 preparations）, 14 Great Britain, Italy（6 preparations）, Spain, and the Republic of Belarus（5 preparations）.

A number of scientific institutions are engaged in the production of biological products of various spectra of action, development and adaptation of technical regulations, and search for new bioagents: The D.K. Zabolotny Institute of Microbiology and Virology of the National Academy of Sciences（Kyiv）, the Institute of Agroecology and Environmental Management of NAAS（Kyiv）, the Institute of Plant Physiology and Genetics of the National Academy of Sciences（Kyiv）, the Institute of Plant Protection of the National Academy of Sciences（Kyiv）, the National Research Center “Institute of Agriculture of the National Academy of Sciences”（Kyiv）; the Institute of Agricultural Microbiology and Agroindustrial Production of the National Academy of Sciences（Chernihiv）, and others.

Bio-nitrogen fertilizers based on bacteria that fix molecular nitrogen in the at-

mosphere are able to provide themselves and the biosphere with bound forms of nitrogen, and the only way to accumulate additional nitrogen is to convert it into a specific soil substance, humus. Thus, the global biosphere significance of this process, as well as the agricultural activities that use it, cannot be overestimated.

Nodule bacteria from legumes were the first to be used for biofertilizer production, as they are visually detectable and provide a fairly high level of nitrogen accumulation, in particular, 70–280 kg/ha in soybeans, up to 40–70 kg/ha in peas, up to 200–350 kg/ha in alfalfa in the second year of cultivation, etc. In the United States, nitrogen needs in agriculture are covered by only 30% with mineral fertilizers, 25% with organic fertilizers, and 45% with biological nitrogen. Only for legumes in the United States, Optimaize and Gravex are used, while in Ukraine, Rhizobophyt, Rhizoactiv, Nitrofix, Biomag Soya, and Ecovital are used; in Mexico - nitragin and para-dor, in Uruguay and Argentina - nitrosol, nitrum, atova, New Zealand - risocote, Australia - tropicol-inoculant, noduleit and nitro-jerm, India - ariss agro, Egypt - okadin, Hungary - rhizonite-torfe. Long-term studies have shown that pre-sowing bacterization of legume seeds contributes to an increase in photosynthesis intensity and yield by an average of 20–35% and improves product quality in terms of protein content by 5–6% [12, 13].

Domestic preparations such as diazophyt, diazobacterin and rhizoenterin provide nitrogen to cereal plants while reducing the doses of mineral nitrogen fertilizers by 25–30%. Azotobacterin, Bioplant-K, and Kleps are recommended for increasing the productivity of vegetable crops: tomatoes, cabbage, and sugar beets [14, 15].

It cannot be argued that biological fixation alone will fully solve the problem of nitrogen supply to cultivated plants and the environmental problems caused by the introduction of its mineral forms into the soil. However, the introduction

of biological products into crop cultivation technologies makes it possible to partially replace mineral fertilizer nitrogen with biological nitrogen fixed by microorganisms from the air, which is not only more cost-effective but also environmentally friendly. The problem of using mineral phosphate fertilizers on a global scale is becoming particularly acute in terms of agroecology. On the one hand, they are in short supply and, on average, not enough is applied in Ukraine - about 5–10 kg/ha, and on the other hand, they are a source of heavy metals in the soil. However, most soils in Ukraine have the required amount of phosphorus, but in the form of hardly soluble mineral compounds that are not available to plants and about 85% of total phosphorus in the form of organic matter.

Phosphobacterin, mycoptil, polymixbacterin and albobacterin are domestic products that help transform soil phosphates into a form available to plants [16–19]. The results of the study of the use of various biological products showed that the factors of positive impact on the plant are biologically active metabolic products produced by microorganisms in the environment, primarily phytohormones and vitamins, which also contribute to high yields and high-quality, complete seed for the next harvest. The widespread use of fertilizer biological products in agricultural practice is limited by their incompatibility with most chemical plant protection products against pests. The sanitary condition of modern seed production leaves much to be desired. Despite the prolonged use of chemical crop protection products that pollute the environment and agricultural products, the seed stock of cereal crops is largely affected by phytopathogenic fungi. Therefore, efforts to achieve a high and high-quality harvest only by optimizing plant nutrition will reduce diseases and pests to nothing. Some representatives of soil microorganisms exhibit antagonistic properties to phytopathogens and increase plant immunity, so they are widely used in the world practice [14, 20–22].

Therefore, the use of bioinsecticides, biofungicides, and biorhodenticides is a

mandatory agricultural measure for environmentally safe agricultural production. In Ukraine, biopolycide, trichodermin, rhizoplan, haupsin, bactophytes, lignorin, agate-25K, phytoflavin-300, casumin 2L and chemomics are used against plant pathogens, and bitoxibacillin and lepidocide-BTU are used as bioinsecticides to control leaf-eating pests. All of them are somewhat inferior in terms of effectiveness to chemical plant protection products, but it has been found that, unlike chemical insecticides, bioinsecticides are highly specific and do not destroy beneficial entomofauna, show antagonism to Fusarium and Alternaria pathogens, have less effect on the physiological parameters of plant development, and therefore contribute to the preservation of the crop without degrading its quality and without polluting the soil of agroecosystems with pollutants [23-28].

Rodents cause significant economic losses to the crop production sector: over the past decade, 43% of agricultural land has been infested with rodents, and the number of colonies of mouse-like rodents in some areas is 150 or more per hectare. Rodents cause damage to food and fodder stocks, pastures, fruit and vegetable growing, horticulture, gardening and forestry. To combat rodents (mice, rats, voles, gerbils, and gophers), domestic biological rodenticides such as bacterodencide and antimouse are used.

Given the steady decline in soil fertility, the development of biological products for the destruction of plant organic residues has become increasingly important in recent years. Cellulase destructors contain a number of cellulolytic enzymes, and their use is advisable when straw and green manure are applied to the soil, as well as to accelerate the decomposition of crop residues.

To fulfill the tasks of bioremediation of agricultural soils contaminated with polutants, preparations have been created to accelerate the destruction of pesticides.

Consistent solution of these issues is relevant for the agriculture and crop pro-

duction sectors, which should not only supply the required amount of biologically complete environmentally safe products, but also not cause undesirable negative effects on the environment, which is declared as the main global problem of agricultural production in the XXI century.

Conclusions. The biologics market in Ukraine is actively developing regardless of the martial law. Strong research and development potential and industrial biotechnology production allow Ukraine to be recognized as a significant player in the biologics market not only in Europe but also in the world.

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