BIOLOGICALS HOLD PROMISE FOR SUSTAINABLE AGRICULTURE

– BIOTECHNOLOGY ENABLES DEVELOPMENT OF ALTERNATIVES TO PESTICIDES AND CHEMICAL FERTILIZERS–

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SUMMARY

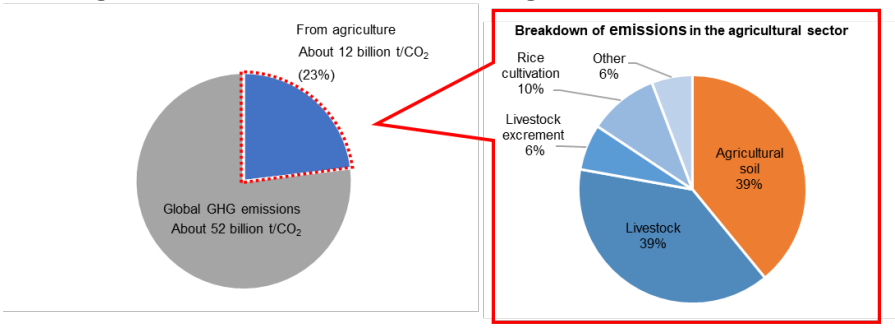
- Agricultural bioproducts such as biopesticides, biofertilizers, and biostimulants are gaining attention as a means to achieve sustainable agriculture.
- Since agricultural bioproducts function differently from existing pesticides and chemical fertilizers, it is important to understand how they work in the production process of agricultural crops.
- The use of agricultural bioproducts is significantly affected by the promotion of smart agriculture. As smart agriculture technologies advance in the future, new businesses are likely to develop, and agricultural bioproducts will perhaps attract even more attention.

1. SWITCHING FROM PESTICIDES AND CHEMICAL FERTILIZERS

Background of the focus on agricultural biologicals

Global population was 7.7 billion in 2020 and is expected to reach 9.7 billion by 2050. This population growth has made it essential to improve crop yields. As a result, the use of pesticides and chemical fertilizers has increased every year: The amount used in 2019 was estimated to be about 1.5 times that of 2002, and the estimates for 2020 are likely to be similar. The impact on the environment has also been cited as a major issue in recent years. Agricultural emissions account for 23% of the world's total GHG emissions. Of that agricultural emission total, agricultural soils account for the largest share, along with livestock (Figure 1). This is mainly due to the dinitrogen monoxide generated from the nitrogen components in chemical fertilizers. Therefore, reducing the use of chemical fertilizers would, in turn, reduce GHG emissions. There are also concerns about the effects of pesticides on the human body. An estimate says that about 390 million people, or 44% of the world's agricultural workers, suffer from acute, if not life-threatening, pesticide poisoning every year.[1]

Figure 1. Global GHG Emissions from Agriculture



Source: Prepared by MGSSI based on the Green Food System Strategy, MAFF, and *Development of Technology for Reducing GHG Emissions from Agriculture [in Japanese]*, the National Agriculture and Food Research Organization

[1] Wolfgang Boedeker et al: BMC Public Health 2020 Dec 7;20(1)
https://pubmed.ncbi.nlm.nih.gov/33287770/ (Accessed on October 5, 2021, same below)

Against this background, the EU has implemented policy measures, as represented by the Farm to Fork strategy established in 2020. This strategy set targets such as a 50% reduction in the use and risk of pesticides and a 20% reduction in the use of chemical fertilizers by 2030, with the 2015–2017 consumption level as a baseline.[2] It has also reviewed its risk estimation method for pesticides and set stricter standards. As the strategy commits to increase the EU's protected area to 30% of the EU's natural environment with a view to improving and conserving biodiversity, it becomes difficult to increase the land area for farming. This brings concern that reduced use of pesticides and chemical fertilizers would decrease crop yields. Biopesticides, biofertilizers, and biostimulants (collectively referred to as "agricultural biologicals" in this report) have been in focus as a solution to this problem. In Japan, the Ministry of Agriculture, Forestry and Fisheries (MAFF) announced the Green Food System Strategy in August 2021, which refers to spreading the use of biopesticides and biostimulants as part of technological development to reduce the use of agricultural chemicals and chemical fertilizers.[3]

Each of the three types of agricultural biologicals had a market size of about USD 2–4 billion as of 2020, with a projected growth rate of about 10–15% per year in the future.[4] Although developed countries, including Europe and the United States, have long adopted agricultural methods using pesticides and chemical fertilizers, some are actively working to protect the environment and preserve biodiversity, seeing an increase in demand for biologicals. These countries are expected to be the main driver to expand the market for agricultural biologicals. Agricultural bioproducts are currently used for crops, especially mass-produced commodities such as corn, but the application is not limited in principle. Thus, the scope will likely expand alongside the progress of research and development. This conflicting issue of increasing crop yields and protecting the environment is expected to arise in the future, not only in developed countries but also in developing ones. It is therefore necessary to closely monitor biologicals as one of the solutions.

2. TYPES AND CHARACTERISTICS OF AGRICULTURAL BIOLOGICALS

2.1. Biopesticides

The definition of biopesticides varies according to the regulations of each country, but the term mostly refers to pesticides manufactured using natural substances such as plants, microorganisms, and biological materials. Biopesticides are used in the form of foliar sprays or added directly to the soil to control the growth of weeds and pests. Compared to conventional chemical pesticides, most of them are toxic only for the pests they target. They have less impact on the human body, and their environmental impact is considered to be small in terms of biodiversity conservation. However, biopesticides have some issues, such as lack of immediate effect and stability.

One of the notable solutions to those issues is the use of RNA, which has also been used in COVID-19 vaccines. This method involves spraying pesticides containing RNA that inhibits protein synthesis in the body and acts only on specific pests. The pests ingest the pesticide and die (Figure 2). GreenLight Biosciences, a US company, has succeeded in developing RNA containing ingredients that kill mites that live on honeybees. This method is

[2] Farm to Fork targets - Progress

https://ec.europa.eu/food/plants/pesticides/sustainable-use-pesticides/farm-fork-targets-progress_en

[3] Green Food System Strategy, Ministry of Agriculture, Forestry and Fisheries

https://www.maff.go.jp/j/kanbo/kankyo/seisaku/midori/attach/pdf/index-47.pdf

[4] Biostimulants Market Size, Share & COVID-19 Impact Analysis https://www.fortunebusinessinsights.com/industry-reports/biostimulants-market-100414

Global Biopesticides Market Size By Type, By Source, By Mode of Application, By Formulation, By Crop Application, By Geographic Scope And Forecast

https://www.verifiedmarketresearch.com/product/biopesticides-market/

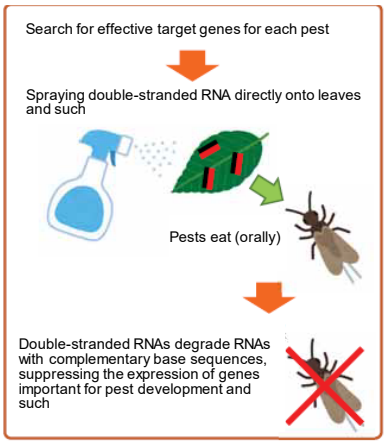
Biofertilizers Market by Form, Mode of Application, Type, Crop Type And Region - Global Forecast to 2026

https://www.reportlinker.com/p04208111/Biofertilizers-Market-by-Type-Microorganism-Mode-of-Application-Crop-Type-Form-and-Region-Global-Forecast-to.html?utm_source=GNW

expected to be highly effective in exterminating specific pests, and development is underway with the aim of expanding it to other insects in the future.

Figure 2. How RNA pesticides work

Development of a pest control method (RNA pesticide) using gene function suppression by RNA (RNAi) method



Source: About the Green Food System Strategy, MAFF
https://www.maff.go.jp/j/kanbo/kankyo/seisaku/midori/attach/pdf/index-7.pdf
(Slide 39)

2.2. Biofertilizers

Unlike chemical fertilizers that directly feed plants, biofertilizers are composed of microorganisms such as algae and fungi, which improve the overall fertility of the soil. These microorganisms promote the growth of crops by changing the components of nutrients for plants, such as nitrogen, phosphate, and potassium, into a form that can be easily absorbed. Although the effect of biofertilizers is not as immediate as that of chemical fertilizers, they can provide nutrients contained in the soil to crops more efficiently in the long term. However, because soil conditions in farmlands vary from region to region and from crop to crop, the types of microorganisms that can be applied vary as well. In addition to this, the difficulty in handling microorganisms poses a storage issue.

Indigo Agriculture of the US analyzes the soil of agricultural land and provides microorganisms suitable for the land. The company coats a seed with microorganisms, which are difficult to store. This enables those microorganisms to work efficiently during the growth of crops. 3Bar Biologics, another US company, has not only seed coating but also a technology for converting microorganisms that are sensitive to dry conditions into powder form and activating them in farmland. The company is working on developing biofertilizer technologies further (Figure 3).

Figure 3. List of major companies developing biofertilizers

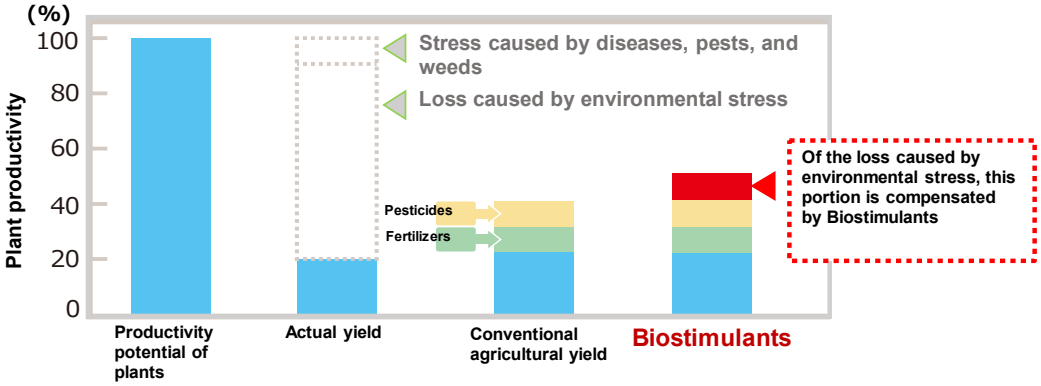
Company	Overview
Locus Agricultural Solutions, US	Explores and sells versatile soil improvement microorganisms. Also plans to increase soil carbon sequestration using microbes. Implemented a carbon credit project in collaboration with Nori.
Indigo Agriculture, US	Collects soil samples from farmland and analyzes them for microflora. Coats seeds with microorganisms optimized for crops and soil and sells the products. Also engaged in the carbon credit business.
Pivot Bio, US	Sprays nitrogen-fixing bacteria during seed coating and sowing to promote high efficiency.
3Bar Biologics, US	Owns a system to extend the life of biofertilizers that contain microorganisms. Collaborates with Pivot Bio.
Azotic Technologies, US	Succeeded in reducing the use of nitrogen-based fertilizer by 25-50% by coating seeds with nitrogen-fixing bacteria (bacteria that fix nitrogen from the air into the soil).

Source: Prepared by MGSSI based on various materials

2.3. Biostimulants

Biostimulants are substances or microorganisms that are used to enhance nutrient efficiency, non-biotic stress tolerance, and/or crop quality to maximize the inherent capacity of the plant. As the term was first used in the scientific literature in 2007, biostimulants are a relatively new category of agricultural biologicals. Using biostimulants is expected to increase crop yields (Figure 4). The specific ingredients and their effects are shown in Figure 5.

Figure 4. Illustration showing yield increase during use of biostimulants



Source: Prepared by MGSSI based on *Agriculture and Horticulture* [in Japanese], Seibundo Shinkosha Publishing Co., Ltd. (https://karuchibe.jp/read/12459/)

Figure 5. Biostimulant substances and their uses

	Use	Humus / organic acid	Seaweed/ poly-saccharide	Amino acid / peptide	Mineral / vitamin	Microbes (bacteria)	Natural extracts
Enhancement/ promotion	Stress tolerance	○	○	○			○
	Metabolism		○	○	○		○
	Photosynthesis			○	○		
	Flower and fruit production			○			○
Adjustment/ control	Transpiration		○		○		
	Osmotic pressure		○	○			
Root activation	Root zone environment improvement	○				○	○
	Root volume increase, root activity improvement	○	○		○	○	○
	Mineral solubilization	○				○	○

Source: Prepared by MGSSI based on the lecture by Atsushi Takagi at the FY2019 Sendai Symposium held by the North Japan Branch of the Society of Biotechnology of Japan

Meanwhile, the active ingredients vary depending on the crop, the growth environment, and other factors. For agriculture in an optimized field, it is therefore necessary to analyze the biome and determine its interaction with the ingredients of the biostimulant. At present, biostimulants can only be applied to tomatoes, which have a relatively high unit price among agricultural crops, and grains such as corn and wheat, which are commodities. Lavie Bio of Israel has a database of 130,000 strains of microorganisms related to plant growth conditions and environmental data. It identifies the most effective ingredients for each farm and provides information to customers.

3. FUTURE OUTLOOK

Smart agriculture and agricultural biologicals

While agricultural biologicals are expected to be a means to achieve sustainable agriculture, they are still in the research and development stage. Currently, their use may lead to a decrease in yields due to a reduction in the use of pesticides and chemical fertilizers. However, the trend to shift to agriculture with less environmental impact is strong, and policy support is being considered for finding solutions. The EU plans to provide EUR 10 billion in funding for research and new technologies to solve problems related to climate change and biodiversity conservation, including agricultural biologicals.[5]

In increasing the use of agricultural biologicals, it will be helpful to clarify what is yet to be technically resolved. Attempts are underway to comprehensively utilize smart agriculture and data obtained using analytical approaches such as omics analysis and phenomics technology. Smart agriculture optimizes agricultural operations based on collected data and yield information, including sunshine, rainfall, temperature, and humidity in the field. Omics analysis is comprehensive for biomolecules in crops, microorganisms, and soil. Phenomics technology enables the analysis of the shape and growth status of plants. If the development and optimal use of these technologies are promoted, agricultural biologicals may become alternatives to, or even be superior to, pesticides and chemical fertilizers. For example, at RIKEN, the introduction of omics analysis into agricultural farms, which had relied on empirical knowledge, made it possible to visualize how the soil microbiota is actually optimized. This provides expectations for developing more efficient agricultural biologicals in the future.[6] It is anticipated that the study of optimal uses will be also promoted.

As mentioned above, research and development of agricultural biologicals is currently underway, utilizing smart agriculture to optimize the amount and timing of use and analytical technologies to accurately determine efficacy. In the future, the smart agriculture business could expand as a total solution, developing the best agricultural bioformulation for each farm and crop and proposing the best time to use it. This may further increase the focus on agricultural biologicals.

[5] Factsheet: From farm to fork: Our food, our health, our planet, our future
https://ec.europa.eu/commission/presscorner/detail/en/fs_20_908

[6] Successful digitization of agroecosystems - Illustrating the importance of soil organic nitrogen in crop production - (RIKEN)
https://www.riken.jp/press/2020/20200609_2/