TECHNOLOGIES TO WATCH IN 2024 (3)

ENVIRONMENTALLY-FRIENDLY ENHANCED EFFICIENCY FERTILIZERS

— ADVANCING TECHNOLOGICAL IMPROVEMENTS FOR SUSTAINABLE AGRICULTURE —

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BACKGROUND TO THE ATTENTION ON ENHANCED EFFICIENCY FERTILIZERS

Chemical fertilizers contain nitrogen, and their excessive use leads to runoff of the nitrogen into the natural environment, causing greenhouse gas emissions as well as deterioration of water quality in rivers and other bodies of water. However, it is unrealistic to grow crops without the use of chemical fertilizers at all. Enhanced efficiency fertilizers (EEF) are beginning to attract attention for their contribution to the stable production of food while reducing environmental impact. EEF are a type of fertilizer that allows for regulation of the rate and duration at which the components dissolve into the soil. They can be classified into three main types, including those that are less soluble in soil moisture and those that are made of water-soluble fertilizers coated with plastic (Figure 1).

Figure 1 Types of enhanced efficiency fertilizers

Chemosynthetic controlled-release fertilizers	Fertilizers with nitrification inhibitor	Coated fertilizers
Fertilizer components gradually dissolve in moisture in the soil and are slowly absorbed by the crop.	Contains an agent that inhibits the action of nitrification by microorganisms, and causes nitrogen to be retained in the soil for a long period of time.	Water-soluble fertilizers coated with plastic etc. The material and thickness of the coating control the dissolution of fertilizer.

Source: Compiled by MGSSI from *Fertilizer Handbook, 6th Edition* [in Japanese] (Rural Culture Association Japan)

EEF have existed since the 1960s, and there has been ongoing technological development to add value, such as through improved performance and reduced environmental impact, in response to changing needs. For example, the U.S. Environmental Protection Agency (EPA) has highlighted the development of EEF as part of its Small Business Innovation Research (SBIR) program.

The use of EEF leads to proper timing and quantity of fertilizer application. For example, it has been reported that when EEF are used in rice paddies, the amount of nitrogen that runs into the natural environment can be reduced by about 30% without reduction of yield.[1] It is also accepted that coated fertilizers can reduce usage by 20% to 30% compared to regular fertilizers, although the exact figure may vary depending on the crop.[2] Additional fertilizer application and other work are also unnecessary, which can improve efficiency. Although

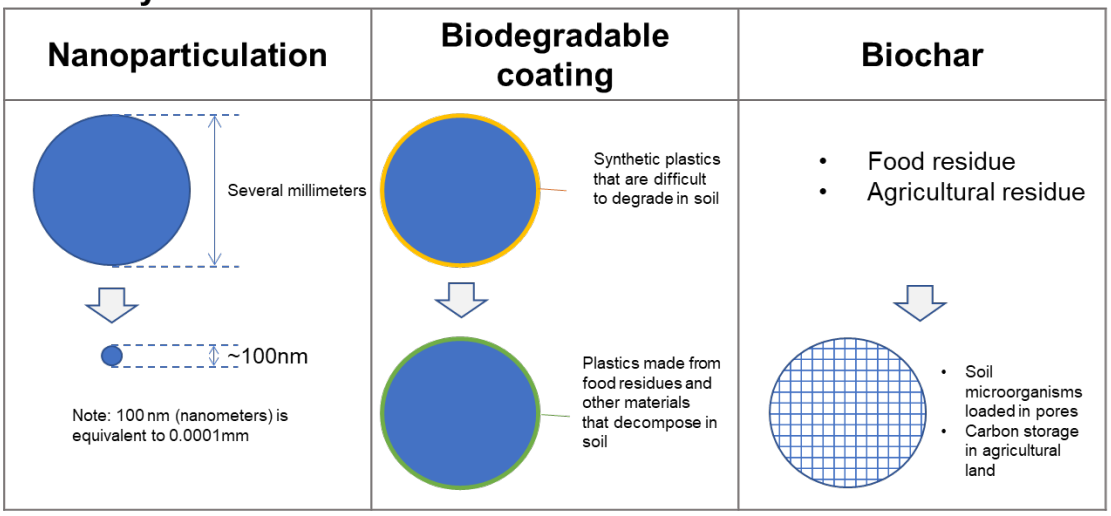
[1] National Agriculture and Food Research Organization website, "Effect of controlled release fertilizer on reducing nitrogen runoff load from paddy fields" [in Japanese]
https://www.naro.go.jp/project/results/4th_laboratory/niaes/2020/niaes20_s10.html#:~:text=%E6%B0%B4%E7%94%B0%E3%81%B8%E3%81%AE%E7%B7%A9%E5%8A%B9,%E6%A0%BD%E5%9F%B9%E3%81%8C%E5%8F%AF%E8%83%BD%E3%81%A8%E3%81%AA%E3%82%8B%E3%80%82 (last accessed: January 4, 2024; same applies to all subsequent links)
[2] Hitoshi Kanno and Takashi Nishio, "Development and future prospects of innovative application methods with resin-coated fertilizer" [in Japanese]
https://www.jstage.jst.go.jp/article/dojo/86/1/86_KJ00010191677/_pdf

EEF are generally more expensive than regular fertilizers,[3] optimization of fertilizer application and other measures are likely to lead to cost reductions overall.

EVOLUTION OF EEF THROUGH TECHNOLOGICAL IMPROVEMENTS

As above, technological improvements of EEF are continuing. The two issues that technological improvements aim to address are (1) further reduction of environmental impact and (2) greater added value. Technologies that address (1) include nanoparticulation and biodegradable coatings, while those that address (2) include the use of biochar (Figure 2).

Figure 2 Promising technologies for solving the issues of enhanced efficiency fertilizers



Source: Compiled by MGSSI

(1) Nanoparticulation

The application of nanotechnology to fertilizers is being attempted. Reducing the size of fertilizer components to the nano level (100 nm or less) enables them to pass through the cell walls of crops and be absorbed faster than conventional fertilizers. For example, it is said that approximately 80% of nitrogen fertilizer applied ends up being lost to the external environment.[4] This technology is therefore anticipated to contribute to resolving such issues.

Typical fertilizers are a few millimeters or larger in particle size. Methods to reduce them to the size of nanoparticles include making the fertilizer itself into nanoparticles, or adsorbing the fertilizer components onto nanoparticles. There are two methods for producing nanoparticles: the "top-down approach," in which a large material is physically reduced to a smaller size by milling or other means, and the "bottom-up approach," in which the material is chemically synthesized by sol-gel method or the like.[5] More energy is consumed in creating the nanoparticles by the top-down approach than the bottom-up approach. In addition, the distribution of particles becomes broader, which leads to issues such as the generation of particles of large size. On the other hand, the bottom-up approach allows for more uniform particles, but since they are produced in a solution,

[3] Although it is difficult to generalize due to differences in composition etc., the price of EEF can be up to three to four times that of regular fertilizers. Ministry of Agriculture, Forestry and Fisheries, "Survey on the State of Agricultural Material Supply" [in Japanese] (September 2021) https://www.maff.go.jp/j/press/nousan/sizai/attach/pdf/210929-3.pdf

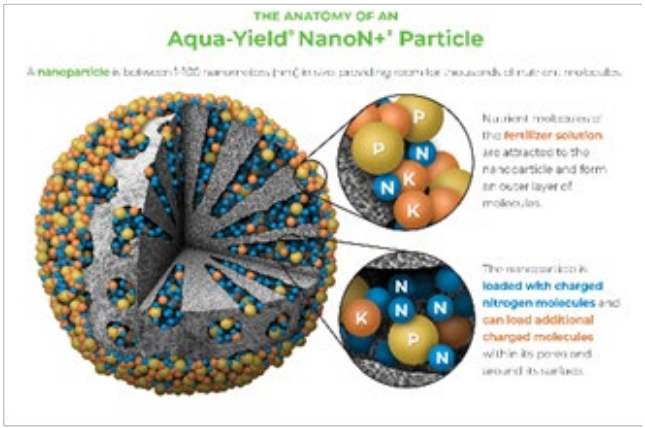
[4] United Nations Environment Programme (2019) "Frontiers 2018/19: Emerging Issues of Environmental Concern" https://www.iges.or.jp/jp/publication_documents/pub/bookchapter/jp/10343/Frontiers2018-19_j_nitrogen_FINAL.pdf

[5] A method of uniformly producing fine particles in a solution by chemical reaction

processes such as drying and powdering become necessary depending on the application. It is important to select a process that is economically rational in line with the application.

Aqua-Yield (US) has developed and is marketing fertilizers made from fertilizer components adsorbed on nanoparticles of 10 nm to 100 nm in size using "nanoliquid" technology (Figure 3). The technology can be applied to biostimulants and agrochemicals in addition to fertilizers. To expand its operations, Aqua-Yield notably received approximately $1.26 million in funding in October 2023 through a program led by the U.S. Department of Agriculture (USDA) aimed at expanding domestic production of fertilizers.

Figure 3 Aqua-Yield's nanoliquid technology



Source: Aqua-Yield website
https://www.aquayield.com/our-technology

(2) Biodegradable coating

Coated fertilizers are fertilizers with a coating of phenolic resin or other materials. They have been used as an EEF since the 1960s. The speed at which fertilizer components dissolve and the duration of effect can be adjusted according to the thickness of the coating.

In recent years, the runoff of coated fertilizer coatings from agricultural lands into rivers and oceans in the form of microplastics has begun to become an issue. Against this backdrop, efforts to replace coating materials with biodegradable materials are gaining momentum. In 2022, three organizations in Japan including the National Federation of Agricultural Cooperative Associations announced a Policy for Efforts to Prevent Marine Runoff of Plastic Coatings from Slow-release Fertilizers, aiming for agriculture that is not reliant on plastic-coated fertilizers by 2030.[6] Also in 2022, Sumitomo Chemical registered a coated fertilizer that uses a resin that is highly degradable in soil.[7] This indicates the commitment of the entire industry to further reduce the environmental impact of coated fertilizers.

Under these circumstances, companies are beginning to offer materials for biodegradable coatings made from food waste and other sources in further consideration of environmental impact. In 2022, Sanyo Chemical announced the development of a coating material using Neoryza, a biodegradable resin derived from rice that is not suitable for consumption as food (inedible rice).[8] Bioweg (Germany) is developing biodegradable plastics using microorganisms that can be used as fertilizer from food residues and other materials in the food supply chain. In November 2023, the company announced a partnership with Bayer (Germany), a major pharmaceutical and agricultural company, for the research and development of seed coatings and coated fertilizer coatings.[9]

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[6] National Federation of Agricultural Cooperative Associations, et al. "Policy for Efforts to Prevent Marine Runoff of Plastic Coatings from Slow-release Fertilizers" [in Japanese] http://www.jaf.gr.jp/pdf/202201_torimatome.pdf

[7] Sumitomo Chemical, "Development of Degradable Coated Fertilizers" [in Japanese] (May 24, 2022)
https://www.sumitomo-chem.co.jp/news/detail/20220524_2.html

[8] Sanyo Chemical Industries "Development of Fertilizer Coating Material Using Neolyza®, a Biodegradable Resin Made from Inedible Rice —Contributing to the realization of sustainable agriculture with covering materials that reduce environmental impact" [in Japanese] (December 1, 2022)
https://www.sanyo-chemical.co.jp/wp/wp-content/uploads/2022/12/k20221201.pdf

[9] Bioweg "BIOWEG and Bayer Forge Collaborative Partnership to Develop New Biodegradable Seed Coatings and Formulation Materials", 16 NOV 2023 https://mb.cision.com/Main/14749/3876449/2432364.pdf

Accordingly, in addition to the use of biodegradable materials for coating materials, there may be a switch to more environmentally friendly raw materials and manufacturing processes for coatings.

(3) Biochar

Efforts are underway to improve fertilizer efficiency by adsorbing fertilizer components to porous materials. Fertilizer components adsorbed to pores in the material move slowly within it and therefore diffuse outward more slowly. This property can be used to sustain efficacy over a long period of time.

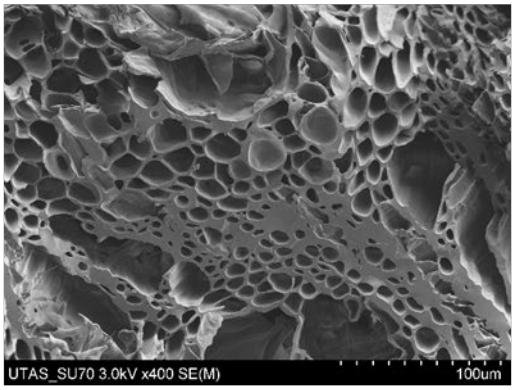
Biochar, which is made by roasting wood and other materials, has recently been attracting attention for this purpose. Biochar is defined as a solid material produced by heating biomass at temperatures above 350°C under controlled levels of oxygen such that it does not burn.[10] If left untreated, raw materials such as wood are decomposed by microorganisms and the like, thereby releasing carbon dioxide into the atmosphere, but carbonizing them to a persistent state enables the carbon to be stored in the soil. In 2020, the application of biochar to agricultural land was approved as part of the J-Credit Scheme.

Biochar is a porous material of natural origins that is traditionally expected to act as a soil improvement material capable of improving water retention and other properties. In recent years, more efforts have been made to add value by loading soil microorganisms that are beneficial to crops into biochar.

bio365 (US) has developed bioCORE, a biochar with very small pores (Figure 4). bioCORE has a structure that is capable of retaining water in its pores. With bioCORE, the company is developing and selling high-performance biochar that combines nutrients and microorganisms.

TOWING (Japan) sells a high-performance biochar called “Soratan,” which is made by carbonizing plant and food residues and adsorbing soil microorganisms to it (Figure 5). In 2023, the company partnered with the Norinchukin Bank to work on value-added fertilizer by linking the network of the bank to the sale of carbon credits.[11]

Figure 4 bioCORE



Source: bio365 website
https://www.bio365.com/benefits

Figure 5 Soratan

Source: TOWING website
https://towing.co.jp/blogs/products/%E5%AE%99%E7%82%AD

[10] Ministry of Agriculture, Forestry and Fisheries, “Methodology for 'Biochar Application to Agricultural Land' in the J-Credit System” [in Japanese] https://www.maff.go.jp/j/kanbo/kankyo/seisaku/climate/jcredit/biochar/attach/pdf/biochar-2.pdf

[11] The Norinchukin Bank and TOWING, “Business Alliance between The Norinchukin Bank and TOWING” [in Japanese] https://www.nochubank.or.jp/news/news_release/uploads/2023/23-28_%E8%BE%B2%E6%9E%97%E4%B8%AD%E5%A4%AE%E9%87%91%E5%BA%AB%E3%81%A8%E6%A0%AA%E5%BC%8F%E4%BC%9A%E7%A4%BETOWING%E3%81%A8%E3%81%AE%E6%A5%AD%E5%8B%99%E6%8F%90%E6%90%BA%E3%81%AB%E3%81%A4%E3%81%84%E3%81%A6.pdf

FUTURE PROSPECTS

EEF are an important material for sustainable agriculture because they help curb excessive use of chemical fertilizers. The next generation of EEF using the above technologies are also likely to attract attention. Although issues of cost and the like remain, use of EEF is beginning in Japan, North America, Europe, and China. If further utilization advances in these regions, cost reductions can be expected. Currently, fertilizer use per unit area is low, and in regions such as sub-Saharan Africa, where population growth is projected from here on, EEF will likely become more widespread, especially for high-value-added crops. The nanoparticulation and biodegradable coating technologies discussed in this paper are also areas of strength for companies that deal with materials. There may be room for companies that hold such technologies to enter the market from other fields, such as by partnering with existing fertilizer manufacturers.

Some companies are beginning to use food residues as raw materials, which is an important initiative from the perspective of the circular economy. However, securing such raw materials is costly in terms of supply chain construction, and stabilizing the quality of raw materials may be a challenge.

Increasing the efficiency of a fertilizer itself is meaningless if the total amount of fertilizer applied is excessive. In order to use fertilizer effectively, for example, a monitoring system combining remote sensing by satellites, aircraft, and drones could be utilized. Fertilizer management would be more effective if EEF could be applied with pinpoint accuracy to plots that are deficient in fertilizer.

In order to make the use of EEF more widespread, it is important to share with farmers the significance of using EEF, in addition to promoting their effectiveness. It will be important to gradually shift to environmentally friendly agricultural materials by utilizing incentives such as carbon credits from biochar and other sources.

TECHNOLOGIES TO WATCH IN 2024 — INTELLECTUAL PROPERTY REPORT —

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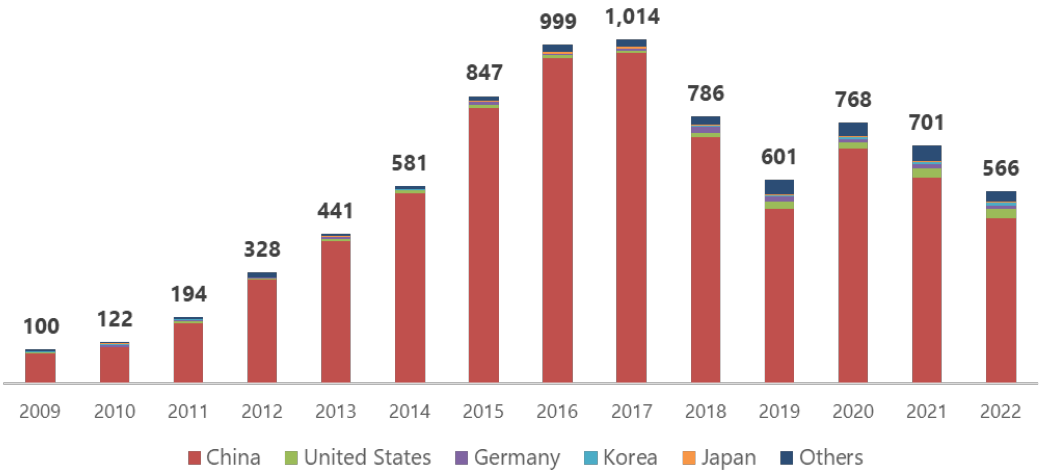
This paper examines, analyzes, and reports on international trends in patent applications related to enhanced efficiency fertilizers, which were featured in Technologies to Watch in 2024. This investigation and analysis were conducted using PatSnap Analytics, a global patent search and analysis tool, and PatSnap Discovery, a search tool for various kinds of technical information, provided by PatSnap. All data was obtained on December 1, 2023.

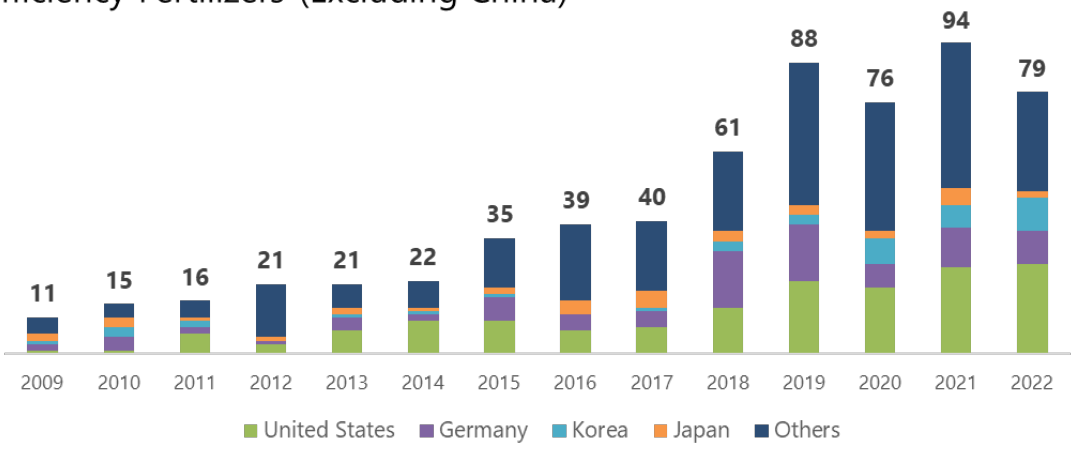
ENHANCED EFFICIENCY FERTILIZERS

Figure 1: Trend in the Number of Patent Applications for High-Efficiency Fertilizers



Source: Prepared by Mitsui & Co. Global Strategic Studies Institute based on PatSnap Analytics data

Figure 2: Trend in the Number of Patent Applications for High-Efficiency Fertilizers (Excluding China)



Source: Prepared by Mitsui & Co. Global Strategic Studies Institute based on PatSnap Analytics data

ANNUAL TRENDS IN PATENT APPLICATIONS

As can be seen from the graphs above, China has the largest number of patent applications related to enhanced efficiency fertilizers, accounting for 92% of the total. Therefore, changes in the number of applications in China have had a significant impact on the overall trend, which has been downward since the peak in 2017. However, excluding China, it can be seen that the number of applications from other countries is increasing. Note that although the graph shows a decrease in the number of patent applications in 2022, it is necessary to take into account the time lag between when a patent application is filed and when it is published. From the data, the final number of patent applications (excluding China) in 2022 is projected to be approximately 112.

With only 2% of patent applications in China also filed in other countries, most applicants seek protection in China alone. For reference, 79% of patent applications in the US are also filed overseas. This ratio is an indicator of how much a country's technology requires protection outside the country and reflects how influential the country's innovation is in the international marketplace.

Patent applications from countries other than China have been filed in various other regions, including Europe, Canada, Australia, Brazil, India, Austria, and Mexico in addition to the applicants' own countries.

TECHNICAL FOCUS

The data on patent applications for 2009 and beyond were analyzed for technical focus.

Various patent applications have been filed for enhanced efficiency fertilizers, with the goal of minimizing environmental impact. For example, inventions have been filed for compositions of fertilizers containing slow-acting nitrogen with the intent of releasing nutrients from the fertilizer over time and reducing runoff into the environment, as well as inventions for new fertilizers that control the release of nutrients, and inventions for novel mixtures of nitrification inhibitors.

Other filings for environmentally friendly approaches include an invention of a urea fertilizer coated with biodegradable polymer, an invention of a bio-based fertilizer coating containing nanoparticles in which the fertilizer particles act as anticoagulants, and an invention of liquid fertilizers made from biodegradable materials. These inventions offer approaches to reduce environmental impact, such as the use of biodegradable materials and the application of nanotechnology. In particular, the number of applications from India is increasing, indicating a growing interest in sustainable agriculture.

REPRESENTATIVE PATENT APPLICANTS

1. BASF (Germany): Minimization of environmental impact by improvement of nitrification inhibitor.

2. JCAM AGRI (Japan): Development of coated granular fertilizer with excellent biodegradability and fertilizer component dissolution control.

3. Koch Agronomic Services (US): Optimization of nitrogen fertilizer through the use of nitrogen stabilizers and calculation.