



Are plant factories the future of agriculture?

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Plant factories are attracting widespread attention as innovative technologies are being developed for light-emitting diode (LED) bulbs. Can plant factories compete and coexist with traditional agriculture? In this roundtable discussion, a leading researcher on plant factories and a representative of a manufacturer striving to develop the plant factory business discuss the advantages and disadvantages of the facilities. Jun Chanoki, a senior consultant at 5 Plus 2 Corporation Ltd., served as the facilitator.

Chanoki: Dr. Toyoki Kozai, Professor Emeritus of Chiba University and President of the Plant Factory Association of Japan, and Masatoshi Miyaki, who works in the Solutions Business Promotion Department of Panasonic Corporation Eco Solutions Company, are here to talk about the potential of artificial-light plant factories, which are being promoted as a form of eco-friendly agriculture. First, could you please explain what a plant factory involves?

Dr. Kozai: Basically, it is a closed space in an airtight building or other structure where plants are grown on tiered shelves under artificial light. In the factory, the concentration of CO₂, temperature, humidity, light intensity, light-versus-dark hours, and other conditions are controlled to help the plants grow faster. Plant factories vary in scale from large ones for commercial use to smaller ones for households. Some factories extend over 1,000 to 2,000 m² with 10 to 20 tiers of shelving, while others can fit on a tabletop.

Chanoki: What is the artificial light source?

Dr. Kozai: Until recently, the major light source was fluorescent tubes, partly because they are economical. Now, LED bulbs are commonly used.

Chanoki: Mr. Miyaki, what is Panasonic's interest in the field of plant factories?

Miyaki: The Panasonic Group is developing technologies for plant factories, determining the feasibility of related businesses, and conducting research. We have not yet launched any commercial products in this field, but have been involved in a nearly 30-year project to grow plants using optical technology. LED bulbs are becoming more economical and their wavelength stimulates plant growth more efficiently than fluorescent lights.

Saving resources

Chanoki: Are plant factories really environmentally friendly and sustainable?

Dr. Kozai: The technology for such factories is still being developed, but they are eco-friendly in that no waste is generated in the crop-growing process. Although the definitions of "chemical-free agriculture" differ, plants can be grown without chemicals in these factories. They also do not waste fertilizer. Unfortunately, a lot of resources and energy are required to set up a plant factory, and we need to increase their productivity to offset that.

Chanoki: Do plant factories save water?



(L-R) 5 plus 2 Corporation Ltd. Senior Consultant Jun Chanoki, Chiba University Professor Emeritus Dr. Toyoki Kozai, and Panasonic Corporation Eco Solutions Company Adviser Masatoshi Miyaki. Photos courtesy of Yuji Ozeki.

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Dr. Kozai: When cultivating leafy vegetables, plant factories consume only 1% or less of the water required to grow them in the field, and 2% or less of that required in a greenhouse. Plant factories are therefore receiving a lot of attention in the Middle East and PR China, where water resources are scarce. About 95% of water is absorbed by the roots and evaporates through the leaves. When a plant factory is cooled to remove the heat generated by the light source, water vapor condenses on the cooling board of the air-conditioner, which can be recycled to water the plants.

Chanoki: Is it true that vegetables grown in a plant factory do not need to be washed before consumption?



Dr. Kozai: Yes. A lot of water is needed to clean field-grown vegetables. The outer leaves are disposed of at harvest or when packaging, and only about 60% of the total weight is actually consumed. In contrast, about 95% of plant factory vegetables, including the roots, can be sold.

Chanoki: Do plant factories make effective use of land and are they productive?

Dr. Kozai: The productivity of plant factories can be increased by optimizing the growing environment

and high-density cultivation. Plants are not exposed to pests, heavy rain, or strong wind, and there is no risk of associated losses. By installing 10 tiers of shelving instead of only one, the cultivation area and productivity increase by a factor of 10 or more. Therefore, the total productivity per square meter can potentially increase by 100-fold or more.

Chanoki: Is their energy efficiency acceptable?

Dr. Kozai: In an artificially lit plant factory, electricity is converted into light and then to chemical energy in the plants. In an outdoor field, the conversion rate of solar to chemical energy is about 0.1% to 0.2%, including losses due to pests and senescence. In a plant factory, the electricity-to-chemical energy conversion rate is estimated at about 11%, but in reality the rate is a maximum of 5% to 6%. The current rate is about 3%, and we expect that to double in future.

In terms of life cycle assessment (LCA), a plant factory saves more resources if it continues operations for more than 10 years. Traditional agriculture uses a lot of energy to operate agricultural machinery and apply pesticides and fertilizer. Field-grown plants need almost twice the amount of fertilizer compared with factory-grown ones. Unexpected weather-related losses also occur.

Miyaki: Yes, field yields can be wiped out by bad weather, but plant factory yields are stable.

Dr. Kozai: Many argue that agricultural products supplied to urban areas should be produced in those areas to reduce transportation costs and eliminate losses during transport. An LCA that takes all these factors into consideration will show that plant factories are competitive with traditional field cultivation.

Reducing CO₂ emissions

Chanoki: CO₂ is a major contributor to global warming and regarded as harmful. Thermal power stations emit high levels of CO₂, but can it be used as a resource in plant factories?

Dr. Kozai: Electricity use peaks during the day and declines at night, which is ideal for plant factories that operate using surplus electricity. Electric power companies are working to reduce peak electricity demand. If they adjust power generation based on peak daytime demand, electricity supply may exceed demand during the night. In most artificial-light plant factories, the lights are switched on only at night, and thus surplus electricity can be utilized. In greenhouses, plants are cultivated using sunlight. The electricity cost for artificial lighting is low but significant amounts of fuel are needed to heat greenhouses. On the other hand, plant factories are closed, insulated spaces with minimal air-conditioning costs and therefore environment friendly.

Benefits to consumers

Chanoki: How do consumers benefit from plant factory produce?

Dr. Kozai: Plant factory produce does not need to be washed, is pest free, and is cultivated without chemicals. Plus plant factory crops contain more vitamin C, carotene, and polyphenols than traditional field crops. Further nutritional improvements can be expected through ongoing research.

Chanoki: Will the market for plant factories expand in the future?

Miyaki: Plant factories represent a new form of industrialized agriculture. They signify a shift from agriculture relying on human intuition and experience to Dutch-style agriculture relying on precise data management. The use of IT and the industrialization of agriculture offer manufacturers and other businesses opportunities to enter this field. Although problems remain, such as uncertainties about the availability of land for next-generation agriculture, I expect the market to increase substantially. Plant factories could



also be established within households, which would involve the creation of completely new demand. For this to occur, consumers must be convinced of the value of plant factories, and the size of that market cannot yet be predicted.

Chanoki: Recently, some sandwich shops in office districts have incorporated plant factories as part of their interior design. If these small factories increase, it could be interesting. Which factors may prevent the expansion of these commercial factories in terms of cost and technology?

Dr. Kozai: First, both installation and operation costs will be reduced by at least half over the first 10 years simply by making combined, optimal use of available technologies. The more important challenge is for consumers to accept the idea. Panasonic is focusing on household plant factories and we need to convince consumers of their advantages.

Huge amounts of food go to waste worldwide, mainly because consumers do not have hands-on gardening experience and do not appreciate how difficult it is to produce food. A household plant factory can give people the opportunity to grow their own food and realize how many inputs are required. This will encourage them to lead more eco-friendly lives. I hope that small plant factories will be established in households, local communities, and universities. I have been researching horticultural and closed plant-production facilities for nearly 50 years because I believe that they will help us lead sustainable lives.

Database of “growth recipes”

Miyaki: We have created what we call “growth recipes,” which are essentially plant growth programs. At each plant factory, we input know-how on growing plants in our database. If small plant factories become popular, the recipes can be collected in a massive database and utilized for the operation of large plant factories. The data can also be used to create new agricultural methods.



Chanoki: The APO has been conducting training in different economic sectors, including agribusiness and food safety, to enhance productivity. Should there be a differentiation between traditionally grown agriproducts and those grown in factories?

Miyaki: We make a clear distinction between them. Basically, staple crops like rice, corn, soybeans, and potatoes should be cultivated outdoors under sunlight.

Dr. Kozai: Some crops are consumed less for energy intake than for functional ingredients, such as leaf vegetables, fruit, and medicinal plants. Others are eaten simply because they are delicious. Artificially lit plant factories are suitable for growing functional plants, and this clear distinction will continue for the next 40 to 50 years. About 80% of the world’s population will be living in cities by 2050, and some believe that perishable produce and crops with high transportation costs should be cultivated in urban areas. Many countries are already committed to urban agriculture. In densely populated countries with little farmland, such as Singapore, this trend is gathering speed. A lecture on plant factories at Chiba University in September was part of an APO project attended by international journalists, including those from developing countries who had never seen, heard about, or felt the necessity for plant factories. Afterward, they agreed that plant factories were necessary, and so I believe that the market has great potential for growth.

Operation of plant factories by farmers

Chanoki: Do any laws or regulations hinder the establishment of large commercial plant factories?

Miyaki: We need to clarify the status and definition of plant factories. It is not clear currently whether they should be classified as “factories” or “farmland.”

Dr. Kozai: Existing systems might hinder their development, but this problem will be resolved over time. The Ministry of Economy, Trade and Industry and the Ministry of Agriculture, Forestry and Fisheries are both involved in the operation of plant factories, and the Ministry of Health, Labor and Welfare oversees medicinal plants. I hope that these three ministries will cooperate to avoid overregulation.

Some problems may originate in the private sector. For example, the efficiency of plant factories cannot be improved through isolated efforts by the construction and home electric appliance industries. All players in the private sector need to cooperate to meet the various challenges, and I believe that this will happen.

Chanoki: At present, publicly listed companies cannot easily participate in agriculture or make use of farmland.

Dr. Kozai: Some critics contend that the spread of plant factories will have an adverse impact on farmers. The number of farming households is already in decline. However, farmers can also begin operating plant factories, and about 100 farming households already are. The role of farmers is changing, and even those operating plant factories are still farmers.

Chanoki: It appears necessary to promote changes in the attitudes of companies, farmers, government agencies, and consumers to spread the idea of plant factories.

Dr. Kozai: Yes, it is critical to deepen public understanding of plant factories. We particularly need help from consumers. From the beginning, Chiba University and the Plant Factory Association of Japan have welcomed the general public and disseminated information on plant factories, including elementary and junior high school students, housewives, and members of consumers’ organizations. Some visited us to protest plant factories. Others mistakenly believed that crops from these facilities were artificial and not tasty. Most changed their minds after hearing our explanations and actually sampling the vegetables.

Miyaki: It is interesting that they completely changed their opinions even before leaving the facilities.

Dr. Kozai: We hold a study seminar on plant factories once a month for anyone who wants to learn more about them. The total number of participants has already reached 5,000. I hope that they will spread the word to others. Meanwhile, we need to continue making steady efforts to educate the public.

Chanoki: Thank you both very much for your interesting input. ☺

Dr. Toyoki Kozai became a professor at Chiba University in 1990 and subsequently served as Dean of the Faculty of Horticulture and President of the university. He is now an Emeritus Professor and President of the Plant Factory Association of Japan. Dr. Kozai received the Japan Prize for Agricultural Science and other awards. His publications include Seeds for Happiness published by Shodensha and books on sunlight-type and artificial-light plant factories, both published by Ohmsha.

Masatoshi Miyaki joined Matsushita Electric Industrial Co., Ltd. in 1984 and subsequently served as General Manager in charge of promoting the environment and maintenance business in the Solution Group of the Customer Create Center at the Electronic Materials Marketing Headquarters. He presently serves as Leader of the Wide-Area Marketing Group, Solution Business Promotion Department, Marketing Division, Panasonic Corporation Eco Solutions Company. He is also a member of the Ministry of Economy, Trade and Industry’s study group on green servicing.

Jun Chanoki worked for some 20 years for HSBC Securities of the UK, Rabobank Nederland, and other international companies in Japan. His positions included securities analyst, food and agribusiness consultant, and human resources development trainer. At present, he is involved in an investment consulting venture focusing on risk management.