

Press Release

The future of crop cultivation?

In vertical hydroponic systems, plants literally grow upward—without soil, with controlled fertilizer input, and in a water-saving setup.

As cities continue to expand, agricultural land becomes scarcer, and climate change progresses, new forms of cultivation are coming into focus. One of these is vertical hydroponic farming: plants are grown on multiple stacked levels, not in soil but in a circulating nutrient solution. This saves space, enables short transport routes, and allows crops to be supplied very precisely. Together with an international consortium, the Fraunhofer Institute for Microengineering and Microsystems IMM developed a multi-ion monitoring system designed to automatically control nutrient input in such closed-loop systems, making the use of water, fertilizer, and other operating resources more efficient.

Precise nutrient control as a key challenge

As efficient as vertical hydroponic systems can be, operating them is demanding. One of the most important tasks is to continuously adjust the composition of the nutrient solution in the closed irrigation loop to the actual needs of the plants.

In practice, operators currently measure primarily conductivity, pH, redox potential, and temperature. While these values provide important information about the condition of the solution, they reveal only limited information about the actual concentrations of individual nutrient ions. Yet this is precisely one of the key factors in optimizing system operation.

Without precise information, nutrients can only be replenished or renewed to a limited extent in a targeted manner. To avoid underfeeding of plants or overloading the solution with nutrients, nutrient solutions are therefore often completely replaced at regular intervals.

This is exactly where the AutoNutri project comes into play. Its goal was to develop a multi-ion monitoring system that enables automated online control of fertilizer input in vertical hydroponic systems. Through feedback-controlled nutrient dosing in closed-loop systems, the nutrient solution can be regenerated precisely. In this way, the consortium—consisting of Fraunhofer IMM, RM Gerätebau, the Institute of Chemical Technology in Mumbai, and HiMedia Laboratories Pvt. Limited—aims to use water and fertilizer more efficiently while also reducing environmental pollution caused by the premature disposal of nutrient solutions.

Keeping track of five nutrients simultaneously

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At the heart of the system is an electrochemical measurement method based on ion-selective electrodes that can detect five different ions directly in the nutrient solution. These ions are particularly relevant to the growth of five crops selected for the project. This makes it possible to see more clearly which nutrients are actually available to the plants and where adjustments are needed.

To this end, the project partners in India investigated five selected crops: lettuce, brahmi, thyme, stevia, and basil. Different nutrient formulations were compared for these plants in order to better understand their specific cultivation requirements. In addition, the crops were also grown in soil to identify differences in growth and nutrient uptake between conventional and water-based cultivation. This provided a more targeted basis for defining the requirements of the measurement system.

For the tests, HiMedia set up an outdoor facility in Igatpuri and an indoor facility in Mumbai. Both sites are sensor-controlled and automated. There, the selected crops were studied under realistic conditions, and the developed components were tested during ongoing operation.

The technical design was also developed with future applications in mind. The system has a modular design, works with automatic calibration, and requires only small sample volumes. Individual components can be replaced when needed. This is intended to make it as easy as possible to integrate the solution into existing facilities and use it in operation. The entire system is controlled by a microcontroller, allowing calibration, sampling, measurement, and data processing fully automated in a continuous workflow. The platform is complemented by a module that automatically adjusts nutrient dosing based on the measured values.

From pilot setup to practical application

An important milestone was the delivery of the prototype to the HiMedia site in March 2025. There, the system was installed and used for testing and validation.

To bring the system into practical use, two commercial farms were selected for beta testing and training: Amrit Agro Hydroponic Farm in Igatpuri, which mainly grows fruiting vegetables such as tomatoes and bell peppers, and Ezzi Hydroponic Farm in Bhiwandi, which grows leafy vegetables and herbs, including basil. Until now, both farms had been working with a commercial nutrient mix. Samples of these nutrient solutions were taken and analyzed at the HiMedia site using the AutoNutri system. This demonstrated how the technology can help control nutrients more precisely and use nutrient solutions more according to actual needs under real-world conditions.

“The system is currently undergoing further testing under real operating conditions. At the same time, we are exploring additional applications where the technology could be used effectively—for example, in wastewater monitoring or for monitoring nutrients in biofermentation systems,” says project manager Rainer Gransee of Fraunhofer IMM.

AutoNutri System to be presented at analytica and IFAT

The AutoNutri System will be presented at analytica 2026 in Hall A3, Booth 312, from March 24 to 27, 2026, and at IFAT 2026 in Hall B2, Booth 115, from March 4 to 7, both in Munich.

Under the topic “How online process analysis technologies (PAT) can improve quality control—from water and nutrient solutions to bioprocess streams,” Fraunhofer scientists look forward to discussing this topic with trade show attendees.

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The BMBF is kindly acknowledged for funding the work within the IGSTC 2+2 program in the project AUTONUTRI, under grant number IGSTC_IND19IGZ1-28.



Figure: Test setup for the AutoNutri system in the Fraunhofer IMM laboratory. The test focuses on online process analysis technologies (PAT), which are used to improve quality control of water and nutrient solutions, as well as bioprocess streams. (© Fraunhofer IMM)

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