GROWERTALKS

Cover Story

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How Far Off (or Far-Fetched) is the Autonomous Greenhouse?

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In the Netherlands, you'll find a small research greenhouse operated by Wageningen University & Research (WUR) that contains six identical 1,033 sq. ft. growing sections. Each contains its own heating, cooling, shading, lighting, fogging, irrigation and carbon dioxide injection systems. Each section is controlled independently by a climate computer to sensors that measure temperature, humidity, CO2, PAR light, pH and EC of fertigation water. And there's a video camera that monitors the crops inside.

Since 2018, teams of researchers from around the world have competed in the "Autonomous Greenhouse Challenge," attempting to grow crops (cucumbers, lettuce and tomatoes, thus far) without any human intervention. They do that by writing computer algorithms that make all the decisions about the greenhouse environment based on the desired outcome (e.g. maximum yield for minimum cost) and the algorithm does the rest, controlling the growing process from transplant to harvest with zero human intervention.

The objective? Bragging rights, of course (it's even better if you beat the control team of expert human growers). But more importantly, it's to better understand how the many variables within a complex greenhouse system interact to affect plant growth, crop quality and resource consumption.

Dr. Silke Hemming, head of the Greenhouse Technology Scientific Research Team at WUR, said these competitions (of which there have been four) have brought the world closer to the fully autonomous greenhouse.

"Letting an algorithm take control of a greenhouse and achieving a full harvest after a few months doesn't yet exist in practice," she stated after the conclusion of the most recent competition last winter. "No grower has fully automated this process. However, specific aspects, such as autonomous temperature control, are already in use. We've demonstrated that cultivation … can be fully autonomous. Of course, there are still many challenges and areas for

improvement, but we now have proof that it's possible to complete a growing cycle with an algorithm."

What it is and why we care

What exactly is an autonomous greenhouse? And why are researchers trying to create it? We asked two experts: Dr. Neil Mattson from Cornell University in New York and Dr. A.J. Both from Rutgers in New Jersey. Neil is professor and greenhouse extension specialist, and A.J. is professor and extension specialist in Controlled Environment Engineering. Both were part of the winning Autonomous Greenhouse Challenge team in 2022, so they know a thing or two about the topic.

"Autonomous would mean able to operate independently without human intervention," Neil offered. "That would be true autonomous. In practice, what I've seen is there are different parts of the process you can automate. At Wageningen and the Challenge, the part that we were controlling was the greenhouse climate and plant spacing. But we weren't automating the processes of transplanting and harvesting and things like that."

And why are scientists pursuing the autonomous greenhouse? High labor costs, said A.J. Neil agreed and emphasized the demand for experienced growers.

"When I talk with operations, they find it's harder to hire really experienced employees that have lots of experience with a given crop. Some industries like greenhouse lettuce are in a big growth phase right now and they can't find enough expert growers … They're trying to use AI as a tool to make life easier for their current grower, who perhaps is in charge of a 5-acre facility, and now with access to these tools can be in charge of 10 acres instead."
Energy savings are another desirable outcome, especially in Europe, where costs are high and margins are thin. A computer can find incremental improvements that a human might miss.

What this AI "tool" that Neil speaks of is doing that an experienced grower can't is analyzing data—lots and lots of data, reams of historical data and gigabytes of real-time crop-growth data, even data from outside the greenhouse, such as energy costs or market prices, and searching for correlations that will result in the optimum greenhouse environment to achieve the objectives set by the grower.

Enter your "digital twin"

The term "digital twin," coined back in 2002, describes a "digital equivalent to a physical system"—a virtual model that mirrors a physical system's properties, behaviors and life cycle using historical and real-time data.

Dwarf tomatoes grown without human intervention during the most recent Autonomous Greenhouse Challenge.
Photo courtesy of Wageningen University & Research.

In horticulture, the digital twin would be a virtual version of your greenhouse, which the AI algorithm uses to process real-time and historic weather, climate and crop growth data to come up with the best climate control settings to achieve the desired outcome. As mentioned above, it can also include data from outside the greenhouse, such as changes in fuel costs or market prices. Combine that with machine learning—where the computer gets "smarter" over time the more data you give it—and you get more optimized decisions as time goes on.

"That's the beauty of this digital twin approach," said A.J. "You make as best you can a representation of the real situation and then you can do a whole bunch of simulations."

For instance, you may want to save energy and are willing to sacrifice some yield or you may be willing to spend more on heating in order to get a bigger harvest to meet demand.

Neil takes the concept a step further, imagining a digital twin of the human grower. Say a grower can manage a 10-acre range and his boss wants to add a second location in another state. Wouldn't it be nice to have a twin to send over there to run it? With AI you can, analyzing the climate data and making recommendations based on all the historical data and machine learning. The grower oversees the process, watching for problems or anomalies—almost like a head grower overseeing section growers. It lets the grower be in multiple places at the same time. Over time, thanks to machine learning, the more it does, the better it gets—just like an experienced human grower.

Currently, as AI systems are being developed, they're working through standard environmental control computers, not replacing them. A leader in the field is Koidra, founded by Dr. Ken Tran, a multi-time winner of the Automated Greenhouse Challenge (Neil and A.J. were on his winning team in 2022). Koidra's two products, DataPilot (for analyzing the data) and KoPilot (a setpoint optimizer), integrate with existing environmental control systems, so you don't have to do a complete system overhaul to utilize this new technology. And it's a safe bet that leading environmental control suppliers are or will be working on their own AI software. All of this advanced technology is likely to be cloud-based and subscription-based.

The path toward full autonomy

As quickly as AI technology is coming into our lives, we can't expect an AI revolution in a small market segment like greenhouse agriculture. But we can expect evolution—implementation of AI into our environmental control computers on a small scale and then regular upgrades as the technology advances. Some vegetable growers, such as Canada's DC Farms and Great Lakes Greenhouse are trialing Koidra's product and seeing impressive results (a 5% increase in eggplant yield at DC and a nearly 20% yield increase in cucumbers at Great Lakes). So when will growers talk about their AI modules as casually as they talk about energy curtains and robotic cutting stickers?

"I think within five years we're going to see a lot more mainstream adoption of AI climate control," Neil forecasts. "And I say that because we're already in the early adopter stage." (Such as with DC Farms above.)

"The question is, can we do this economically?" A.J. asked. "And that is still up in the air. We have the technology … but is this profitable for a grower in a commercial environment? That, I think, is the big question."

Which brings up the question of cost. While we weren't able to pin down what it'll actually cost to subscribe to an autonomous growing system, will that cost be justifiable based on the savings or increased revenue a greenhouse might see? Certainly, greenhouse-grown produce is only becoming more common and prices are predicted to go down, not up, so companies like Koidra need to sharpen their pencils.

And what about the truly growerless greenhouse, where anyone can grow a crop by pushing a button? Will that ever come to fruition? Neil said that's an economic question, not a technical question.

"I suspect if we threw enough money at this problem—if we put a billion dollars in—we could probably develop, at least within bounds for specific crops, an AI greenhouse that worked pretty well," he said. But the key question is, "Is the crop economically important enough to invest all these resources to automate every step of the process?"

Which raises another question: Which crops are most suited to autonomous growing? High-dollar crops such as vegetables, pharmaceuticals, possibly young plants. And monoculture crops, where the environment is optimized

for a single variety rather than having to find a compromise between what a petunia needs and what a geranium needs.

Job security

Should growers worry about losing their jobs to a computer? No, said both A.J. and Neil, for one simple reason: Plants are biological systems, with random variations that can't be accounted for by computer algorithms. Because of that, humans will always be needed to establish the desired outcomes, oversee the growing, watching market trends and tweaking the algorithms for new varieties. Plus, things go wrong in a greenhouse—fans quit, pumps burn out—and AI can only inform you of a failure, it can't (yet) fix it.

"I don't think the human factor will disappear," said A.J. "It will change. But there will still be a person who makes the ultimate decisions about what crops we're going to grow and what varieties we're going to select and what kind of yield we are trying to aim for."

"There's no substitute for someone observing what's happening in a greenhouse," said Neil. "Maybe someday we'll get there, but for right now, human eyes that know what plant issues look like can detect things pretty well. I think the future is bright. We don't have enough good growers." **GT**