Low-heat full-LED tomato trial achieves 50% reduction in heat

Efficient

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LED lighting is an energy-efficient lighting solution, and comes with a low radiant heat output. Therefore, when tomato growers switch to full-LED systems, they often find themselves requiring a different heating approach. To help growers find a solution for cultivating a full-LED winter lit crop with a low heat input without impacting on yield or quality, Philips Horticulture LED Solutions and Grodan ran a joint trial at Botany Research Center, the Netherlands. The trial, which used active air dehumidification, has demonstrated that controlling and optimising all the aspects in a greenhouse enables a lower heat input to be realised while enabling sufficient transpiration to support strong and healthy crop production. In fact, the final results were even better than expected: the heat input was reduced by more than 50%.

Due to high energy prices and the rising importance of sustainability, growers are under ever-greater pressure to decrease their heat input. However, a switch to a full-LED cultivation system risks conflicting with this, since LEDs produce significantly less radiant heat than other lights. Therefore, growers often need to add extra heat from other sources – such as grow-pipe heating –and to adjust their heating strategies. "We realised that if we truly want to take the next step in energy efficiency, it's not enough to focus on just one cultivation factor. For optimal results, it's necessary to control a crop's irrigation, the nutrient recipe, the climate as well as lighting strategies. After all, if you adjust one of these, it has an influence on all the others, so we decided to take a holistic approach together with Grodan," says Erik Stappers, Manager Plant Specialists Vegetable & Fruit for Philips Horticulture LED Solutions.

"Next-Generation Growing, which is focused on increasing energy efficiency in the greenhouse horticulture sector, reminds us of this fact," agrees Andrew Lee, Green Knowledge Manager at Grodan. "But in the past, energy-related trials have tended to focus on just one single aspect. That's why we were happy to run this trial together with Philips Horticulture LED Solutions. We're also grateful to the other partners – Ridder, Normec Groen Agro Control, BASF Nunhems and Wireless Value – for contributing their technology and expertise."

Key results thanks to a holistic approach to growing with full LEDs and active air dehumidification

- Over 50% less heat input compared to commercial practice
- Increased production efficiency in g/kWh and EUR/kg
- A very stable climate, facilitating predictive water uptake and additional possibilities to steer the veg/gen balance in the crop
- Monitoring the uptake of individual nutrient elements opens up new steering possibilities in optimising nutrient recipes

Technical details of the trial	
Duration	30 weeks (from Week 39 in 2023 to Week 17 in 2024)
Lighting	Philips Greenpower top lighting compact at 300μmol/m²/s
Substrate	Grodan GT Master 10cm 3 Plantop Delta blocks/slab
Data capture	GroSens sensors
Dehumidification	Air/air heat exchanger (max. capacity: 15m³/m²/hour)
Nutrient & EC strategies	'Standard' nutrient strategy: 22mmol/l NO3 'Adjusted' nutrient strategy*: 14mmol/l NO3
Cultivar	BASF/Nunhem's Vitalion at an initial stem density of 4.1/m² (increased to 4.6/m² and 5.0/m² in Weeks 50 and 52, respectively)

"We started by establishing a baseline of the minimum heat needed by a typical commercial grower, and then we aimed to reduce that by 40% – not only to help growers make important savings on their energy costs, but also because this is better for the environment," explains Stappers.

"At the end of the trial, we were very happy to see that we had actually achieved more than a 50% reduction in the amount of heat required: rather than our baseline gas consumption of 22.5m³/m² over 30 weeks, our low-heat approach only used 10.7m³/m² of gas (see Figure 1). While the mild winter helped us a little, the majority of this saving was a direct result of our integral approach."

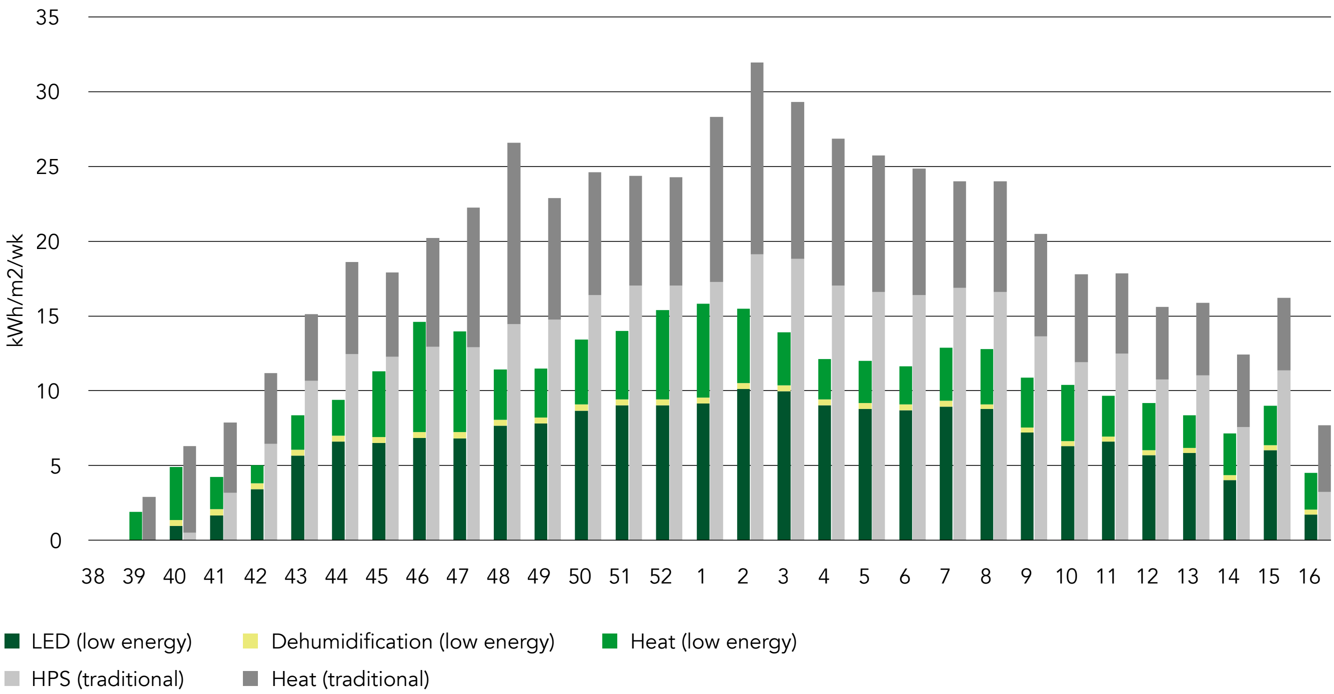

Figure 1. Energy efficiency comparison between low-energy approach and traditional.

The dynamic relationship between lighting, screening and dehumidification

"We used top lighting with our optimal tomato spectrum, and the dimmable LED lights were either switched on or off in this initial trial. The desired light sum goals were reached with a capacity of 300μmol and the plant activity was sufficient," continues Stappers.

In combination with the use of LEDs as a low-energy source of artificial light, one way to retain the heat in the greenhouse and therefore save further energy is to keep the climate screens closed. In the trial, the screens were kept completely closed for a total of seven weeks in the winter. This is in contrast to commercial growers, who have to open or 'gap' the screens for at least a couple of hours every day to avoid excessive humidity that could potentially cause issues with plant health and fruit quality. As a solution to this, an active air dehumidification system was installed.

This also gave Grodan the opportunity to understand the impact of active air dehumidification on plant transpiration in a low-heat input cultivation. The company's GroSens sensors were used to monitor all the relevant data, including water content (WC%) and electrical conductivity (EC) in the growing media.

"We wanted to focus on gaining knowledge about creating the optimal climate so that we can help growers to get the very best out of our lighting solutions. Therefore, we also set out to find the sweet spot between the light sum and temperature: the Radiation and Temperature Ratio (RTR)," says Stappers. "By focusing on the RTR, we learned how the active dehumidification system could fit into the crop steering strategy: not just to regulate humidity, but also as a tool for creating the ideal conditions for growth. However, because we kept the greenhouse so 'closed' in terms of vents and screens, we had to maintain a higher RTR compared to normal practice," he adds.

The trial demonstrated that a stable climate created by LEDs in combination with active air dehumidification facilitates an equivalent water uptake per mol of light compared to a full-HPS or hybrid LED system without active air humidification.

"Plants need a certain level of activation to keep the transpiration going," states Lee. "Extra radiant heating from pipes wasn't an option in the trial because that would increase the energy consumption, and there was no radiant heat coming from the sun in the winter. By creating air movement, the active dehumidification system stimulated convection and therefore transpiration," he adds.

This resulted in a water uptake of 0.11-0.12l/m²/mol of light. "That is comparable to the level we would expect in a conventional greenhouse," states Lee. "Moreover, the water uptake was more predictable. When the screen was closed and the lights were on, the greenhouse climate was so stable over 24 hours and between days. These guaranteed conditions meant that the irrigation could run like clockwork. It was easy to predict precisely how much irrigation to give, because the greenhouse climate was very stable. Every day was the same; all we had to do was look to the GroSens data to ensure we matched water uptake with transpiration."

The importance of drain analysis

Another objective for Grodan over the 30 weeks was to highlight the differences between EC measurements in the root zone and in the drain – both of which are important drivers for decision-making. The company's GroSens sensors were also used to monitor this data as the basis for analysis and decision-making.

"A lot of growers steer on the EC measurement in the drain, but that can be a lot higher than the EC in the slab itself, especially at low (<20%) drain volumes. In our trial, the average drain EC was 8.1mS/cm, whereas the average slab EC was just 4.4mS/cm," comments Lee (see Figure 2). "Focusing on the drain EC in a low-heat-input cultivation can lead to over-irrigation. That makes the crop more vegetative rather than generative, reducing the production potential and increasing the risk of diseases such as *Botrytis*."

"In the trial, we demonstrated that the precise control offered by our growing media in combination with our sensors means you don't need to chase a certain drain volume. By aligning the irrigation period with the lights-on and lights-off times, and matching the volume and frequencies to the uptake based on the GroSens data, we achieved an average drain of just 8% over the 30 weeks," he continues.

"Even with these low drain volumes, we were still able to keep the EC in the root zone stable. It is particularly important to avoid irrigation inefficiencies in a low-heat strategy, because if you put excess water in you have to use extra energy to extract it again. I can imagine a future in which the irrigation focus should be based on plant uptake rather than drain volumes. By definition, drain is a sign that you've over-irrigated," adds the Green Knowledge Manager.

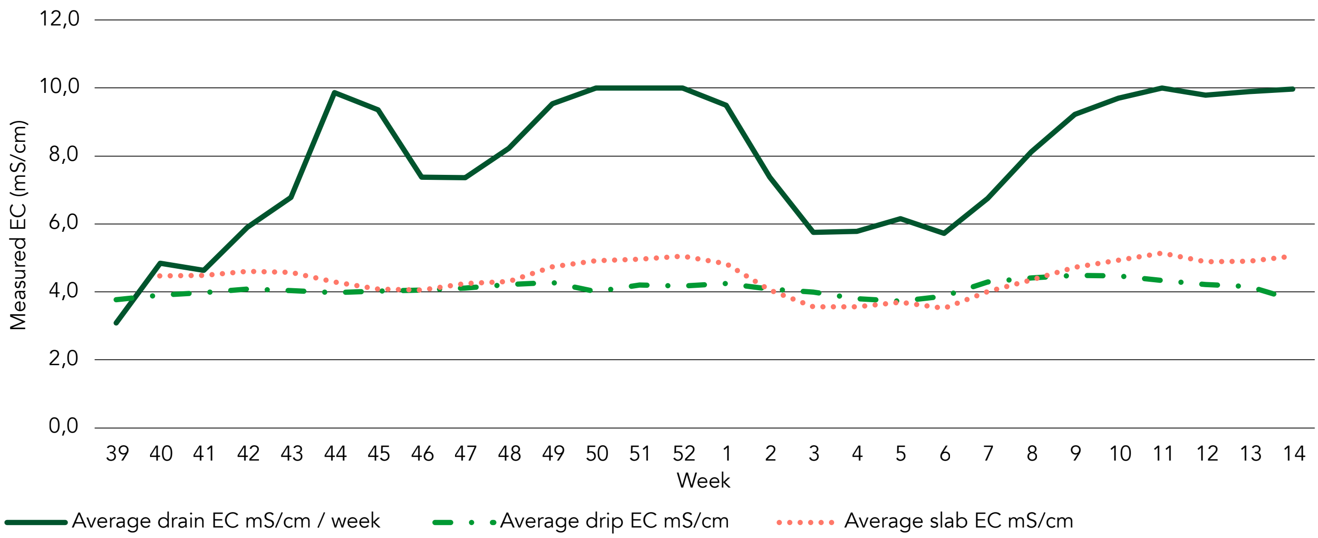

Figure 2. Weekly average irrigation, slab and drain EC (mS/cm)

How to stimulate transpiration
Challenge
How to achieve sufficient nutrient uptake and the right plant balance, fruit size and Brix in the fruits?
Possibilities
• **Stimulate transpiration** Consequence: extra energy is needed • **Modify nutrient composition** Higher part potassium (K) Higher part nitrogen (N) **Consequences for manipulation of nitrate levels (NO3):** Influence dry matter content of the crop Higher NO3 = higher fresh weight (LAI) Conversely, lower NO3 = lower fresh weight (LAI) Higher NO3 = higher fruit weight Conversely, lower NO3 = lower fruit weight Higher NO3 = Lower Brix. Conversely, lower NO3 = higher Brix
Needed
The right nutrient composition: Determination of optimum magnesium (Mg), potassium (K) and calcium (Ca) levels in the drip water

Table 1. How to stimulate transpiration

Steering on nutrient uptake

The trial also explored the effect of the nutrient recipe on plant growth and development. For example, for the first seven weeks of the cultivation, two nutrient recipes were applied: a standard strategy of 22μmol/l of nitrate (NO3), and an adjusted strategy of 14μmol/l of NO3. "To put this into context, a lower nitrate concentration should result in plants with a lower leaf area index (LAI) and therefore an extra generative plant balance," comments Lee. "Additional benefits would be a higher dry matter percentage (DM%) in the plant and therefore fruit with higher Brix values."

"However, and most importantly, by monitoring and adjusting the balance of individual nutrient elements, we did not compromise the uptake of the cations (potassium, magnesium and calcium) that are important for plant growth and fruit quality with the lower nitrate recipe," he explains. "All this is possible because the stone wool growing medium has no cation-exchange capacity. Therefore, we can adjust not only the slab EC but also the balance of individual nutrient elements very quickly based on plant demand."

Crop performance

"We are happy with the total production level; we achieved an average production of 0.63kg/m²/wk during December and January, which was in line with our expectations. The light use efficiency was also good. Overall, this approach was 50% more energy efficient per unit of production than conventional methods," states Stappers.

As hypothesised, the reduced nitrate input from Week 46 to Week 2 resulted in a crop with a higher DM% and, as a result, higher Brix values in the fruit at the start of the harvest. The trade-off was a slight reduction in fruit weight, but still within the target range. The team then started pushing the boundaries with the nutrient recipe and also increased the plant density. "Although this caused the Brix to fall again, it gave us clear learnings about how we could potentially make a trade-off between Brix and fruit size," he adds (see Table 1).

The most surprising outcome was that the development speed of the plants was 10 to 12% higher than initially anticipated. "We expected our higher temperatures to increase the development speed a little, but we achieved 37 trusses in 30 weeks, which equates to 1.23 clusters per week – much faster than in conventional growing," comments Lee. "This could offer a higher production potential, but we first need to further explore the consequences for the stem density strategy – so further research is needed."

Looking ahead

Rooted
in science

The team members already intend to extend the joint trial from September 2024 to April 2025. This will allow them to push new boundaries as the basis for making new discoveries and further fine-tuning the low-heat strategy. “We are looking forward to building on this experience to gain an even better understanding of how all the factors in low-heat cultivation interact to impact on the uptake of water and nutrients. These include the lighting strategy based on spectrum-controllable LEDs and optimising the use of a daily light integral (DLI) controller; the irrigation strategy based on stone wool growing media; the nutrient recipe; and the climate strategy, including screening and active air dehumidification. We will continue to share our insights aimed at helping growers to use this knowledge for their benefit during the lighting season,” says Stappers.

Lee adds: “Back in the year 2000, the industry set out a vision for energy reduction. We’ve gone from 60m^3 gas per m^2 per year then to 30m^3 gas per m^2 per year today. And we remain committed to continuously evolving the way we grow by further enhancing the sustainability performance in high-tech greenhouse production systems. We are guided in this by the Plant Empowerment principles, which look to nature itself to find the solution for sustainable cultivation to achieve optimal results with less resources. In this trial, thanks to a holistic approach, we’ve now demonstrated that a further 50% reduction in heat input is possible, and 15m^3 gas per m^2 per year is within reach in conjunction with active air dehumidification.”

“We’ve shown that the combination of vents closed, screens closed, low-energy LED lights and active dehumidification not only offers considerable energy savings, but also makes generative climate control and crop steerability easier. We believe that these findings mark a new dot on the horizon that will help the industry as a whole to continue to move forward. The main question now is how quickly that will happen,” he concludes.

Follow us

Follow us on social media to receive updates about future trial plans and participate in the discussion about low-heat tomato cultivation. If you have any questions, contact our technical experts:

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Designed to grow

Grodan is the global leader in supplying soilless rootzone management solutions for Controlled Environment Agriculture. These solutions are applied to the cultivation of vegetables and flowers, such as tomatoes, cucumbers, sweet peppers, egg plants, roses and gerberas.

At Grodan, we aim to help feed and treat the world's growing population by innovating solutions from our stone wool growing media to enable 'more-with-less' growing. Through the method known as out-of-soil, our stone wool substrates, sensor systems, software and expertise support the reliable, informed growing of healthy, fresh, high quality produce. Our material is 100% recyclable, and supports growing methods that use up to 50% less water, 20% less chemical plant protection products and 75% less land. Sustainability plays a prominent role within Grodan, from manufacturing stone wool substrates to creating recycling solutions and services.

Grodan has more than 50 years of cultivation experience. We pioneered the development of hydroponic growing methods in the 1960s, and today, our soilless rootzone management solutions are used in large-scale commercial greenhouses and indoor facilities in over 70 countries across the globe. The head office is located in Roermond, the Netherlands.

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