PHILIPS

Low-energy growing is today's new reality

3-year joint research trial confirms energy savings and quality benefits of a holistic approach to lit tomato cultivation

In the third and final year of their joint low-energy tomato trial programme, Grodan and Signify – together with other industry-leading partners (Ridder, Wireless Value, Normec Groen Agro Control, and Axia Vegetable Seeds) – have shown that growers of both cherry tomatoes and larger truss tomatoes with a full-LED setup can already start implementing a low-heat approach to reduce their energy costs while benefiting from improved yield and quality. The key to this lies in applying a holistic approach to all aspects of cultivation – lighting, irrigation, nutrition and climate management – to create a stable and predictable greenhouse environment. In combination with additional highly efficient insulating screens, the use of active air dehumidification saves at least 50% on heat input. Combining LED interlighting with LED toplighting further improves the light use efficiency (LUE) of the crop, boosting the development speed and increasing fruit weight to contribute to a 10% higher yield. In the root zone, the nutrient recipe – rather than EC alone – can be used to steer the generative plant balance by managing the leaf area index (LAI). Moreover, adjusted nutrient ratios – supported by uptake analysis – significantly reduce incidences of blotchy ripening in the Macxize cultivar compared to practice. This paves the way for even more precise irrigation in line with plant demands.

Focus area

Strong results were achieved with the cherry tomato cultivar Vitalion in the first two years of the research programme initiated by Grodan and Signify's Philips Horticulture LED Solutions. Building on this in year 3, the partners set out to show that also the larger truss tomato cultivar Macxize can be grown successfully with reduced heat input in a full-LED setup. The technical setup, including the use of an active air dehumidification unit and advanced thermal-insulation screens, remained largely the same. The main changes in year 3 of the research trial were:

- **Lighting and climate control:**
  - Increasing the LED light level to 350 µmol/m^2/s in line with the industry trend towards higher light levels in the Netherlands
  - Combining LED interlighting and toplighting with the aim of increasing production by 5-8%
  - Temperature adjustments in relation to the additional light

- **Irrigation and nutrient management:**
  - Restricting nitrate concentrations to steer generatively rather than steering on a higher irrigation EC
  - Experimenting with adjusted nitrate, potassium and calcium ratios with the aim of reducing blotchy ripening (green spots) while maintaining target fruit weight (150 g)

Key takeaways about low-energy growing

The results confirm that low-energy tomato cultivation is possible based on a holistic approach:

- Yield: Combining Philips GreenPower LED toplighting with Philips GreenPower LED interlighting delivers a 10% yield increase vs Philips GreenPower LED toplighting only
- Nutrient steering: Adjusted nutrient schedule supports generative plant steering by creating a lower leaf area index (LAI). In combination with adjusted potassium concentrations, this also decreases problems with blotchy ripening in the Macxize cultivar
- Analysis: Nutrient uptake analysis opens up new avenues for precision steering in the root zone
- Crop stability: A data-driven approach to screening, heating and lighting strategies supports greater crop stability, leading to more predictable and uniform growth and production, while also delivering additional energy savings

Technical details of the trial	
Duration	30 weeks (from Week 39 in 2025 to Week 16 in 2026)
Lighting	Two light strategies of 350 µmol/m²/s: 1. Philips GreenPower toplighting force deep-red, white, low blue with colour control. 2. Philips GreenPower toplighting force deep-red, white, low blue dimmed to 247 µmol/m²/s + Philips GreenPower LED interlighting, providing an additional 103 µmol/m²/s
Substrate	Grodan GT Master 10cm with 3 Plantop Delta blocks/slab
Data capture	GroSens, Ridder and Wireless Value sensors
Dehumidification	Air/heat exchanger (max. capacity used: 12m³/m²/hour)
Nutrient & EC strategies	1. Reference: 3.8 mS/cm 2. Adjusted: 3.1 mS/cm for managing blotchy ripening (green spots) The adjusted nutrient strategy had a higher potassium concentration (higher K/N and K/Ca ratios)
Cultivar	Macxize (Axia Vegetable Seeds) at a stem density of 3.73 stems/m² from the start

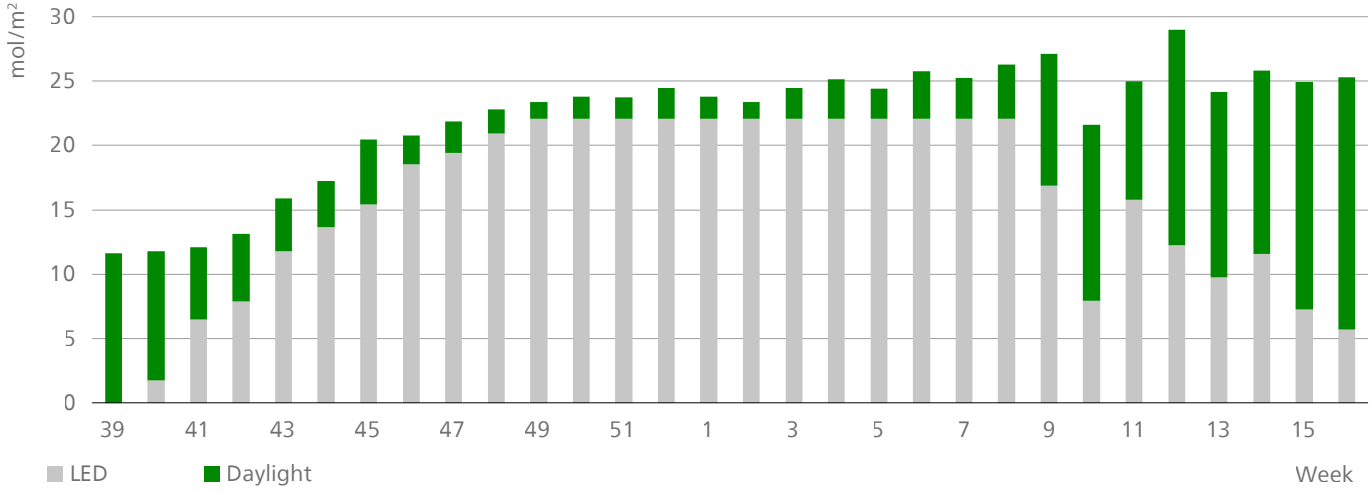
In detail: lighting

The challenge of balancing light quality, temperature and humidity

In line with the industry trend towards higher light levels, the LED light level was increased from 300 µmol/m²/s to 350 µmol/m²/s in this year's trial. To maintain the desired Radiation to Temperature Ratio (RTR), it was therefore also necessary to increase the temperature setpoints, meaning that the average 24-hour temperatures in the greenhouse were slightly higher overall compared to previous years.

In combination with the insulating double screens from Ridder, which were kept closed as much as possible to save energy, the extra light and higher temperatures created more humidity. This is where the active air dehumidification unit came in. "Humidity control was even more of a focus than last year. By fine-tuning the dehumidification setpoints in the Ridder Hortimax Pro climate computer, we succeeded in stimulating evaporation and therefore the plants' water and nutrient uptake while maintaining absolute humidity in the greenhouse at defined control points," explains Marcel Raats, Plant Specialist at Philips Horticulture LED Solutions.

Graph 1. Average DLI (daylight integral)



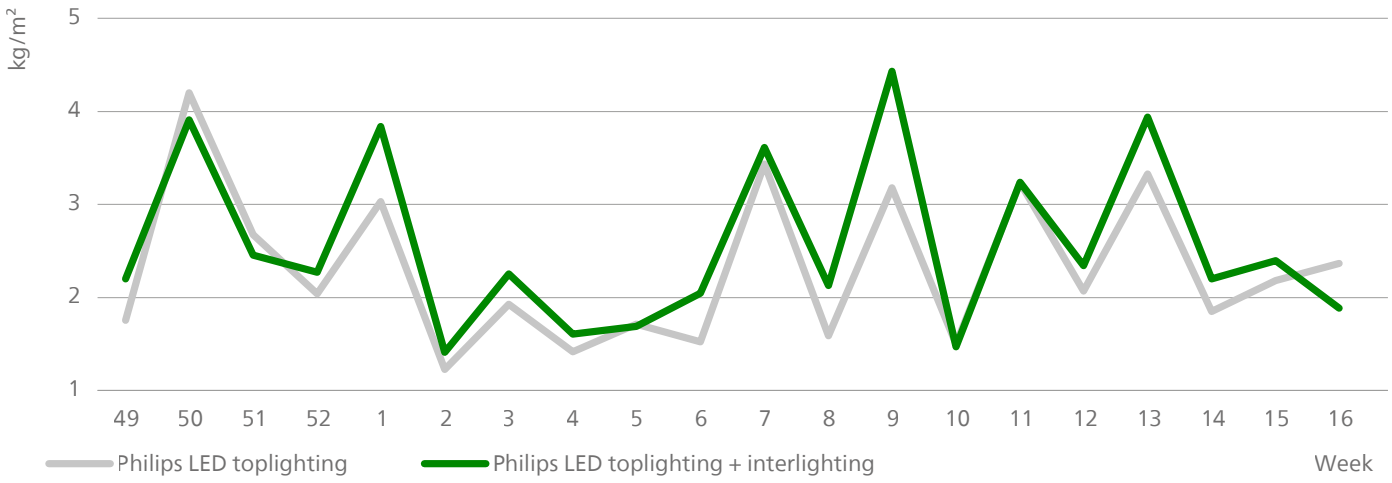
The added value of interlighting

In an A/B testing approach, the interlighting treatment produced 10% more yield compared to the tomatoes grown under toplighting only. "The explanation for this is that the heads of the plants with toplighting only become more easily light-saturated, making it difficult to achieve 100% light use efficiency (LUE). Interlighting improves the uniformity of the light distribution on the plant and also enables it to reach the lower leaves in the belly of the crop, increasing the LUE," states Raats.

Additionally, although LEDs generate less heat than HPS lamps, interlighting nevertheless adds around 10W of heat.
This contributes to keeping the evaporation going and improving the uptake of nutrients. The results in the interlighting setup showed a 4% increase in fruit weight combined with an extra cluster thanks to faster flowering and fruit setting. Overall, these plants produced 10% more yield than the plants with toplighting only.

"And we didn't even reach the full potential of a top-lighting plus interlighting strategy in this trial, due to the limitations of having both setups in the same compartment," comments Raats. "In a commercial setting, with a dedicated compartment, the climate, nutrition and irrigation strategies could all be fine-tuned for interlighting, enabling even more efficient crop steering."

Graph 2. Weekly harvest

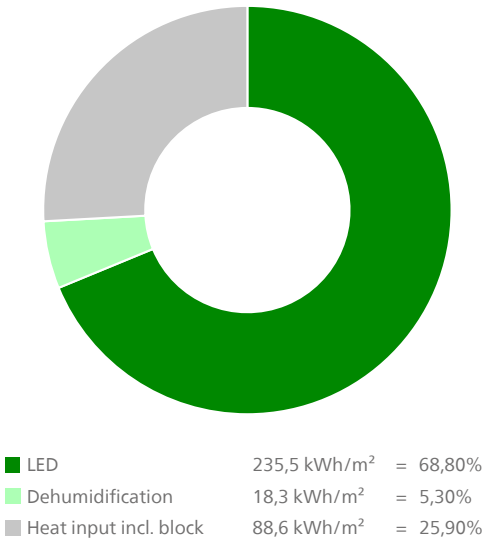


Energy consumption and savings
By fine-tuning the dynamic relationship between lighting and climate control, including the use of the advanced climate screens, the heat input required from the rail pipe system was reduced by more than 50% compared to practice.

More intensive use of active dehumidification did result in a slight increase in the electricity costs. "However, the costs of running the dehumidification system still accounted for less than 6% of the total energy input, so the effect of a slight increase to this is inconsequential to the bigger picture," states Andrew Lee, Head of Crop Advice, Europe and Asia at Grodan.

"The heat generated by the increased light capacity also has a positive impact on the plant temperature, so this contributes to some savings on pipe heating – especially in combination with the screening strategy and dehumidification," he adds.

Graph 3. Total energy consumption - week 39-16



In detail: irrigation and nutrient management

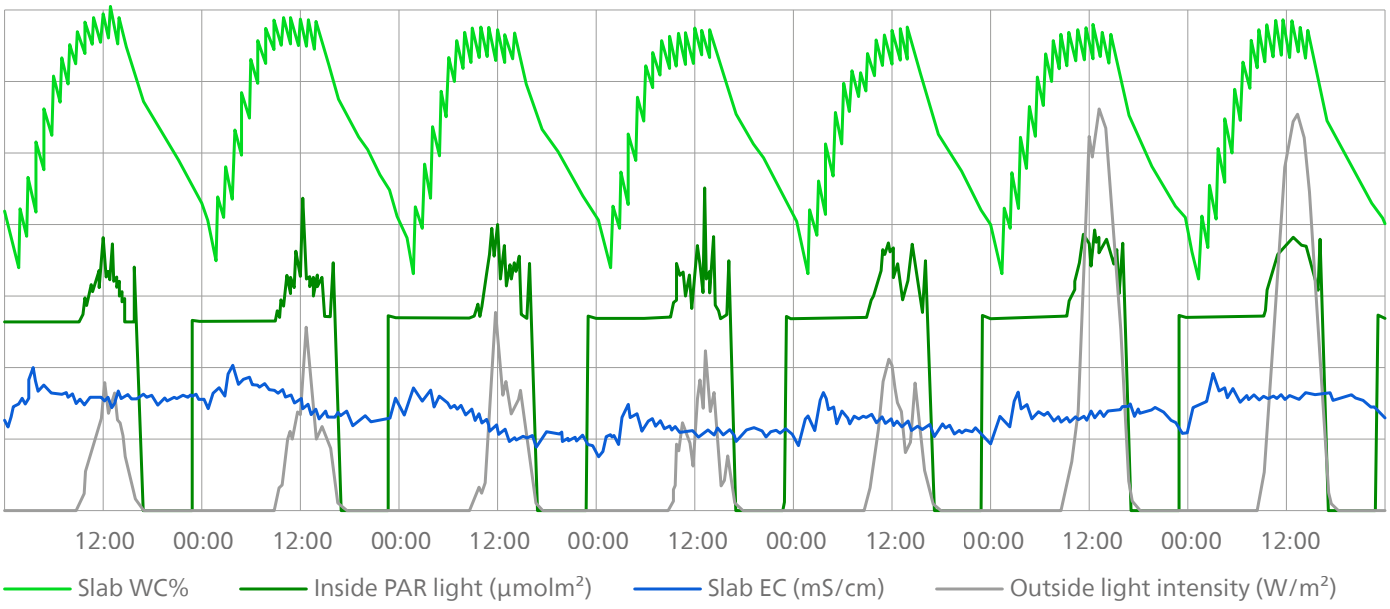
Precision steering in the root zone gives synergistic effects

In terms of irrigation and nutrient control, the focus was on creating a strong generative plant balance and ensuring sufficient total nutrient uptake for optimal plant growth and yield. For example, the team explored different nutrient and irrigation scenarios – in particular a lower-nitrate concentration (10-11 mmol/l) – as a way of gaining more control over the Leaf Area Index (LAI).

"Too much leaf volume is counter-productive in a low heat-input system," explains Lee. "Firstly, too much foliage creates more evaporation and therefore humidity, which takes more energy to remove. Secondly, a higher than necessary LAI also means that the plant requires more nutrition, including nitrogen to feed it, which in turn generates more leaf volume. So it's a vicious circle that can spiral out of control." The target range for the LAI was established at between 2.5 and 3.0.

To get the crop off to a generative start, the steering strategy gradually reduced the water content percentage (WC%) in the Grodan stone wool slab as the electrical conductivity (EC) increased. "This steering phase lasted until the fifth cluster had flowered. Notably, we maintained an average drain volume of 5% during this phase of growth, which was in line with our previous trials. In other words, rather than chasing drain, the drain volume was the result of the irrigation strategy we applied, this was the thought process throughout the cultivation," continues Lee. "At the end of the steering phase we then stabilised the WC% and EC, until we imparted more 'vegetative' steering as spring approached."

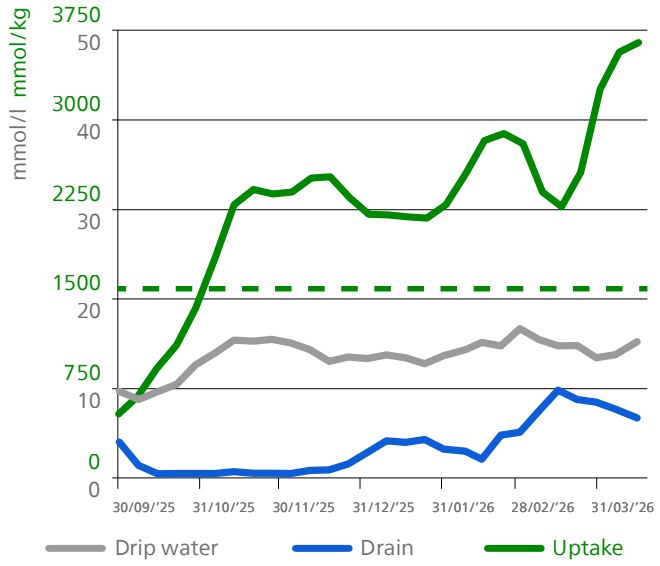
Graph 4. Water content, PAR and light intensity integrated in climate computer



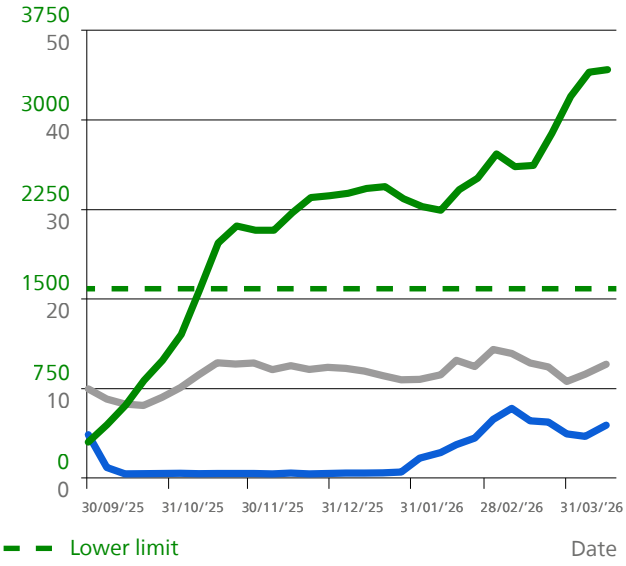
The team had already demonstrated in the first two years of the trial programme that reducing the nitrate in the gift to 8 mmol/l was more generative than steering based on a higher drip EC at the start of the crop. “However, we also know that nitrate uptake is also important for stimulating the uptake of other nutrient elements, so it must not be a limiting factor in growth,” says Lee.

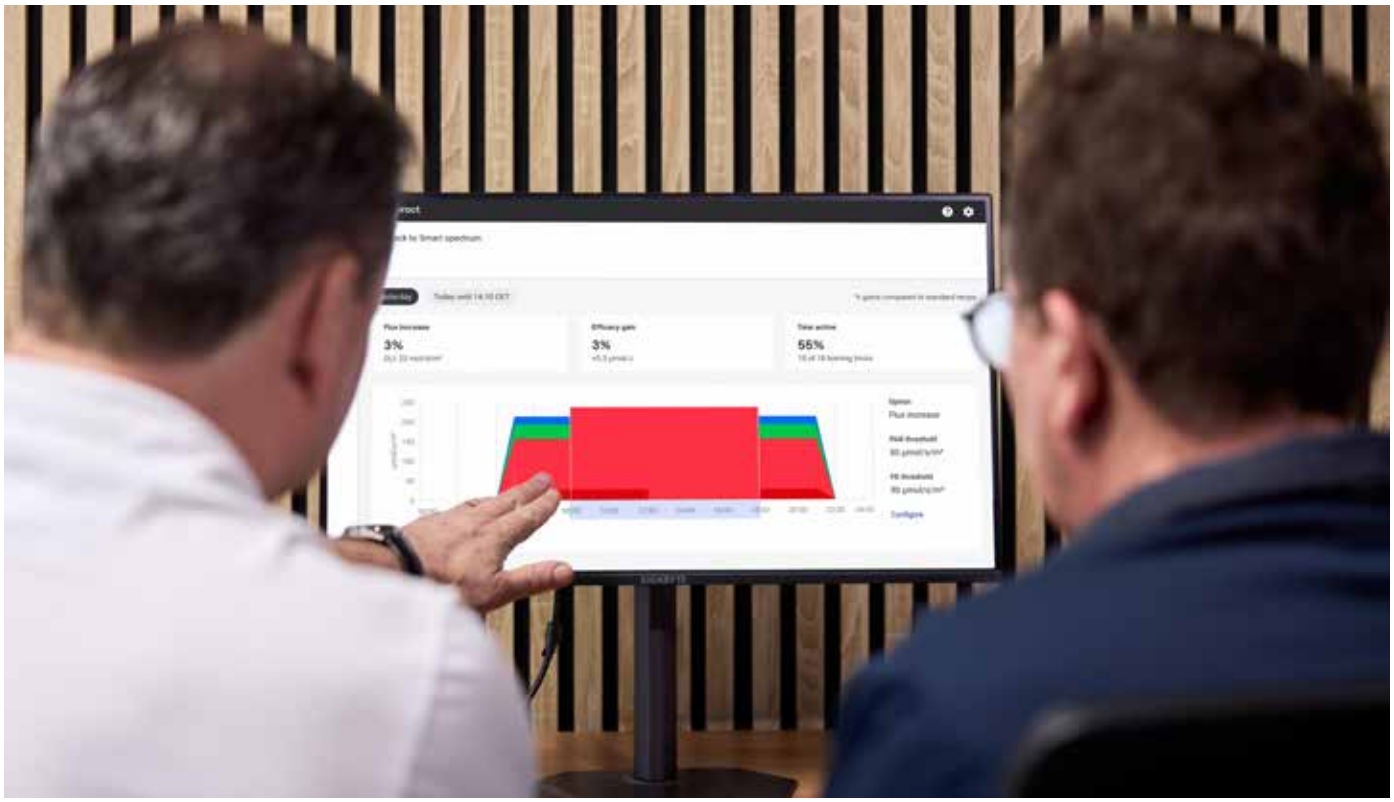
“A larger-fruited variety like Macxize will logically need more nitrate than we gave the cherry tomatoes. However, we wanted to experiment to find the ‘pain point’ for nitrate to judge its impact on total nutrient uptake. We discovered that starting with 8 mmol/l in the drip was too low; the total nutrient uptake was negatively impacted, which reduced the development speed of the crop. We subsequently established that a gift of 13 mmol/l was required to stimulate sufficient total nutrient uptake. As more vegetative steering became necessary, this was increased to 15 mmol/l” he continues.

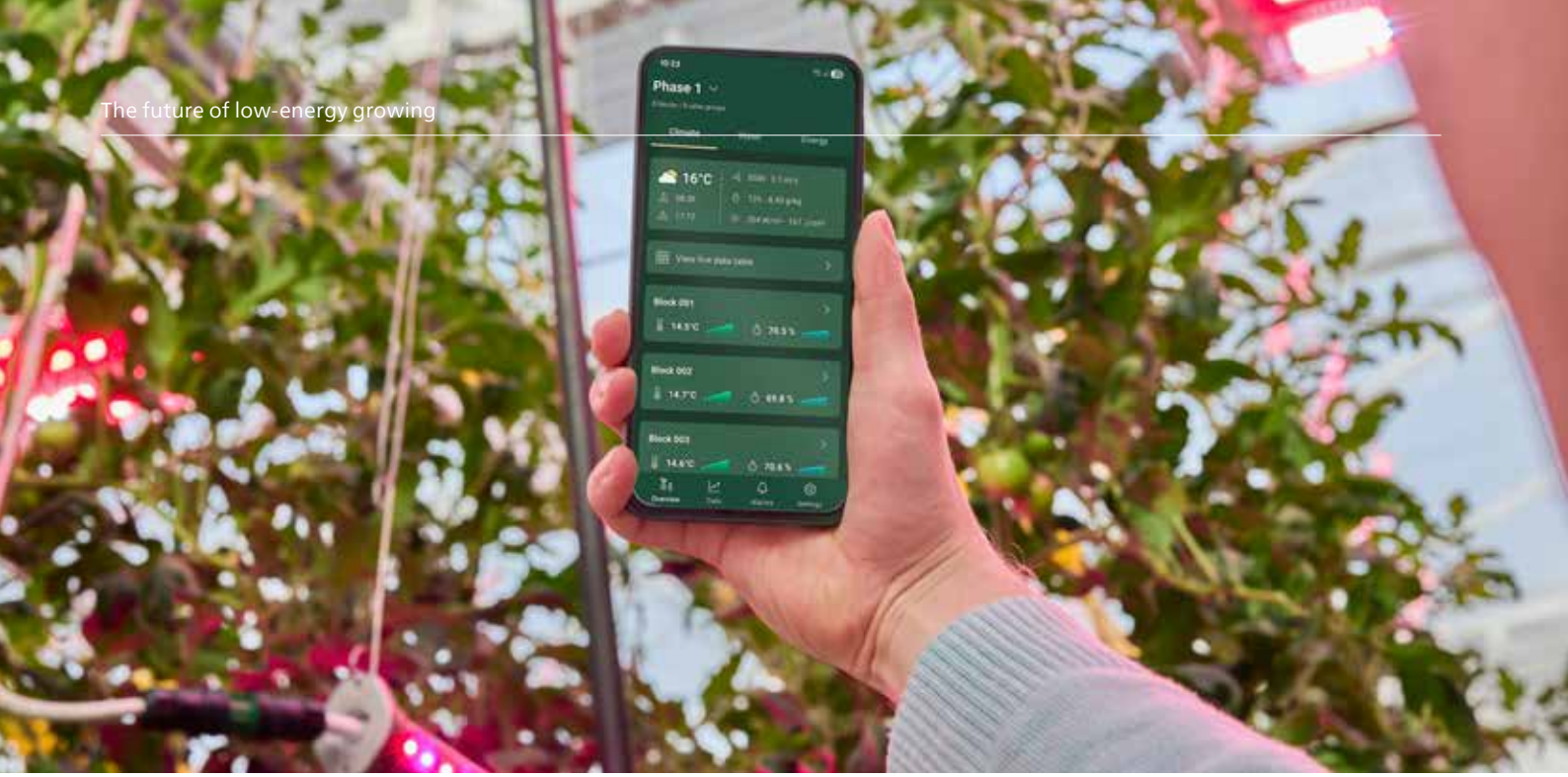
Graph 5.1. Standard nitrate uptake



Graph 5.2. Adjusted nitrate uptake







Sensor based insights improve decision-making

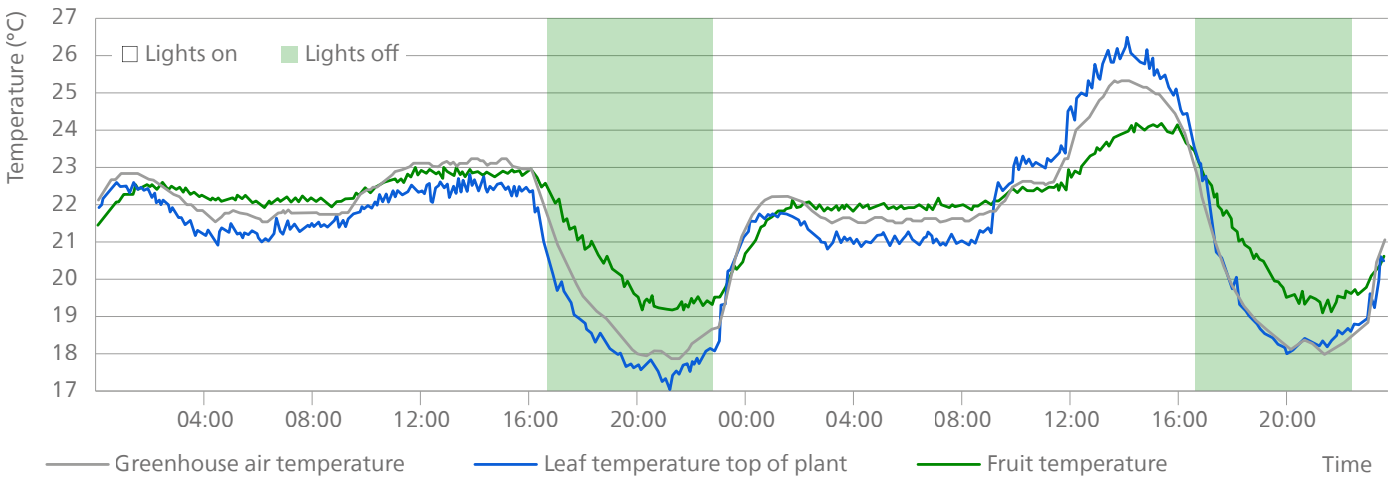
Thanks to extensive use of sensors and their integration with the Ridder Hortimax Pro climate computer via APIs, the team had even more possibilities to monitor the crop than in previous years.
The setup included temperature and humidity sensors, plant weight measurement systems, a net radio sensor from Wireless Value and Grodan GroSens sensors for monitoring WC% and EC in the root zone. All sensor and climate data is combined in one central platform for a complete overview of the greenhouse conditions.
This supported data-driven decision-making in real time, allowing the irrigation and climate strategies to be precisely synchronised with the plants' demands.

"By maintaining maximum stability of both the vertical air temperature and the plant temperature, we could keep the plant optimally balanced in terms of water uptake and assimilate distribution. The graphs showed that there was only ever a slight difference between the air temperature and the plant temperature, which indicated that we succeeded in creating a very stable environment," says Raats. "And as our trial shows, creating a more stable climate with minimal stress is key in cultivating healthier, more resilient plants that produce bigger yields of higher-quality fruits."

The GroSens graphs visualising the root-zone sensor data guided the irrigation strategy. "Targeted uptake was the name of the game," states Lee. "Because everything else was kept stable every day – the lights-on/off times, the temperatures, the humidity – we could use the data to monitor trends in EC and WC% rather than absolute values."

In practice, this enabled the team to be very precise with the irrigation start and stop times. Every single day during the winter lit season, irrigation started two hours after lights on and continued with one irrigation per hour, matching water supply to demand until two hours before lights off. This maintained stable WC% and EC levels in the substrate.

Graph 6. Greenhouse air, leaf and fruit temperature



Blotchy tomatoes with standard nutrient schedule

"Because the climate, lighting and irrigation strategies were stable and predictable, the overnight decreases in the WC% were also stable and predictable. This, in combination with the uniform and 'inert' nature of Grodan's stone wool growing media, enabled us to see exactly what the plants were taking up. Therefore, we could precisely steer the nutrient gift in accordance with the plants' demands to achieve the desired generative or vegetative effect," Lee explains.

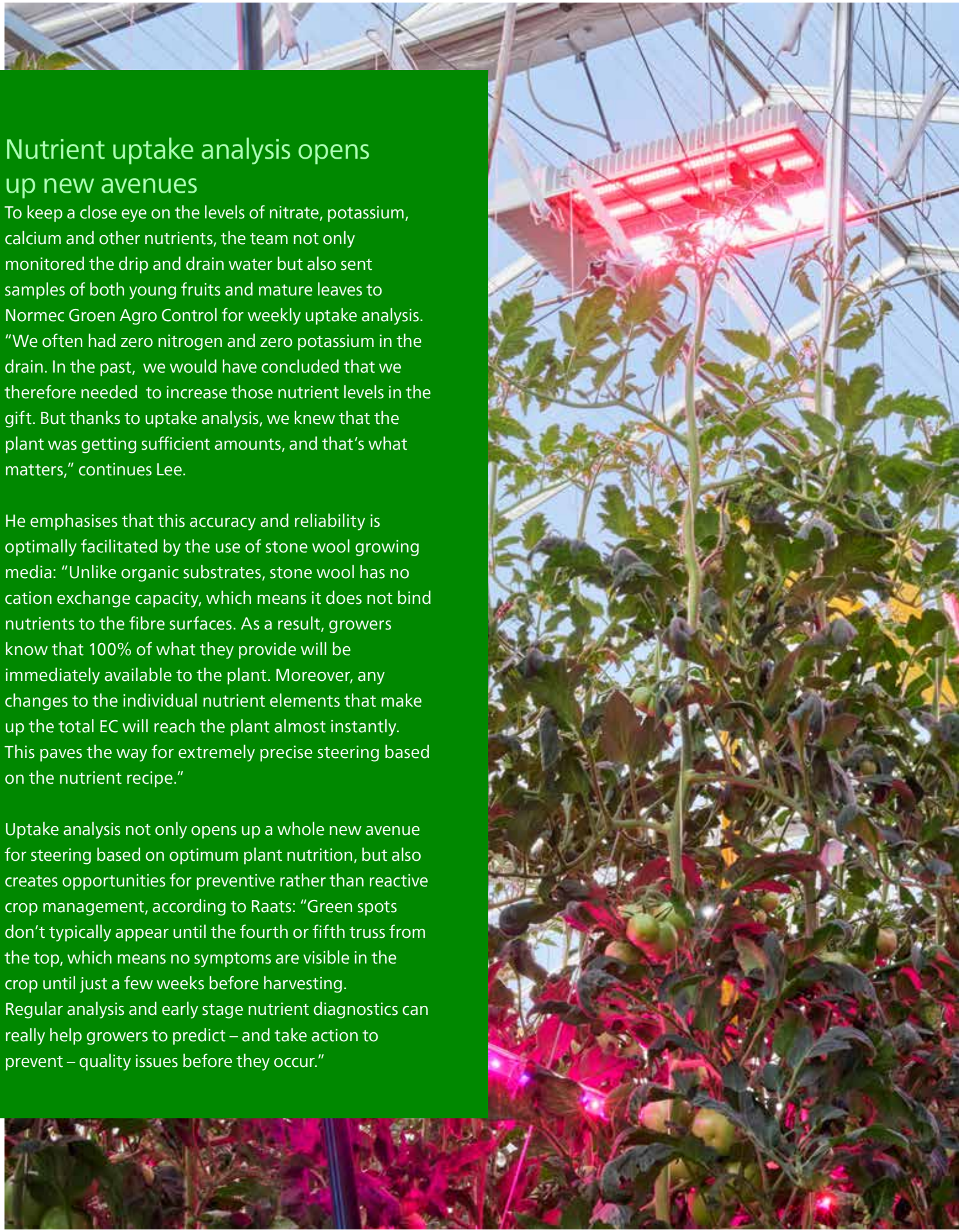
Improving fruit quality by reducing blotchy ripening

In combination with the low-nitrate feed to limit leaf volume and steer generatively, the trial also explored whether an adjusted nutrient schedule would reduce incidences of blotchy ripening, which is a common problem in big-cluster tomatoes under LED. By the end of the trial, the team had succeeded in demonstrating the role of potassium uptake in relation to green spots.

"In full-LED systems, blossom-end rot (BER) is a common fruit-quality disorder. Therefore, growers often maintain lower potassium levels in the nutrient solution to minimise the risk," comments Lee. "In practice, however, for generative growth growers often also increase the sulphate concentration and consequently lower the nitrate concentration in the irrigation gift. We hypothesised that the combination of low nitrate and low potassium in the drip water was increasing the risk of blotchy ripening," he adds.

Therefore, due to the lower nitrogen level, the potassium-to-calcium ratio was increased to 3:1 in the adjusted nutrient strategy instead of the usual 1:1 ratio. "Through weekly monitoring via a technique called 'uptake analysis', we ensured that the potassium uptake stayed between 1,000-1,400 mmol/kg of dry weight and the calcium uptake between 200-550 mmol/kg of dry weight, as minimum and maximum levels. This resulted in 15% higher potassium uptake in the adjusted nutrient strategy during the lit season and significantly reduced the incidence of blotchy fruits compared to practice," he states.

No blotchy tomatoes thanks to an adjusted nutrient schedule



Nutrient uptake analysis opens up new avenues

To keep a close eye on the levels of nitrate, potassium, calcium and other nutrients, the team not only monitored the drip and drain water but also sent samples of both young fruits and mature leaves to Normec Groen Agro Control for weekly uptake analysis. "We often had zero nitrogen and zero potassium in the drain. In the past, we would have concluded that we therefore needed to increase those nutrient levels in the gift. But thanks to uptake analysis, we knew that the plant was getting sufficient amounts, and that's what matters," continues Lee.

He emphasises that this accuracy and reliability is optimally facilitated by the use of stone wool growing media: "Unlike organic substrates, stone wool has no cation exchange capacity, which means it does not bind nutrients to the fibre surfaces. As a result, growers know that 100% of what they provide will be immediately available to the plant. Moreover, any changes to the individual nutrient elements that make up the total EC will reach the plant almost instantly. This paves the way for extremely precise steering based on the nutrient recipe."

Uptake analysis not only opens up a whole new avenue for steering based on optimum plant nutrition, but also creates opportunities for preventive rather than reactive crop management, according to Raats: "Green spots don't typically appear until the fourth or fifth truss from the top, which means no symptoms are visible in the crop until just a few weeks before harvesting. Regular analysis and early stage nutrient diagnostics can really help growers to predict – and take action to prevent – quality issues before they occur."

Next steps for tomato growers

According to Lee, even growers without an active dehumidification unit can start applying the general principle from this research trial: "Everything we've done is transferrable to some extent, because the same way of thinking still stands. It's about using data to make informed steering decisions so that you maintain a balanced energy setup that creates stability and uniformity."

He emphasises the need to consider the role of nitrate above and beyond the EC, such as its relationship in generative control as well as the total nutrient uptake. While nitrogen can be decreased, it must not be allowed to become suboptimal. Therefore, he recommends uptake analysis to ensure the plant stays above the minimum levels for this and other individual nutrients.

On the topic of lighting, Raats recommends the use of higher light levels because it still achieves a good LUE while also giving growers the flexibility to capitalise on dynamic energy prices on the grid. "Interlighting creates room for growers to increase the light use efficiency (LUE) by bringing the extra light into the belly of the plant and setting those leaves to work rather than saturating the top," he says.

Importantly, Raats points out that increasing the light level – and perhaps also adding interlighting – calls for an adapted lighting schedule. In Northwestern Europe, for example, growers may benefit from using the LEDs for a few hours each day throughout the whole season, rather than just in the wintertime.

Changing the lighting setup doesn't only create the need for a different lighting strategy; all other cultivation strategies should be adjusted too in order to get the best out of the crop. "To maintain the plant balance, you need to take the impact on temperature, CO2, nutrition and irrigation into consideration. As demonstrated in this trial programme, taking such a holistic approach ultimately benefits not only the crop and therefore the yield and quality, but also the grower's overall resource use efficiency – especially in terms of gas consumption – and therefore their costs and profitability," concludes Lee.

Reach out

To discuss in more detail how to start implementing a low-heat approach in your own commercial tomato cultivation activities, reach out to our technical experts:

Philips horticulture LED solutions
horti.info@signify.com

Summary of low-energy tomato trial findings

- **Year 1:** Achieved 50% heat input reduction for cherry tomatoes.
- **Year 2:** Maintained energy reduction and achieved additional improvements in plant performance and fruit quality (measured in fruit size and Brix).
- **Year 3:** Achieved the necessary crop stability and uniformity. Improved the LUE combining interlighting and toplighting, therefore boosting yield. Fruit quality - measured in lower incidence of blotchy ripening in larger truss tomatoes - was improved by ensuring sufficient potassium uptake with an adjusted feed recipe. All thanks to a holistic approach to lighting, irrigation, nutrition and climate management, combined with data-driven insights.

Partnered with

Grodan · wirelessvalue · ridder · Normec Groen Agro Control · nunhems · BASF · ammerlaan

Document order number: 442295729006
06/2026 | Data subject to change

For more information about Philips Horticulture LED Solutions visit: www.philips.com/horti

Write us an e-mail:
horti.info@signify.com

Or follow us:
Philips Horticulture LED Solutions