Arize

Lighting for Growth

Current and Wageningen University & Research investigate the impact of intra-canopy lighting on tomato yields

GE current
a Daintree company

Why is it important to study the potential of intra-canopy lighting?

The pressure on growers is mounting on all sides. Energy costs are increasing, and global sustainability goals demand ever-greater efficiency, whilst consumers demand year-round fresh produce with lower air miles and stable prices. With margins already feeling the squeeze, growers must investigate all opportunities to maximize production and minimise costs in order to survive and thrive in the long term.

Supplemental lighting is a key part of any year-round greenhouse set-up. In darker winter months, growers can significantly reduce energy consumption and improve sustainability scorecards by replacing traditional high-pressure sodium (HPS) lamps with a new generation of horticultural LED top lights. However, in the race to ensure sustained commercial success, it's not simply a question of what lighting technology you use, but also how you use it for maximum impact. Many universities, such as Wageningen University & Research (WUR) and grower consortiums are working hard to address these challenges.

Research conducted previously has concluded that in general terms, and with some caveats such as the crop grown, that more light will drive more growth and higher yields. More light means more energy input. Sadly, exponential reserves of cheap energy, allowing growers to crank up the light intensity on their crop is simply not a realistic expectation. Therefore, when Current's product experts, plant scientists and lighting designers come together to advise new customers on their ideal lighting set-up, we know that our lighting must work smarter, not harder.

But how much "smarter"? This was the question we wanted to answer with our research collaboration with Wageningen University & Research. The study, led by WUR's Prof. Dr. Leo Marcelis, focused on determining the value and uses of intra-canopy lighting for greenhouse vine crops like tomatoes, to give us more scientific data about the impact of light in the 3D growing environment.

"When we create new lighting designs for horticulture applications, we factor in many contributing variables within the 3D space, from the crop cultivar to regional climate trends as well as the mechanical and electrical structures involved."

Charlie Benson, Design & Application Director
at GE Current, a Daintree company

Why Tomatoes?

Tomato is one of the most significant horticultural crops grown in greenhouse environments, with the salad staple found on supermarket shelves all year round.

According to global analysts, in 2018, global tomato production topped 182 million tonnes*. In northern markets, more supplemental lighting is required to maintain production volumes and quality throughout the winter months, creating a significant opportunity for any research findings to have greater real-world impact on a sizeable market.

As one of the most important high-wire crops grown, research conducted on tomato growth is also expected to be representative of other high-wire crops such as bell peppers and cucumber.

The challenge of top-down lighting

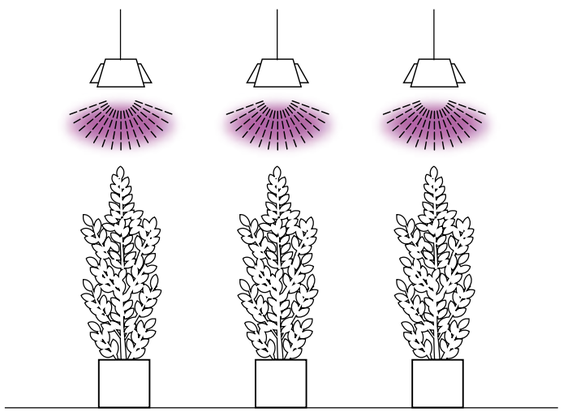
Imagine the canopy of a high-wire crop like tomatoes. It makes logical sense that the leaves at the top of the plant, grow, spread and effectively block the amount of light reaching deeper towards the base. However, the drop off in light energy as you penetrate the canopy is significant. Light levels found at the top-leaf layers of the plant can diminish by 90% when measured at the bottom-leaf layers.

When you reach half-way down the canopy, the plant may only receive a quarter or a third of the light energy compared with the top. When you consider that the leaves at the top of the canopy are also still growing and not yet capable of maximizing the use of light energy through photosynthesis, whilst the more-established, mature leaves found below are essentially under utilized as they don’t receive enough light, the natural “top-down” model for lighting doesn’t seem as efficient as it could be.

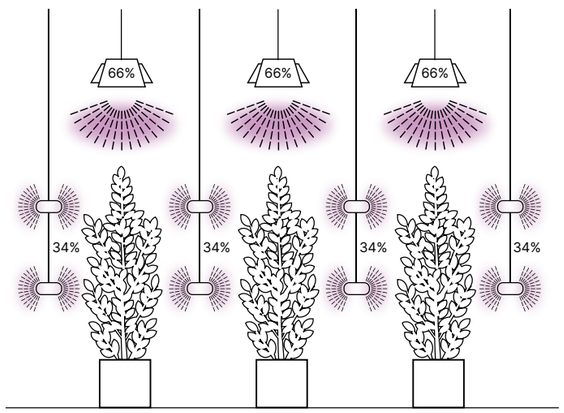
Testing the theory

In partnership with WUR, we wanted to discover exactly what impact the use of intra-canopy lighting could have on tomato yields – not simply by adding more light, but by shifting the ratio of light delivered from above with top light, to deep within the canopy with intra-canopy lighting, allowing the established plant architecture to make the best use of available energy and lighting resources.

Top Lighting only



34% Intra-Canopy Lighting, with 66% Top Lighting



The assumption stood that the use of intra-canopy lighting would have a beneficial impact on plant growth, but how significant could it be? What kind of TL/ICL split would be enough to justify the use of both top lighting and intra-canopy lighting for high-wire crops?

The research was conducted using Current's Arize® Element L1000 top light and new Arize® Integral intra-canopy lighting. The WUR team set up two identical trial spaces, growing two popular tomato cultivars: "Marinice" and "Santiana" under either 100% of supplemental light provided by the L1000 top light, or a 66:34 split between top light and ICL. The ICL light bars were suspended at 150cm and 210cm above the floor to ensure more uniform light dispersion within the crop as it reached its full height.

For consistency, Current's PPR spectrum was used for both TL and ICL, with a high proportion of red wavelengths designed to encourage a strong growth and development rate with natural sunlight providing a strong broad-spectrum background of light.

The Daily Light Integral was set at no more than 18 mols m^{-2} d^{-1} with the total supplemental light intensity maintained at 300 µmol m^{-2} s^{-1}. The photoperiod was never greater than 16 hours per day and the supplemental lighting was always switched off 45 minutes before sunset to allow natural end-of-day light signalling to quickly switch circadian processes from day to night.

All other growing conditions (from water and nutrition, to ambient temperature and CO_2) were kept at a uniform level across the trial to ensure that the supplemental light distribution was the only variable.

Over a period of five months, the team grew and analysed the yields of approximately 20 trusses of fruit, recording the details of plant growth, photosynthesis rates, yield quality and weight.

Beyond expectations:

The Results

The results of the trial were conclusive. Although there was some variation between the cultivars, the treatment with 66% top lighting and 34% ICL delivered an average increase in tomato yield of 14%, with one cultivar recording an overall increase of 17%.

There was also no discernible difference in quality, with the fruit from both treatments recording similar Brix values for sugar content and similar levels of acidity.

“We were expecting higher yields from the 34% ICL treatment but we were shocked by the scale of the increase in output.”

Prof. Dr. Leo Marcelis, Professor of Horticulture & Product Physiology at Wageningen University & Research

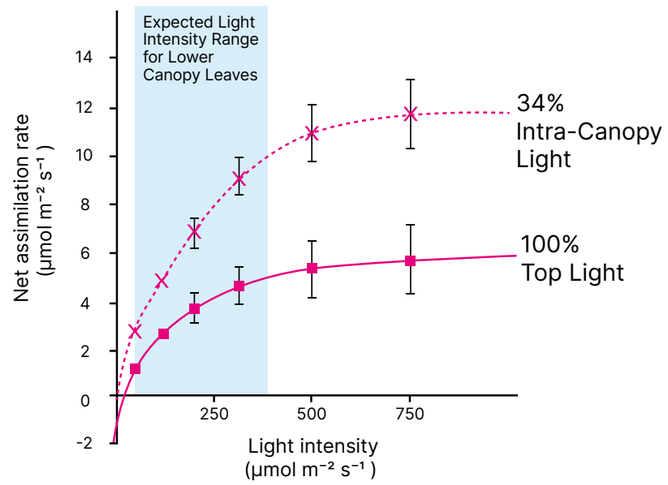
Behind The Results

How could the yields increase simply by moving a proportion of the light energy from the top to deeper within the canopy? One interesting finding was a 73% higher maximum photosynthetic capacity of the bottom leaves in the ICL treatment vs the bottom leaves of plants supplemented only with top lighting, allowing them to do more with the available light energy.

Increasing the proportion of light delivered from intra-canopy lighting and applying photons to the lower areas of the plant sparked a few changes of plant architecture and physiology. For example, the bottom leaves were 6% larger and able to process more CO_2 in photosynthesis. These two changes contributed to more overall growth or biomass for the light energy delivered. Replacing top light with intra-canopy light also results in less light energy reflected away from the canopy and out of the greenhouse, reducing the amount of energy wasted and inevitably increases the amount of light absorbed by the plant.

This proved to be a far more efficient use of the supplemental lighting available than merely focusing more and more energy at the top of the canopy where light use efficiency is lower, as leaves here are most likely to be saturated by the combined energy of solar and supplemental top lighting. However, this is just the first phase of research that proves the value of ICL within a high-wire greenhouse operation.

Lower Canopy Leaf Photosynthetic Rate



Running the numbers:

do more with... the same

For growers exploring the path from HPS to LED, the energy savings are significant alone but by factoring intra-canopy lighting into your LED lighting plan, you could also significantly increase revenue, whilst maintaining or reducing operational costs.

For example, new-generation intra-canopy lighting such as the Arize Integral offer high levels of efficacy – up to 3.5 µmol/J – to keep energy costs low across its 54,000+ hour lifespan.

According to the research to date, an up-front capital investment in LED top lighting and intra-canopy lighting, could result in double-digit growth in high-wire crop yields simply by optimizing your installation to do more with the same energy resources as before.

Whether planning a new fit-out of an existing space or designing a new facility, it's important to explore all options to maximize your production capacity, whilst keeping operational costs under control. Smart environmental controls allow growers to make full use of natural sunlight through daylight harvesting, focusing the supplemental lighting where and when it's needed and only delivering the agreed amount of light that the plant needs.

Looking to the future

Based on the outcomes of the research Dr. Hans Spaholz leading plant scientist at Current, recommends applying a high proportion of supplemental light through inter- or intra-canopy lighting in high-wire vine crops such as tomatoes, or even peppers and cucumbers.

With 34% of supplemental lighting delivered via intra-canopy lighting, tomato yields within the study were increased by up to 17%, with no change in energy costs.

An increase of this size in marketable yields and associated profits could help a business mitigate rising energy prices, as well as provide increased capital for expansion, modernisation or shareholder returns. Yet this study is just the start of Current's commitment to establishing solid scientific foundations for the horticulture lighting industry and further investigation into the impact of different applications of ICL is also planned to provide an even clearer picture of the value of intra-canopy lighting for glasshouse growers.

"Further plans are currently being explored with Wageningen University & Research to determine the most productive division of light energy between LED top lights and intra-canopy lighting. However, for now, the results at 34% ICL are extremely encouraging and allow us to make more informed recommendations to growers who are keen to utilize lighting for maximum returns."

Dr. Hans Spalholz, Horticulture Scientist at GE Current, a Daintree company

To learn more about this study or to find out how Current's range of horticulture LED lighting can help you maximize productivity, get in touch today www.arizegrow.com/integral

About

Wageningen University & Research

Considered by many as the world's leading university for controlled environment agricultural sciences**, WUR's mission is "to explore the potential of nature to improve the quality of life". With this goal front and centre, WUR strives to find solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 5,000 employees and 12,000 students, the unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

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* FAO STAT 2021; RaboResearch Food & Agribusiness 2018

** ShanghaiRanking's Global Ranking of Academic Subjects 2021 - Agricultural Sciences

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