Global Daily Light Integral Guide for Greenhouses

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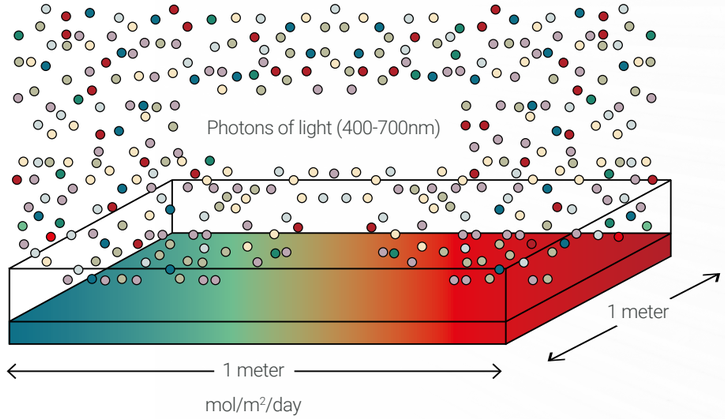
Optimizing the DLI (Daily Light Integral) in your greenhouse can be a daunting task. Every crop has its own DLI needs, and seasonal and daily changes to natural light make providing the right amount of supplemental light extremely challenging. But getting it right brings great rewards. Growers who are able to optimize the DLI they provide to plants can eliminate seasonal changes in production cycles, accelerate harvests, bring the highest quality products to market faster, cut energy costs and significantly improve their profitability.

What is DLI?

DLI is the amount of PAR (Photosynthetically Active Radiation) that is received by your plants over the course of a 24-hour day. It is a measurement of light intensity x photoperiod and is expressed in moles of photons (mols) per square meter (m^2) per day (d). PAR is the range of light on the spectrum between 400 and 700 nm that plants use for photosynthesis. This range includes red, blue and green light. There is discussion that PAR may extend a little beyond 700 nm, but 400 to 700 nm is a good guideline.

DLI

The total amount of PAR received per square meter per day



DLI = [intensity] x [duration]

$$DLI = \frac{\mu mol/m^2/sx\ (3600 \times photoperiod)}{1{,}000{,}000}$$

Source: Daily Light Integral Defined (Dr. Erik Runkle, Department of Horticulture at MSU, 2006).
https://www.canr.msu.edu/resources/daily_light_integral_defined

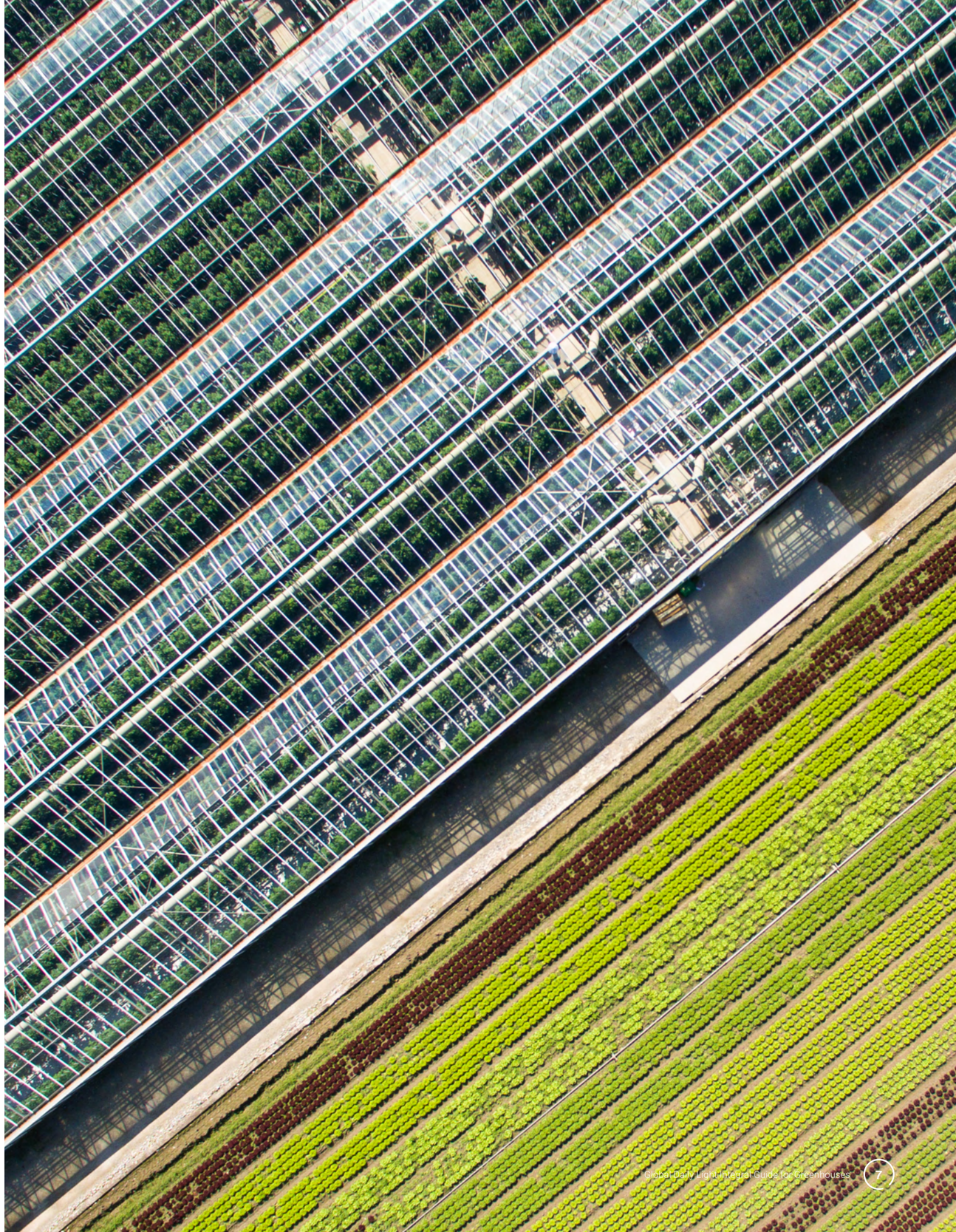
Why is DLI important for your crops?

In general, an increase in DLI is related to an increase in overall crop quality and production rates. DLI influences plant growth, development, quality and yield. Different plant species have different light requirements at each stage of their development, and DLI can impact everything from root and shoot growth to plant morphology (i.e. height, stem thickness, flower number) to plant finish (i.e. color, taste, texture).

Plants grown under low DLI conditions will show delayed growth and development, while plants grown under optimal DLI will maximize photosynthesis and development. The trick is knowing and controlling how much light you are giving to each particular crop so that it falls within the optimal DLI range, (for example between 15 and 20 for lettuce), without going over, stressing plants and wasting energy. There is a saturation point after which adding more DLI will not be beneficial to your plants or your bottom line.

The goal of optimizing DLI is to ensure that each crop receives the correct total amount of light every day. The DLI will be the sum of the natural light and the supplemental light that the plants receive over the photoperiod or day. To increase the DLI in your greenhouse, supplemental light may be used. In order to increase the DLI in the best way possible you want to ensure that the DLI target is met without using supplemental lighting more than necessary and wasting energy. There are technologies that can help with this. Heliospectra's helioCORE™ system, for example, can predict how your lights should be used to provide your DLI target in the most efficient way over the given photoperiod.

Light-hungry plants need a high DLI, while low-light plants need less. When controlling the supplemental lighting in your greenhouse, you also need to consider the natural light levels in your facility. The geographic region, the season, the time of day, the light transmission factor coming through the glass and even the shade cast from the greenhouse structure and fixtures, all play a role in the amount of supplemental lighting your individual crops require. No matter the growing environment or the crop, however, ensuring optimal year-round DLI is a critical factor for maximizing quality and yield.



DLI and light intensity

PPFD (Photosynthetic Photon Flux Density) measures light intensity, which plays a key role in the DLI plants receive. How does PPFD measure light intensity? It measures the amount of light within PAR that actually falls on a given surface (for example, the plant canopy area) each second. The unit used to express PPFD is micromoles of photons per square meter per second (µmol/m^2/s).

PPFD accounts for PAR light (400-700 nm). However, numerous research papers have shown that far-red (FR) light, which lies outside of PAR at 700-800 nm, also has a positive effect on plant development, architecture and flowering. This means that if you are using a light that includes far-red, the FR light (700-800 nm) will not be included in calculating the DLI, which only accounts for light within PAR (400-700 nm).

Since light intensity is a very important part of estimating the DLI that your crops receive, it is important to measure not just the supplemental lighting, but the natural light intensity as well. The relevant light is the light that actually reaches your crops, which means you also need to consider where crop canopies are situated in your greenhouse and how that will differ considerably between crops, such as herbs/lettuce versus tomatoes. In the case of herbs/lettuce the canopy can be meters below the greenhouse glass.

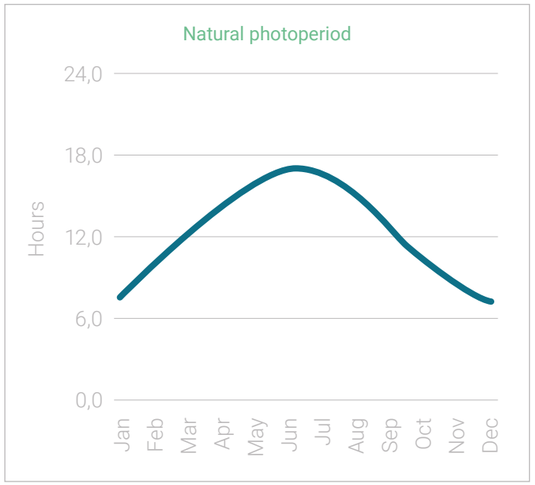
While the natural light intensity received at canopy level can be different for each crop, it will also be changing throughout the day, rather than remaining constant. This presents additional challenges for growers wanting to know what light levels are available to their crops. Therefore, light intensity can't be measured at a single moment (instantaneous reading) to estimate the DLI for the natural light in the greenhouse. Also, from one day to another the weather may change, from full sunshine to rain, creating large differences in the natural light intensity levels from day to day.

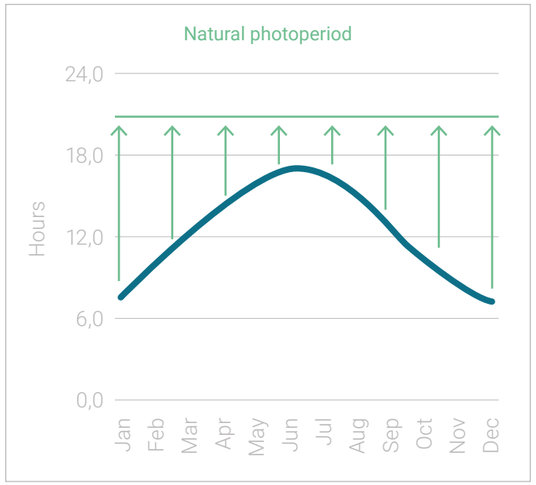
DLI and Photoperiod

As mentioned above, DLI is a measurement of light intensity in relation to photoperiod. Photoperiod is the duration or number of hours of light plants are exposed to. Note that the same DLI can be achieved by using different intensities over different photoperiods (see table below).

Intensity PPFD (µmol/m²/s)	Photoperiod (hours)	DLI (mol/m²/day)
350	15	15
230	18	15

The photoperiod may shift over the year, depending on where you are located (see graphs below). In this example, supplemental light is used to increase the photoperiod when the natural photoperiod is low, resulting in periods when the light received by the plants is mainly from the lighting system.





DLI in a greenhouse vs. a sole source environment

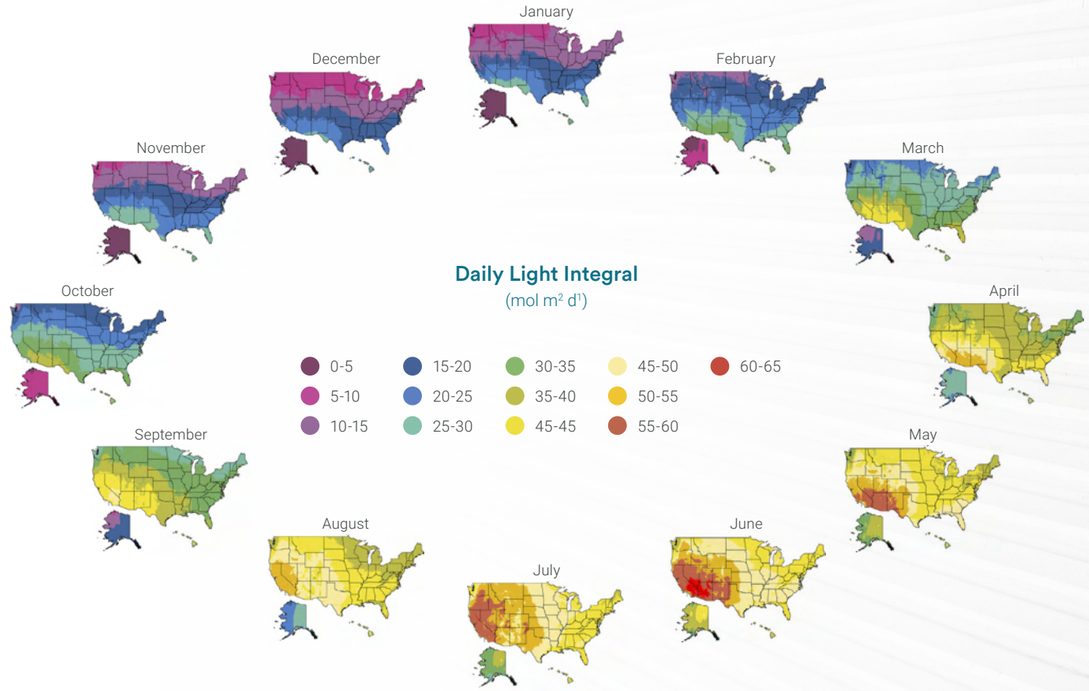
Optimizing DLI in a greenhouse is more complex than optimizing it in a sole source lighting environment. A sole source environment has known and stable light intensities and photoperiods, while in a greenhouse, growers need to account for factors inside and outside the greenhouse that affect the natural light, and supplement accordingly to reach their DLI targets.

DLI breakdown by country

Depending on your greenhouse location, the DLI will typically change over the seasons, as the natural day lengths (photoperiods) and light intensities (PPFDs) can differ quite drastically over the course of a year. In many locations, summer provides long days and high light intensities, while in winter, both the light intensities and the day lengths are lower, which decreases the DLI considerably.

There are interactive calculators available that can give you a good idea of the monthly DLI in your region. For example, for the United States, Jim Faust of Clemson University and Joanne Logan of the University of Tennessee developed interactive maps by location and month, supported by the American Floral Endowment.

Daily Light Integral: a research review and high resolution maps of the United States



Source: Daily Light Integral: A Research Review and High Resolution Maps of the United States (James E. Faust and Joanne Logan, 2018.) https://endowment.org/dlimaps/

DLI breakdown by crops

While some crops prefer a warm, sunny climate, others thrive in a cooler, shaded environment. Additionally, light requirements differ depending on the stage of plant development. Generally, plants can be divided into high-light crops, like tomatoes, that need a high DLI in order to produce a quality product, and low-light crops, like ferns, that require a much lower DLI. The following chart shows DLI recommendations and how crop productivity is affected:

	Lettuce	Cucumber	Tomato	Strawberry
Minimum DLI (mol/m²/d)	12	12	12	12
Optimal DLI (mol/m²/d)	15-20	≥ 30	≥ 30	≥ 17-19
Productivity (grams/mol)	4-7	17	8-14	2-3

Conversions from solar radiation to DLI

$1MJ\ m^{-2} = 100\ J\ cm^{-2}\ d^{-1} = \sim 2\ mol\ m^{-2}\ d^{-1}$

$1kWh\ m^{-2}\ d^{-1} = 3.6\ MJ\ m^{-2}\ d^{-1} = \sim 7.6\ mol\ m^{-2}\ d^{-1}$

Source: Dr. Chieri Kubota, Ohio State University, Doraiset al. (2015, 2016), Kubota et al., (2016)
https://www.heliospectra.com/growers-center/food-cultivation-ebook

The Benefits of providing the right amount of DLI vs. not enough DLI

While too little light inhibits plant growth, increasing DLI has positive effects on plants – up to a certain point. As mentioned above, every plant has a threshold beyond which further light exposure may no longer encourage growth. To ensure that the target DLI you set is delivered to your crops in the most efficient way, without using supplemental lighting more than necessary and wasting energy, intelligent technology, such as Heliospectra's new helioCORE™, can help. Its predictive DLI algorithm and improved interface can help you grow every crop to its full potential, all while optimizing your operational and financial performance.

helioCORE™ can enable you to:

Set a precise DLI target: The predictive algorithm considers factors such as minimum/maximum thresholds of light intensity and photoperiod, geographic location and historical PPFD data to maintain an accurate target DLI.

Optimize energy efficiency: With a precise DLI, you can ensure plants are getting the light they need 365 days of the year, no matter the weather conditions. The predictive algorithm not only implements a proper DLI but also helps keep costs down by uploading local time-of-day utility rates to prioritize lamp usage when energy costs are lowest.

Control Light Intensity (PPFD) levels: The highly sophisticated system enables you to maintain consistent light intensity levels to maximize plant efficiency, optimize photosynthesis and maintain consistent year-round production schedules.

Customize light strategies using scheduling: You can create customized and repeatable light schedules on any device, from end-of-day treatments to full growth cycles, giving you control over flavor, morphology, nutrition and shelf life, while getting crops to market on time.

Receive real-time data and actionable feedback: No matter where you are or what device you are using, you can monitor up to 5,000 lights, check equipment status, adjust light settings, intensities and spectra, and analyze graphs showing your energy consumption and light usage over time.

When the right amount of DLI is applied to crops, the results include:

- Healthier crop development
- Better color, flavor and more nutrients
- Higher and more predictable yields
- Faster time to market

How to calculate and implement the right amount of DLI: Real-World Examples

Calculating and implementing the right amount of DLI is simple if you have the right tools. When Ontario's Greenbelt Microgreens was struggling with yields that could change within hours, given their short 4- to 12-day production cycles, they knew they needed to set precise, consistent daily light integrals. Since microgreen leaves have the tendency to grow thinner and more delicate during the short, dark days of winter, Greenbelt needed a year-round DLI strategy to maintain a consistent harvest of grams per tray for their retail customers. Ian Adamson, Greenbelt Microgreens' CEO, commented, "If we turned off the tap in December because of lack of production, we would lose that market until the sun returned in May. That is unacceptable to retailers…."

By using Heliospectra's ELIXIA adjustable-spectrum LED lights with the helioCORE™ control system, Greenbelt is able to increase their wintertime yields and produce summer-quality crops 365 days a year. Greenbelt's Head Grower, Alice Farris, commented, "Supplemental DLI lighting aids us in the ability to keep our production cycles similar from summer to winter…. Four days in the summertime will give us 62 hours of natural light, whereas it takes seven days in the depths of winter to give us the same amount of light. When we installed Heliospectra lights we saw an immediate 13% increase in yield."

In addition to increasing yield, helioCORE™ helped Greenbelt save on energy costs, by scheduling supplemental lighting during the lowest-cost energy hours.

Research conducted by Dave Llewellyn and Dr. Youbin Zheng at the University of Guelph also found that energy savings could be achieved using helioCORE™ technology. The researchers grew cut gerbera (variety Alliance) using LEDs and DLI-controlled helioCORE™ versus conventional threshold-controlled HPS. With helioCORE™ they saw a "15 per cent reduction in lighting capacity [which] equates to an equivalent reduction in energy use." They went on to note that, "Light intensity is fixed at a set level for HPS, but this varied between 0 and 100 per cent for the LEDs due to the DLI-control algorithm." They concluded that, "…this trial clearly demonstrated the potential for intelligently-controlled LED systems which manage light output on an ongoing basis in real time, to maintain or even increase productivity while simultaneously reducing energy use."

Summary

Intelligent DLI controls can ensure that your plants receive the right amount of total light every day, providing quality crops and consistent yields while never overusing energy. Heliospectra's helioCORE™ software platform comes from decades of plant biology and research to enable growers unprecedented control over light intensity, spectrum and photoperiod. After two years of testing and data collection through rigorous trials and grower feedback, Heliospectra is launching a new and improved version of.helioCORE™, the best and latest in horticulture lighting control. Sign up for a free demo. [link]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