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DLI Measurements:

A Valuable Addition to Your Toolbox

In the past, measuring daily light integral was costly, but with the products out there now, this method may be your future.

By Jim Faust

The Greenhouse Weather Tracker was developed in 2003. (Photo courtesy of Spectrum Technologies)

Over the past five years, with the support of Floriculture Industry Research and Scholarship Trust (FIRST), we conducted a series of experiments to develop guidelines for using the daily light integral (DLI) to gauge the light environment in greenhouses. DLI is a term that refers to the total quantity of light delivered to a surface. An analogy will help to clarify the technique and usefulness of measuring DLI. If you wanted to know how much rain fell yesterday, you would place a bucket outdoors to capture all the raindrops delivered to that particular spot. Similarly, if you wanted to know how much light was available for plant growth yesterday, you would place a light sensor on the greenhouse bench and capture all the light particles (photons) delivered to that particular spot. This value would be the light quantity, or DLI.

CURRENT METHODS

We have survived to this point with basically two methods of measuring light. Most commonly, growers use foot-candle meters to estimate the maximum light delivered to a crop inside a greenhouse or to estimate the greenhouse light transmission by comparing outside and inside measurements. While there is nothing wrong with this, its usefulness — its ability to describe the greenhouse light environment — is very limited. A single light intensity measurement cannot take the day length (or the number of hours of sunlight) into account. For example, if a crop is said to receive 2,000 foot-candles in December and 2,000 foot-candles in June, the total amount of light (the DLI) delivered to the June crop is considerably higher than the December crop, since the June crop receives 15-16 hours of sunlight, while the December crop receives only 8-9 hours.

More recently, growers have used outdoor weather stations connected to climate control computers. These stations can report the DLI delivered outside the greenhouse; however, they cannot estimate the light delivered to the greenhouse crop, especially if a retractable shade curtain is used.

Our dilemma is that we never know how much light is actually being delivered to the greenhouse crop. DLI is not a new concept for plant scientists; however, few growers have ever used this measurement because the equipment for measuring DLI has been cost prohibitive. That has changed, thus we are writing this article now, because DLI measurements can be a reality for commercial greenhouse growers. But first, let's discuss the value and use for DLI measurements.

USING DLI

Plants are "light counters." Photosynthesis is driven by the amount of light intercepted by the plant canopy and the amount of carbon dioxide that can be absorbed through the stomata. Since DLI is the sum of the light delivered during the course of one day, there is an excellent relationship between plant growth and DLI. So, if you measure the DLI, you have an excellent estimate of the plant growth to be expected. ➧

Excessive hanging baskets or excessively large hanging baskets can reduce the DLI delivered to the greenhouse bench by more than 40 percent. (Photo courtesy of Jim Faust)

The FIRST Web site (www.firstinfloriculture.org/research_reports.htm and click on Light Management in Greenhouses) contains a detailed report on the use of DLI, so only a brief overview will be presented here. The first challenge in using a new unit of measure is getting used to the numbers and units. The unit of measure for DLI is "moles per day" or (more technically correct) "mol·m^{-2}·d^{-1}," which means moles per square meter per day.

MEASURING DLI

The value of DLI measurements has been evident for many years; however, commercial growers never had the ability to measure DLI due to the high equipment cost. In 2003, Spectrum Technologies, Plainfield, Ill., developed a portable datalogger (Greenhouse Weather Tracker) that measures DLI. The meter can be easily positioned within any greenhouse crop. A digital display provides the current DLI for that particular day as well as a 30-day archive for previous days. The display also shows the current light intensity (micromoles per second or µmol·m^{-2}·s^{-1}) and current air temperature. The minimum and maximum daily temperatures are also archived. DIF measurements will be displayed in future versions. ➧

We have been making DLI measurements for several years in research and commercial greenhouses. The measurements never cease to amaze me. We usually rely so heavily on our eyes to evaluate the greenhouse light environment; however, the human eye is a lousy light sensor. This is because our eyes are so effective at adjusting to the ambient light conditions. It is remarkable that we can see well under a full moon (0.01 µmol·m^{-2}·s^{-1}) or during a sunny day (2,000 µmol·m^{-2}·s^{-1}). The following are some of the conditions that provide surprising DLI measurements (although they seem like common sense once you've made the measurement):

- Shadows cast during a sunny day are much darker than the same shadow cast on an overcast day. Similarly, if you have a sensor positioned in the shadow of a greenhouse wall on a sunny day, the light intensity may actually increase as a cloud moves overhead, since the cloud reflects the light into the shaded area.
- In east/west-oriented greenhouses, the benches immediately north of the gutters can have very low DLI on sunny days (less than 5 moles per day in South Carolina in October).
- The DLI measured at the truss (where a hanging basket would be positioned) is much higher (20-50 percent) than the DLI measured on the floor or bench, even without any hanging baskets.
- The outdoor DLI increases 100 percent (or doubles in magnitude) from December to June.
- The DLI delivered to the bench inside the greenhouse is often only 50 percent of the outdoor DLI, even without hanging baskets or shade curtains.
- The DLI delivered to the greenhouse bench may be lower in May than in March if a lot of shade is applied to the greenhouse.
- Excessive hanging baskets or excessively large hanging baskets can reduce the DLI delivered to the greenhouse bench by more than 40 percent.
- White hanging baskets intercept 10-30 percent less light than green hanging baskets.
- Even though the glazing material may allow 90-percent light transmission, the complete greenhouse structure may allow only ➧

Figure 1. Guidelines for providing the desired DLI to greenhouse crops. These responses are based on ornamental characteristics; however, if the measure of success is plant growth (fresh weight, fruit yield, number of cut stems, etc…), then higher DLI can be beneficial, assuming that heat or water stress does not occur.

DLI	Plant Response
5	Enough light to support adequate vegetative growth; however, flowering may be delayed, and flower number will be relatively low. Branching may be poor. Only "shade" crops grow well at this level. This DLI is common inside greenhouses during the winter months, so supplemental lighting can be very beneficial.
10	Most species produce good quality crops. At 10 moles per day and higher the time to flower is not usually limited by light, so temperature or photoperiod are often the most limiting factors. Shade crops perform very well and may show little additional ornamental improvement from DLI above 10 moles per day.
15	Very good quality growth and flowering for most species. Some species, such as many flowering potted plants, may not display any additional ornamental value at DLI above 15 moles per day.
20	Excellent quality for "high light" crops (e.g., most bedding plants and perennials). Excellent branching and high flower number per plant. Shade crops may be damaged or appear less attractive at this or higher DLI, especially if drought occurs.
25	The highest DLI typically observed inside greenhouses. Only "high light" crops would benefit being grown at 25 moles per day. Outdoor DLI may be much higher; however, shade cloth or whitewash used during the summer for greenhouse temperature control rarely allow the DLI inside the greenhouse to exceed 25 moles per day.
25-50	DLI delivered outdoors or inside retractable roof greenhouses during the growing season (spring to fall). Excellent quality produced on "high" light crops; however, proper water management is critical due to the high evapotranspiration rates.

35-70 percent, depending on the angle of the sunlight, the amount of infrastructure, overhead curtains, dust, condensation, etc.

• Even though the shade curtain may allow 50 percent transmission, the entire shade structure may allow only 40 percent transmission when the retractable curtains are pulled.

• The DLI delivered inside a retractable roof greenhouse is less than the outside DLI due to shadows cast by the structure, even when the roof is open. This is particularly true in hinged roof systems, compared to accordion-style retractable roofs.

As you can see, there is a lot to be learned about the light environment inside a greenhouse. Everything seems straight forward until you make some measurements, then you realize there's more variation and differences than you've ever imagined.

THE NEXT STEP

EC and pH measurements became commonplace in the 1980s. This tool has dramatically improved a grower's ability to reliably produce crop after crop. Graphical tracking became a commonplace in the 1990s. This tool took much of the guesswork out of height control. DLI meters have the potential to be the next major tool for growers to add to their repertoire. DLI measurements made inside the greenhouse will provide growers with further insight into greenhouse crop management. It will take time, but I believe that over the next decade growers will become familiar with the DLI concept. This will improve our ability to accurately communicate to each other about light and will improve our ability to reliably grow quality crops. GPN

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