e-GRO Alert
Volume 1, Number 4 February 2012

Shining Some Light on Young Plant Production

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If you have watched the weather forecast recently, you have undoubtedly heard that much of the U.S. has experienced record breaking warm temperatures this winter. What you have probably not heard is that light levels have been unseasonably low. These low light levels are resulting in delayed rooting, increased timing, and lower-quality young plants (cutting liners and plugs). Now that we are in peak liner and plug production it is important to make sure you are providing the ideal environmental conditions for your young plants.

Inside a greenhouse, light levels are often reduced by 40 to 70 percent due to the structure, glazing material and age, energy curtains, overhead baskets, and a host of other factors. This may raise a few questions. How low is low with light during vegetative propagation? What impact does light really have on liner and plug production timing, quality, consistency and subsequent flowering? In this article, we will cover the relationship between light measurements, photosynthesis, and plant growth; discuss the impact of photosynthetic daily light integral (DLI) during the production of liners; and provide general guidelines and recommendations for increasing the DLI inside of your young plant greenhouses.

First, we need to focus on the light that plants utilize for photosynthesis, which influences growth and quality. Most growers use instantaneous foot-candle (f.c.) meters to measure light in the greenhouse. These "photometric" units are based on the amount of visible light detected by the human eye (primarily green light). That means foot-candles are focused on people and not appropriate for measuring light used in plant photosynthesis.

Most horticultural researchers measure instantaneous light in micromoles (µmol) per square meter (m^{-2}) per second (s^{-1}), or $\mu mol \cdot m^{-2} \cdot s^{-1}$. This "quantum" unit quantifies the number of photons (individual particles of energy) used in photosynthesis that fall on a square meter (10.8 square feet) every second. However, like foot-candles this light measurement also is an instantaneous reading and instantaneous light levels can change dramatically throughout the course of a day or even a few minutes.

Daily light integral (DLI) is the amount of photosynthetically active radiation (PAR) received each day as a function of light intensity (instantaneous light, or $\mu mol \cdot m^{-2} \cdot s^{-1}$) and duration (hours of light, or day length). It is expressed as moles of light (mol) per square meter (m^{-2}) per day (d^{-1}), or $mol \cdot m^{-2} \cdot d^{-1}$ (moles per square meter per day). One

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Volume 1, Number 4
February 2012

www.e-gro.org

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can compare the DLI concept to a rain gauge. Just as a rain gauge collects the total amount of rain received in a particular location over a period of time (ie. 24 hours), DLI measures the total amount of PAR received in a day. Greenhouse growers can use light quantum meters connected to data loggers or weather stations (ie. Spectrum Watchdog) to measure the number of light photons that accumulate in a square meter over a 24-hour period (for more information read Purdue Extension bulletins HO-238-W and HO-238-B-W.

Many growers provide the proper air and substrate temperatures, mineral nutrients, misting schedule, and high-quality water during propagation of young plants. However, we frequently observe and hear that little or no efforts are made to monitor or modulate light during propagation.

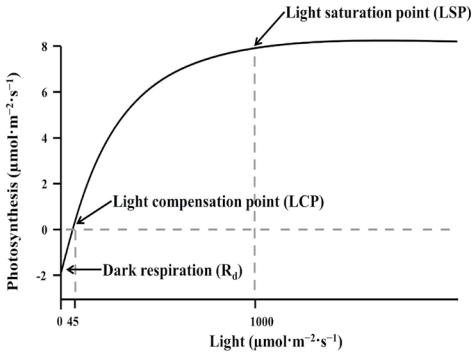

Figure 1. Photosynthetic light response curve of a typical bedding plant with the dark respiration (R_d), light compensation (LCP), and light saturation (LSP) points.

Figure 1 shows the response of net photosynthesis (net photosynthesis = photosynthesis – respiration) of common annuals to light levels. There are several points on the figure that are important. The dark respiration rate (R_d) is the rate of respiration in darkness when stored carbohydrates are used, since photosynthesis is not occurring. The point at which net photosynthesis is equal to zero is called the light compensation point (LCP), when respiration is equal to photosynthesis. Lastly, the point at which the increase in photosynthesis stops is the light saturation point (LSP), the point when photosynthesis is maximized.

During the winter and early spring, when DLIs are low, instantaneous light levels are often low. For example, the average outdoor DLI in West Lafayette, Indiana was 8 and 9 mol·m^{-2}·d^{-1}, respectively in December and January. If light transmission is reduced by 40 to 70 percent in a greenhouse, DLI could be as low as 2 mol·m^{-2}·d^{-1}. Therefore, growers are potentially rooting their cuttings under light levels that are below the LSP and even the LCP in some instances. As a result, the production of carbohydrates and growth of plants is not maximized. By managing light

during cutting propagation, you will be able to maximize growth and minimize production time.

Similar to plug production, there are four different stages of cutting propagation: Stage 1 = Harvesting, shipping, and sticking; Stage 2 = Callusing; Stage 3 = Root development; and Stage 4 = Toning. These stages not only differ in cultural requirements but light requirements as well. In Stage 1 (harvesting), the goal is to minimize stress for cuttings that have been recently harvested, shipped, and stuck. Once cuttings are packaged and shipped, they are exposed to dark conditions until sticking. Before sticking, keep cuttings out of direct sunlight to avoid increasing plant temperature, which increases respiration. Once cuttings have been stuck and are placed in the greenhouse for callusing (Stage 2), our research indicates a DLI of approximately ≈ 5 mol·m^{-2}·d^{-1} is desirable to minimize stress from high light. During callusing, cuttings are not photosynthesizing very much so increasing light will not benefit growth. Light intensity should be maintained at 500 to 1,000 foot-candles (100 to 200 µmol·m^{-2}·s^{-1}).

It is time to increase your greenhouse light levels to 1,000-2,000 foot-candles (200 to 400 µmol·m^{-2}·s^{-1}) once roots have initiated and they have entered Stage 3 (root development). The presence of roots allows cuttings to take up more water and maintain turgor. This means the guard cells surrounding stomata can open, allowing for increased gas exchange and, therefore, photosynthesis. What DLI should you try to achieve during root development? The response of different species to DLI during root development is variable. However, our research has led us to conclude that a general recommendation for DLI during root development is around 8 to 10 mol·m^{-2}·d^{-1}. Increasing the DLI during root development has been shown to increase root and shoot growth, stem caliper, and overall liner quality. During toning (Stage 4), the DLI can be further increased to levels recommended for finishing, from 10 to 12 mol·m^{-2}·d^{-1}.

By increasing the DLI during root development and toning, you can reduce the time until a liner is finished or "pullable," while increasing the quality of the finished product (Figure 2).

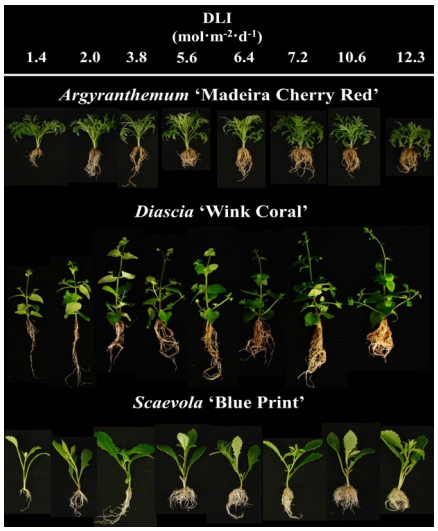

Figure 2. Cuttings of *Argyranthemum*, *Diascia*, and *Scaevola* grown under daily light integrals in propagation ranging from 1.4 to 12.3 mol•m^{-2}•d^{-1} during root development.

Furthermore, cuttings propagated under higher DLIs have been shown to flower earlier than cuttings propagated under lower DLIs, reducing production time for a finished, flowering crop (Figure 3).

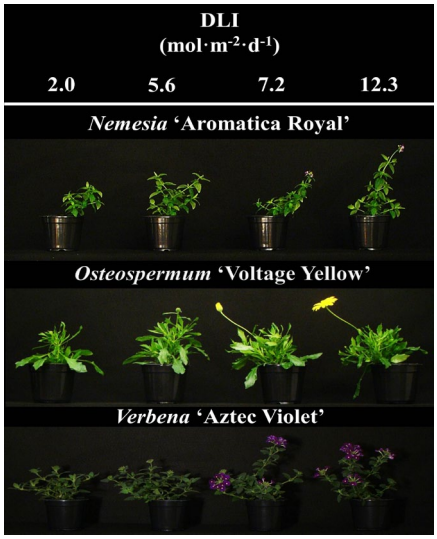

Figure 3. Plants of *Diascia*, *Osteospermum*, and *Verbena* grown under daily light integrals in propagation ranging from 2.0 to 12.3 mol·m^{-2}·d^{-1} during root development.

How can you increase Your DLI?

It is apparent that ambient DLI is low across most of the U.S. during young plant production. What can growers do to increase DLI within their facilities? One easy way to increase the amount of "free light" from the sun within the greenhouse is too thoroughly remove whitewash, dust, and algae from your glazing material. Greenhouse glazing alone can reduce light transmission by up to 25 percent depending on the material (glass, plastic, polycarbonate, acrylic, etc.) and age. The greenhouse frame and sash can further reduce light

transmission by 10 to 12 percent and 5 to 7 percent, respectively. Another way to increase the DLI in your facility is to use supplemental lighting such as high-pressure sodium (HPS) lamps. How many hours should a HPS lamp be on? This depends on many factors such as:

- The target DLI you want to achieve
- Only using supplemental lights when they are needed (ie. cloudy days)
- Cost of electricity during the day and night

The amount of time the lamps are on is as important as the amount of supplemental instantaneous light they provide. Table 1 gives some examples of how DLIs ranging from 1.4 to 9 mol·m^{-2}·d^{-1} may be achieved with HPS lamps.

Table 1. Cumulative amount of supplemental light (DLI; mol•m^{-2}•d^{-1}) provided by high pressure sodium lamps achieved by varying light intensities and durations (hours).

Duration (hours)	Foot-candles (µmol•m^{-2}•s^{-1})				
	250 (33)	400 (52)	500 (65)	600 (78)	800 (104)
12	1.4	2.3	2.8	3.4	4.5
15	1.8	2.8	3.5	4.2	5.6
18	2.1	3.4	4.2	5.1	6.7
21	2.5	3.9	4.9	5.9	7.9
24	2.8	4.5	5.6	6.7	9.0

The Take-Home Message

Propagation of young plants such as cuttings takes place when outdoor and greenhouse DLIs are low. With a little knowledge of how to properly quantify photosynthetic light, how plants respond to light, and how to properly manage and increase light in your greenhouse you can increase the efficiency and quality of your rooted cuttings while reducing propagation time and increasing profitability.