e-GRO Electronic Grower Resources Online

Measuring and Monitoring Photosynthetic Light in a Greenhouse

Roberto Lopez PURDUE UNIVERSITY

THE Fred C. Gloeckner FOUNDATION, INC.

Review of Light Concepts

- Light is a form of energy referred to as electromagnetic radiation.
- Therefore light can vary in:
  - Duration (photoperiod),
  - Quality (color and wavelength), and
  - **Quantity or Intensity (quantity of light at each wavelength or color)**

Review of Light Concepts

- Light quantity is the number of light particles (called photons) capable of performing photosynthesis
- Plants growth is driven by photosynthesis, which converts water, carbon dioxide, and energy from light into carbohydrates

Review of Light Concepts

- However, less than half of the energy (43%) from the sun is in the photosynthetically active radiation (PAR) range of 400 to 700 nm
- Increasing energy in the PAR range, up to an optimal light intensity maximizes photosynthesis and plant growth

How can we Determine if Our Crops are Receiving Enough Light in the PAR Range?

This greenhouse operation is reducing light in the PAR region to the crops on the bench by hanging too many baskets

Factors Affecting Light Intensity

- Time of day/ year
- Latitude and elevation
- Cloud density
- Pollution
- Dust in the atmosphere
- Moisture and haze
- Glazing/superstructure/ curtains
- Greenhouse orientation
- Hanging baskets
- Supplemental lights

Do you currently measure light in your greenhouse?

Measuring Light

Measuring Light

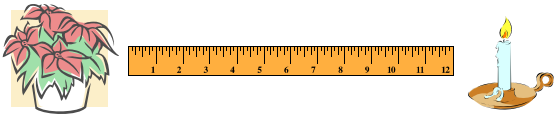
- Light may be measured instantaneously or cumulatively
- Instantaneous readings provide a "snapshot" of the light environment
- Cumulative readings more accurately reflects light received over the course of a day

Light Units

- Photometric (lux or foot candles)
  - Includes visible light
- Quantum ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
  - includes photosynthetically active radiation
- Radiometric ($w \cdot m^{-2}$)
  - Includes radiant energy

Light Units

- Photometric (lux or foot candles)
  - Is the most common unit used to measure instantaneous light by U.S. growers
  - It represents the amount of light visible to the human eye



Light Units

- Quantum ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
  - Measures the amount of photosynthetically active radiation (PAR), 400 to 700 nm
  - This quantum unit quantifies the number of photons of light used in photosynthesis that fall in a square meter every second

Measuring Instantaneous Light

Hand-held quantum meters are available with a single-or multiple-diode sensor

Measuring Instantaneous Light

- A single-diode sensor is smaller and easier to carry
- A multiple-diode sensor takes a reading from each diode and reports the average light level, giving a more "representative" reading
- Quantum meters may also have the ability of switching between measuring electric and sun light

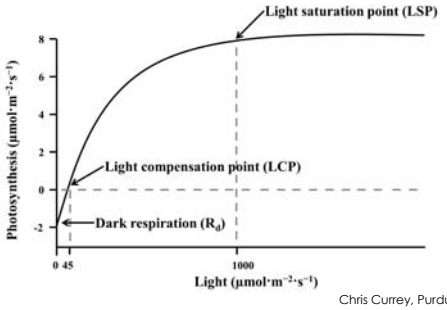
Measuring Instantaneous Light

- Natural light levels are continuously changing and a single measurement in time does not accurately represent the amount of light a plant has received in a day
- However, they can be used to make decisions such as whether to pull shade cloth or when to turn on supplemental lamps

Instantaneous Light Intensity

Sun light	**Summer Day** 10,000 foot-candles (2000 µmol·m^{-2}·s^{-1})
	Greenhouse Conditions
High light	4,000 to 6,000 foot-candles (800 to 1200 µmol·m^{-2}·s^{-1})
Moderate light	2,000 to 4,000 foot-candles (400 to 800 µmol·m^{-2}·s^{-1})
Low light	<2,000 foot-candles (<400 µmol·m^{-2}·s^{-1})

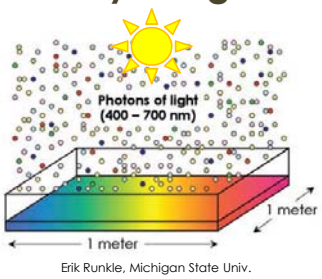
Instantaneous Light and Photosynthesis



Chris Currey, Purdue Univ.

Quantity of Light

The term daily light integral (DLI) describes this cumulative amount of light (photons of light) that an area or location receives during one day



Erik Runkle, Michigan State Univ.

Therefore, DLI is the cumulative amount of photosynthetic light received in 1 square meter of area (10.8 sq. ft.) each day

Daily Light Integral

- DLI cannot be determined from an instantaneous reading
- DLI is similar to a rain gauge. A rain gauge is used to measure the total amount of rain that was received in a particular area during a 24-hour period

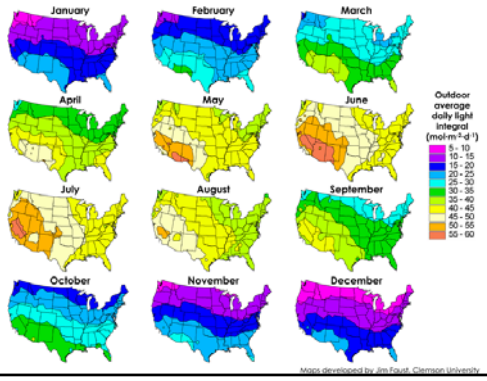
Daily Light Integral

- DLI is expressed in units of moles of light (mol) per square meter (m^{-2}) per day (d^{-1}) or $mol \cdot m^{-2} \cdot d^{-1}$
- Values from sunlight **outdoors** vary from 3 (winter) to 60 (summer)

Daily Light Integral

- In a greenhouse, values seldom exceed 30 $mol \cdot m^{-2} \cdot d^{-1}$ because of shading which can reduce light by 40 to 70%
- Target minimum DLI inside a greenhouse is 10 to 12 $mol \cdot m^{-2} \cdot d^{-1}$

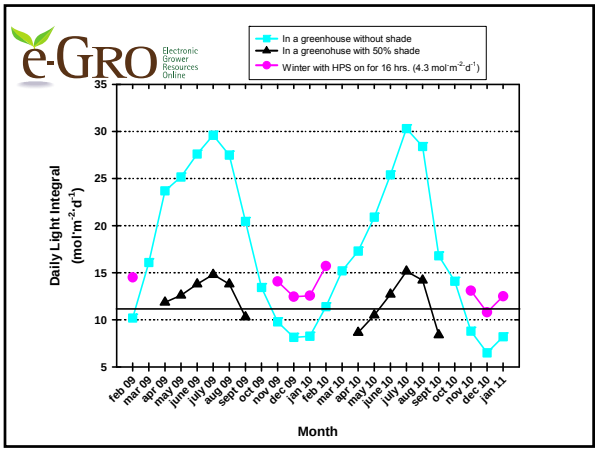
Outdoor Daily Light Integral



Maps developed by Jim Faust, Clemson University

Methods to Increase DLI

- Minimize overhead obstructions such as hanging baskets
- Make sure your glazing is properly cleaned (ie. whitewash, dust, algae removed)
- Provide supplemental lighting from high-pressure sodium lamps (HPS), metal halide (MH) or light-emitting diodes (LEDs)



Measuring DLI

The goal of a successful greenhouse operation is to measure, monitor, and record DLI and then to create conditions (using supplemental lighting or shade curtains) in which their crops can efficiently absorb light and use that that light for photosynthesis

Measuring DLI

- There are three ways to calculate, measure, or estimate the DLI in your greenhouse:
  - Use a quantum sensor and then calculate DLI
  - Use a portable unit that calculates DLI for you
  - Estimate DLI in your greenhouse using DLI maps
- The accuracy of each of these methods varies

Measuring DLI – Quantum Sensors

- Place a light sensor connected to a computer, data logger, or environmental control system to record light intensity at plant height in the greenhouse
- The sensor measures instantaneous light intensity (preferably in quantum units: $\mu mol \cdot m^{-2} \cdot s^{-1}$) at some defined interval (such as once every 15 to 60 seconds)
- You can then easily calculate DLI in $mol \cdot m^{-2} \cdot d^{-1}$

Measuring DLI – Quantum Sensors

Calculating DLI

Take the hourly $\mu mol \cdot m^{-2} \cdot s^{-1}$ averages for the 24 hour period, add them, and then divide this sum by 24

For example, you have 24 hourly $\mu mol \cdot m^{-2} \cdot s^{-1}$ readings: 0 + 0 + 0 + 0 + 0 + 0 + 9 + 76 + 137 + 175 + 164 + 432 + 254 + 226 + 244 + 228 + 300 + 263 + 374 + 195 + 86 + 80 + 0 + 0 + 0

= 3,243 $\mu mol \cdot m^{-2} \cdot s^{-1}$ ÷ 24 hours

Average light intensity = 135 $\mu mol \cdot m^{-2} \cdot s^{-1}$

Calculating DLI

Convert your average instantaneous readings to DLI

Do this by using the following equation: PAR ($\mu mol \cdot m^{-2} \cdot s^{-1}$) × 0.0864

The 0.0864 factor is the total number of seconds in a day divided by 1,000,000

135 $\mu mol \cdot m^{-2} \cdot s^{-1}$ × 0.0864

= 11.7 $mol \cdot m^{-2} \cdot d^{-1}$

Measuring DLI – Portable Units

- Place a portable unit such as the Spectrum Technologies Weather Tracker or LightScout (http://www.specmeters.com/) at plant height
- These units record light intensity and give you the DLI your crops received over a 24 hour period

Measuring DLI – Portable Units

Measuring DLI – Using Maps

- The DLI in your greenhouse can be estimated using outdoor DLI maps developed at Clemson University
- You will first need to use a portable light sensor to determine the outdoor light intensity (noon on a cloud less day)

Measuring DLI – Using Maps

- Now determine the light intensity at plant height inside your greenhouse
- Use these values to determine the percentage of sunlight that reaches your crop

Measuring DLI – Using Maps

- For example, if you measure 7,000 foot-candles (1,400 $\mu mol \cdot m^{-2} \cdot s^{-1}$) outdoors and 3,600 foot-candles (720 $\mu mol \cdot m^{-2} \cdot s^{-1}$) inside your greenhouse, the light transmission is approx. 49%
- If the DLI map indicates that the average outdoor DLI in your area is 20 to 25 $mol \cdot m^{-2} \cdot d^{-1}$, then you can estimate that your average DLI at plant level is approx. 10 to 12.5 $mol \cdot m^{-2} \cdot d^{-1}$

Take Home Message

- Instantaneous: $\mu mol \cdot m^{-2} \cdot s^{-1}$
  - Fine for a static light source (i.e. supplemental light)
  - Good for making daily lighting/shading decisions
- Cumulative: $mol \cdot m^{-2} \cdot d^{-1}$
  - The integrated amount of light received over a day
  - Think of the daily light integral as a rain gauge
  - Good for seasonal lighting/shading decisions

More Information on DLI

Visit: flowers.hort.purdue.edu

- Click on the Extension bulletin tab