1st International e-GRO Webinar Conference

e-GRO Electronic Grower Resources Online

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11:00 to 11:40

IMPROVING LIGHT QUANTITY PAYS

Roberto Lopez

PURDUE UNIVERSITY

Review of Light Concepts

- Plant growth is driven by photosynthesis, which converts water, carbon dioxide, and energy from light into carbohydrates.
- However, less than half of the energy (43%) from the sun is within the Photosynthetically Active Radiation (PAR) range.
- When light is limiting, additional light in the PAR range increases photosynthesis and plant growth.

Measuring Instantaneous Light

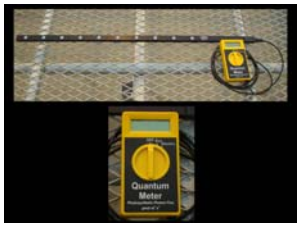
- The foot-candle (fc) is the most common unit used to measure instantaneous light by U.S. growers.
- It is a photometric unit that represents the amount of light visible to the human eye.

Measuring Instantaneous Light

- The quantum unit is a unit used to measure light that is correlated to plant photosynthesis.
- Micromoles per square meter per second ($\mu mol \cdot m^{-2} \cdot s^{-1}$) are the units used for measuring Photosynthetically Active Radiation (PAR).
- This quantum unit quantifies the number of photons of light used in photosynthesis that fall in a square meter every second.

Measuring Instantaneous Light

- You can select a hand-held quantum meter with a single-diode or a multiple-diode sensor.

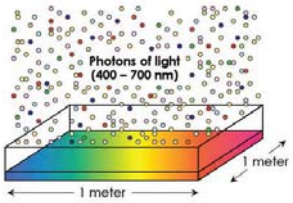


Measuring Instantaneous Light

- Both units only provide instantaneous light readings at the time the reading is taken.
- 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.

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)

- DLI cannot be determined from an instantaneous reading.
- Measurement of DLI is analogous to measurement of rainfall.
- Both are measured by the cumulative amount of rain or light received during a 24-hour period.

Daily Light Integral (DLI)

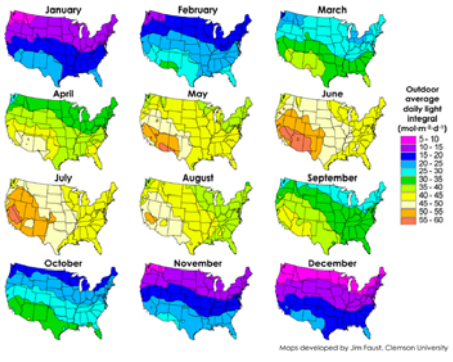
Varies due to factors that influence light intensity and duration:

- Time of the year (sun's angle)
- Location and cloud cover
- Day length (photoperiod)
- Greenhouse glazing/ covering (s)
- Structure and obstructions
- Hanging baskets
- Supplemental lights

Daily Light Integral (DLI)

- 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 5 (winter) to 60 $mol \cdot m^{-2} \cdot d^{-1}$ (summer).
- In a greenhouse, values seldom exceed 30 $mol \cdot m^{-2} \cdot d^{-1}$ because of shading applied to prevent excessive temperatures.
- Target minimum DLI inside a greenhouse is 10 to 12 $mol \cdot m^{-2} \cdot d^{-1}$.

Outdoor Daily Light Integral



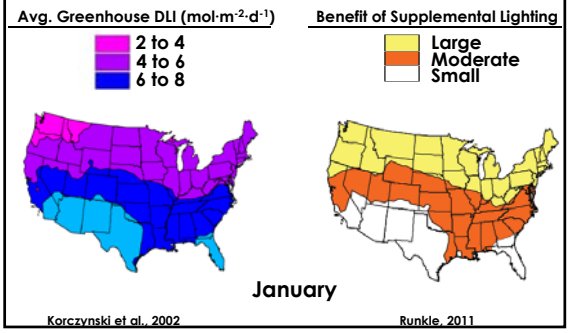
Plant Responses to Higher DLI

- Smaller and thicker leaves
- More and larger flowers
- Reduced time to flower (partly due to temperature)
- Increased branching
- Increased stem diameter
- Increased root growth of plugs and cuttings

Daily Light Integral (DLI) and Young Plants

- During propagation, the DLI outdoors typically ranges from 5 to 20 mol·m^{-2}·d^{-1} across the northern U.S.
- In greenhouses, light levels can be 50% or less of that outdoors because of structures, glazing, shading, and obstructions.
- Therefore, the DLI during propagation can be as low as 2.5 to 5 mol·m^{-2}·d^{-1}, and sometimes even lower during extended periods of cloudy weather.

Daily Light Integral (DLI) and Young Plants

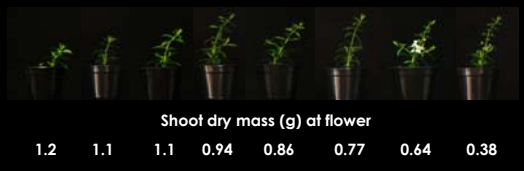


Angelonia 'Angel Mist White Cloud'

Photo taken after 21 d of propagation

Angelonia 'Angel Mist White Cloud'

Photo taken 14 d after transplant



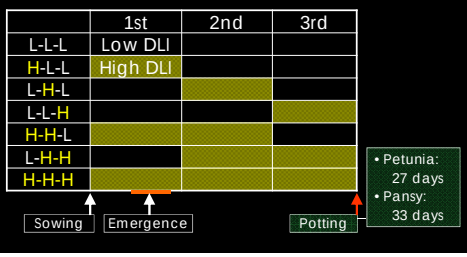
Most Bang for the Lighting Buck

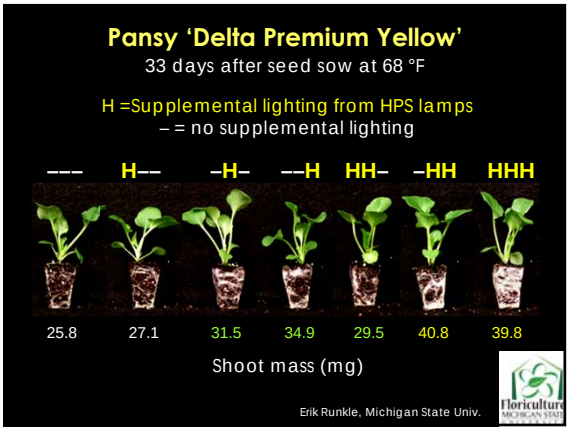
- Objective: Determine the impact of increasing DLI for different durations of time during the seedling stage on transplant quality and subsequent growth and development.
- Identify the relative sensitivity to timing and duration of supplemental lighting during the seedling stage.

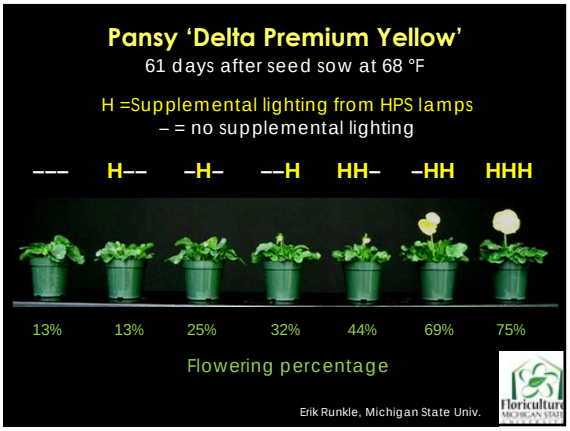
Erik Runkle, Michigan State Univ.

DLI Treatments

- The seedling stage was divided into thirds, each lasting 9 or 11 days
- Plugs were lighted for 1/3 or 2/3 of the plug stage, not at all, or during the entire period.







Young Plant Supplemental Lighting Conclusions

- When light is limiting (<10 mol·m^{-2}·d^{-1}), adding supplemental lighting provided the most benefit when provided during the later stages of young plant production.
- The highest-quality plugs and rooted cuttings were those grown under constant supplemental lighting.
- Young plants provided with high light flowered earlier than those not provided with supplemental light.

Methods to Increase DLI

- Get as much "free" light as you can:
  - Minimize overhead obstructions such as hanging baskets.
  - Make sure your glazing is cleaned (no white-wash, dust, or algae) when the DLI is low.
  - Consider a glazing material that diffuses light to more evenly distribute sunlight to crops below.
- Provide supplemental lighting

General Light Intensity Guidelines For Rooting Cuttings

Stage 1: Stick to callus formation

- Low light: 100–200 µmol·m^{-2}·s^{-1} (500–1000 fc)

Stage 2: After root initiation

- Moderately low light: 200–400 µmol·m^{-2}·s^{-1} (1000–2000 fc)

Stage 3: After roots fill half the liner

- Moderately high light: 500–800 µmol·m^{-2}·s^{-1} (2,500–4,000 fc)

General Light Intensity Guidelines

- Diffuse, indirect light is best.
- White wash or exterior shade in combination with retractable shade curtains can provide an excellent system for light modulation, especially in the spring and summer.
- Retractable shade curtains alone can also be very effective when properly controlled.
- Avoid excessive shading during winter months and cloudy weather.

Supplemental Lighting Guidelines

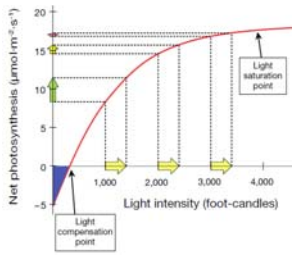
- The high-pressure sodium lamp is the most economical lamp type for many seasonal greenhouse applications
- Lamps should turn on/off automatically by an environmental control computer based on light conditions, for example:

  On: Light intensity less than 185 µmol·m^{-2}·s^{-1} for more than 5 minutes

  Off: Light intensity more than 370 µmol·m^{-2}·s^{-1} for more than 5 minutes

Greatest Benefit from Supplemental Lighting

- From October to March (North)
- From November to February (South)
- During non-sunny conditions (during the night and on cloudy days)



Supplemental Lighting Guidelines

- Choose lamps based on:
  - Efficiency: Photons per watt (µmol/W)
  - Greenhouse dimensions, especially hanging height
  - Reliability: Use trusted brands with warrantees
  - Purchase and installation cost and return on investment
  - Light spectrum for desired plant responses

Electrical Efficiency of Lamps for Supplemental Lighting

Source: Bruce Bugbee, Utah State University
http://cpl.usu.edu/ledandhps

Lamp type	PPF efficiency (µmol/W)
High-pressure sodium, magnetic, 400 W	0.93
High-pressure sodium, magnetic, 1000 W	1.02–1.15
High-pressure sodium, electronic, 1000 W	1.30
Ceramic metal halide, 315 W	1.34–1.44
Red + Blue LED fixtures	0.84–1.60

LEDs for Photosynthetic Lighting

- Situations when LEDs could be more favorable:
  - High electricity costs
  - Limited energy availability
  - Utility rebates
  - Improved growth characteristics (compact growth, improved pigmentation, etc.)
  - Year-round use, such as in completely enclosed environments (sole source or multilayer production)
  - Can place lights close to crop (vertically or horizontally)

LEDs for Photosynthetic Lighting

- Potential challenges with LEDs:
  - Investment cost
  - Don't emit heat to plants below; crops under HPS lamps can be 2–4 °F warmer than with LEDs
  - Durability and reliability
  - Light emission pattern (often directional light)
  - Shading of fixtures

How much Light (DLI) can you add with Supplemental Lighting?

- Common recommendation is to provide 400 to 500 footcandles at plant level, which adds 0.19 to 0.24 mol·m^{-2} each hour lamps are on. For example:

Duration (hours)	Footcandles (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

DLICALC

- How long do I need to run my supplemental lights to achieve a target supplemental DLI?
- I am currently operating supplemental lights, what is my supplemental DLI?
- http://extension.unh.edu/Greenhouse Floriculture/Web-Based

Installation Costs

- Typical installation costs for HPS lights are shown below.
- Lighting level in both situations is for 500 foot candles (65 µmol·m^{-2}·s^{-1}).

Situation	Lamps	Wiring	Total
1- 400 W lamp/86 ft^2	$2.03/ft^2	$0.87/ft^2	$2.90/ft^2
1- 600 W lamp/143 ft^2	$1.96/ft^2	$0.52/ft^2	$2.48/ft^2

Operation Costs

- Operation costs are primarily electrical
- At 10.3 cents per KWH and a lighting level of 500 fc (65 µmol), the electrical costs in cents per ft^2 week are shown below:

Situation	12 hr/d	15 hr/ d	18 hr/d	21 hr/ d	24 hr/ d
400 W lamp	4.6	5.8	7.0	8.2	9.3
600 W lamp	4.1	5.1	6.1	7.1	8.1

Supplemental Lighting Advantages

- Increased dry mass (higher quality)
- Greater root mass and stem caliper
  - More "pullable" plugs for transplanting
- Heat from lamps (for HPS & MH lamps only)
  - Increases rate of development
  - Reduces finish crop time
- Carry-over effects for the finished plant

Is it cost-effective to increase DLI during cutting propagation?

Angelonia propagated at 73/ 70 ºF (23/20 ºC) in a 1 acre greenhouse in Indianapolis, IN

Scenario	Prop. DLI (mol·m^{-2}·d^{-1})	*Heating cost/sq .ft.	**Lighting cost/ sq. ft.	Total heating and lighting cost/ sq. ft.
No light	5	$ 1.02 (5 weeks)	0	$ 1.02
With light	10	$ 0.83 (4 weeks)	$ 0.03 (3 weeks)	$ 0.86

*58 - 400 W HPS lamps (75 µmol·m^{-2}·s^{-1}) for 18 hr
**Heating with propane

Savings of $0.16 sq. ft. (16%)

Is it cost-effective to increase DLI during cutting propagation?

Argyranthemum grown at 73/ 70 ºF (23/20 ºC) in a 1 acre greenhouse in Indianapolis, IN

Scenario	Prop. DLI (mol·m⁻²·d⁻¹)	*Heating cost/sq .ft.	**Lighting cost/ sq. ft.	Total heating and lighting cost/ sq. ft.
No light	7	$ 1.02 (5 weeks)	0	$ 1.02
With light	12	$ 0.75 (3 weeks)	$ 0.02 (2 weeks)	$ 0.77

*58 - 400 W HPS lamps (75 µmol·m⁻²·s⁻¹) for 18 hr
**Heating with propane

Savings of $ 0.25 sq. ft. (25%)

The economics of lighting during cutting propagation on heating costs during finishing

Angelonia grown at 73/ 70 ºF (23/20 ºC) in a 1 acre greenhouse in Indianapolis, IN

Scenario	Prop. DLI (mol·m⁻²·d⁻¹)	**Heating cost during finishing /sq .ft.
No light	5	$ 0.58 (32 days)
With light	10	$ 0.42 (23 days)

Savings of 0.16 sq. ft. (28%)

For More Information

http://flowers.hort.purdue.edu

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