2nd International Webinar Conference

Benefits of Supplemental Lighting

Roberto Lopez, Purdue University

2nd International Webinar Conference

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BENEFITS OF SUPPLEMENTAL LIGHTING FOR SPRING ANNUALS

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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.

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).**

Measuring Instantaneous Light

- The footcandle (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.

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.

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 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

- 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.

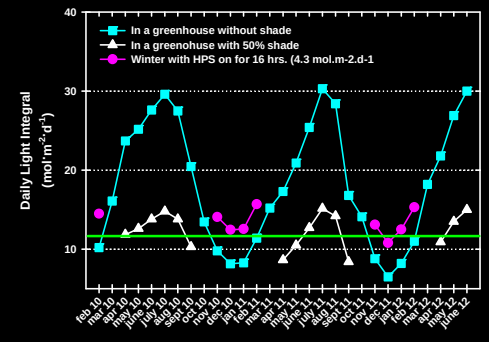
Daily Light Integral (DLI)

- 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.

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

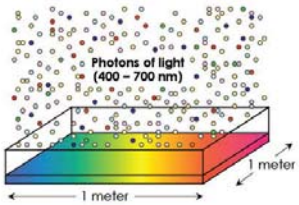
This greenhouse operation is reducing light in the PAR region to the crops on the bench by hanging too many baskets.

DLI in a Greenhouse located in West Lafayette, IN



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)

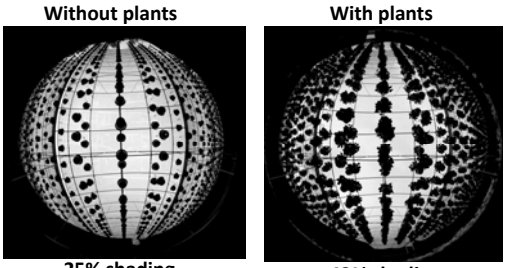
Varies due to factors that influence light intensity and duration:

- 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)

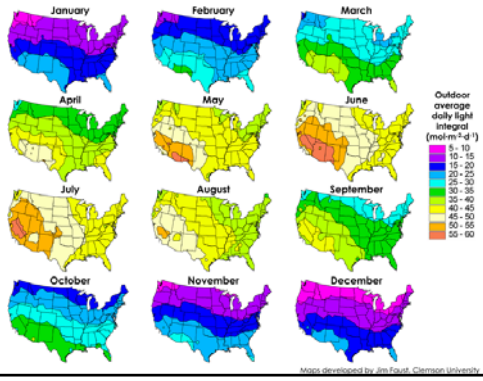
- DLI is expressed in units of moles of light (mol) per square meter (m^{-2}) per day (d^{-1}) or $mol \cdot m^{-2} \cdot d^{-1}$.
- Values from sunlight outdoors vary from 3 (winter) to 60 $mol \cdot m^{-2} \cdot d^{-1}$ (summer).
- In a greenhouse, values seldom exceed 30 $mol \cdot m^{-2} \cdot d^{-1}$ because of shading which can reduce light by 40 to 70%.
- Target minimum DLI inside a greenhouse are 10 to 12 $mol \cdot m^{-2} \cdot d^{-1}$.

Shading Increases as Plants Grow



Jim Faust, Clemson Univ.

Outdoor Daily Light Integral

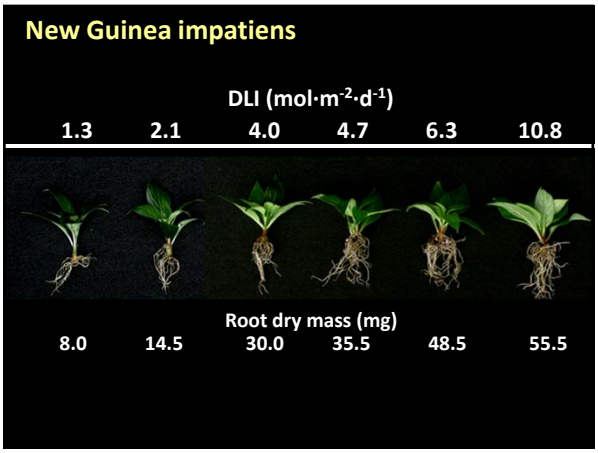


Plant Responses to Higher DLI

- 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
- Increased yield (cut flowers , vegetables, and fruits)

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 or Light Emitting Diodes (LEDs).



Benefits of Supplemental Lighting

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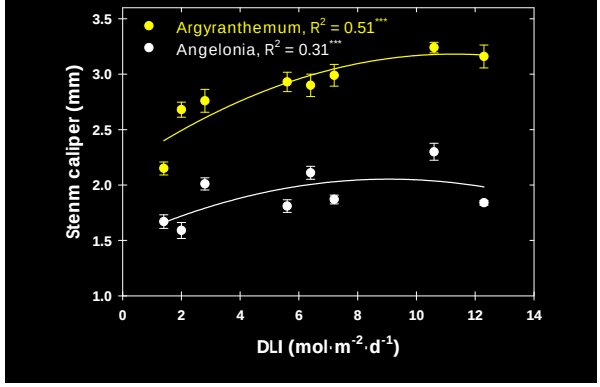
Angelonia

DLI (mol·m^{-2}·d^{-1})

1.4	2.0	3.8	5.6	6.4	7.2	10.6	12.3

Root dry mass (mg)

8.3	10.9	18.7	31.6	27.5	33.0	38.4	30.9



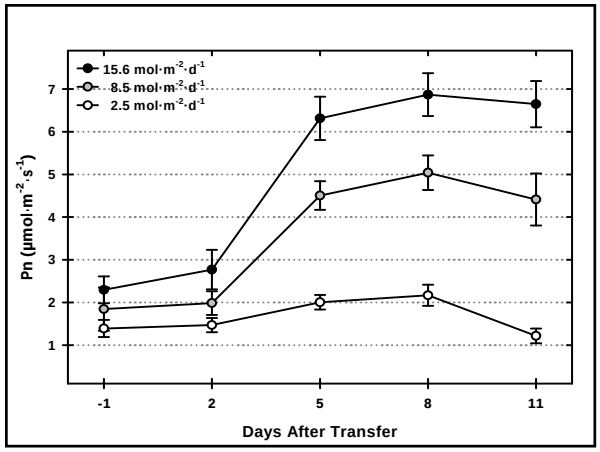
Argyranthemum

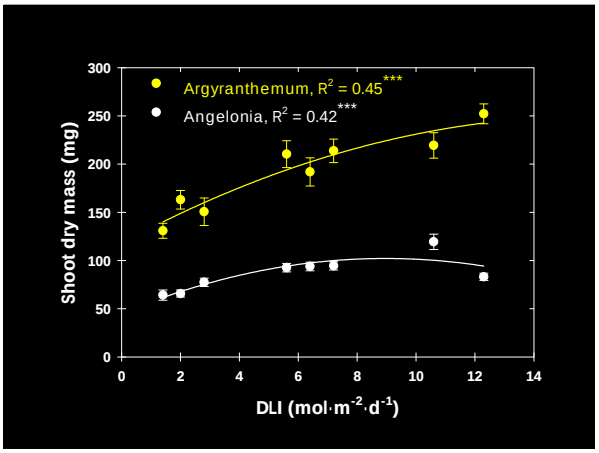
DLI (mol·m^{-2}·d^{-1})

1.4	2.0	3.8	5.6	6.4	7.2	10.6	12.3

Root dry mass (mg)

14.9	22.6	27.1	48.0	40.1	45.6	56.0	84.0





Angelonia

DLI (mol·m^{-2}·d^{-1}) during Propagation

1.4	2.0	3.8	5.6	6.4	7.2	10.6	12.3

Photo taken 14 d after transplant

Shoot dry mass (g) at flower

1.2	1.1	1.1	0.94	0.86	0.77	0.64	0.38

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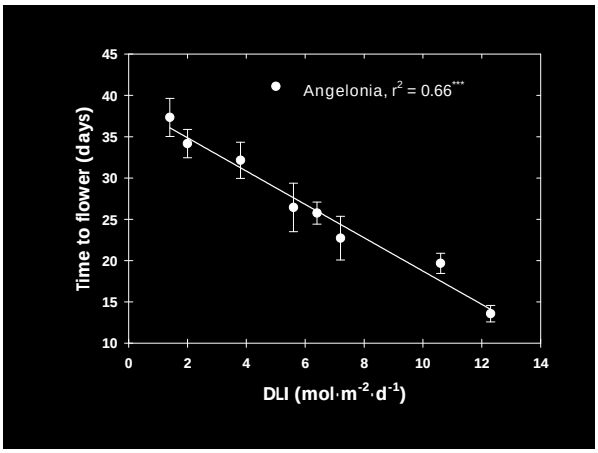


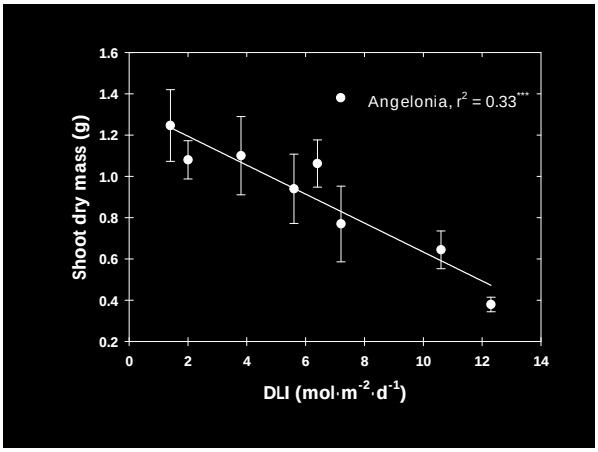
Economics of Lighting during Propagation on Heating costs during Finishing

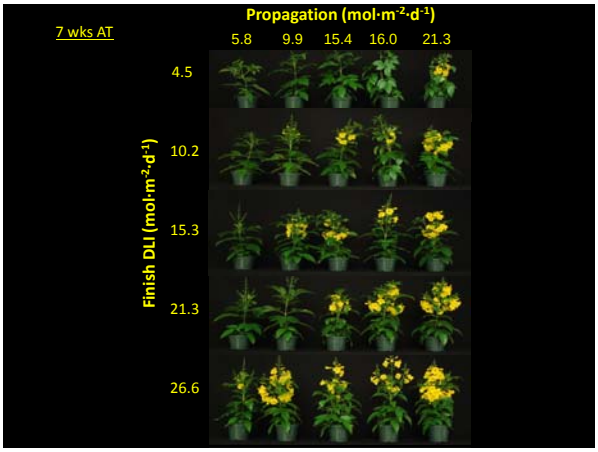
Total Heating during Finishing and Propagation Lighting Cost: $ 18,264 for *Angelonia* propagated under a DLI of 7.2 mol·m^{-2}·d^{-1}

Cost of Heating with Propane for 23 d

Finishing (23 d)
70/70 ºF day/night
($18,264)

Savings of $6,795 (27%)



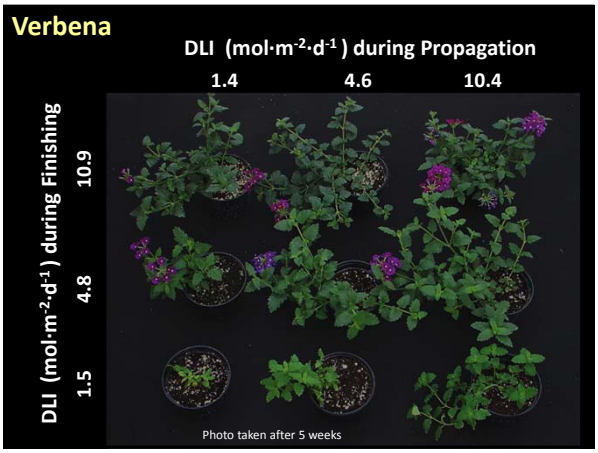


Economics of NOT Lighting during Propagation on Heating costs during Finishing

Total Heating Cost during finishing: $25,059 for *Angelonia* propagated under a DLI of 3.8 mol·m^{-2}·d^{-1}

Cost of Heating with Propane for 32 d

Finishing (32 d)
70/70 ºF day/night
($25,059)



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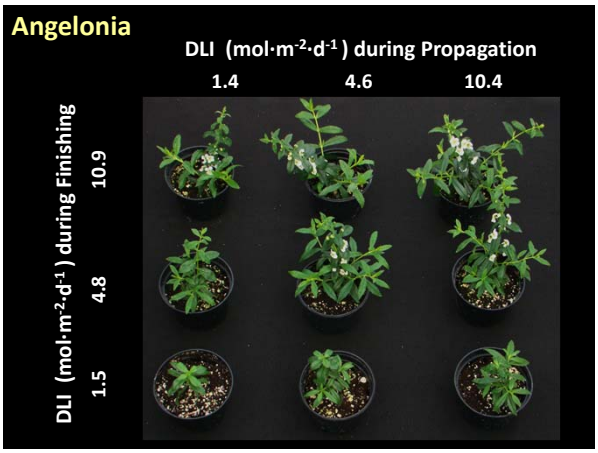

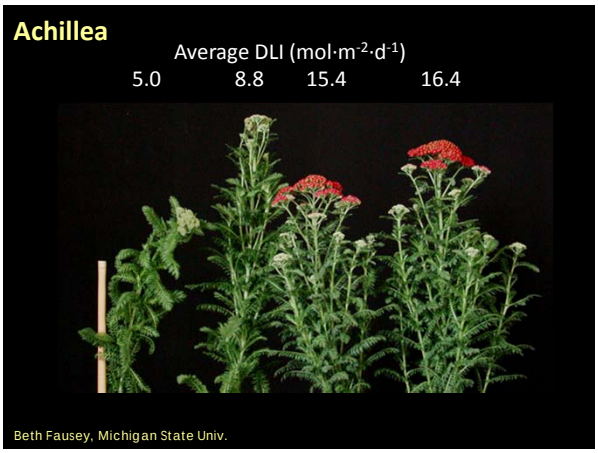

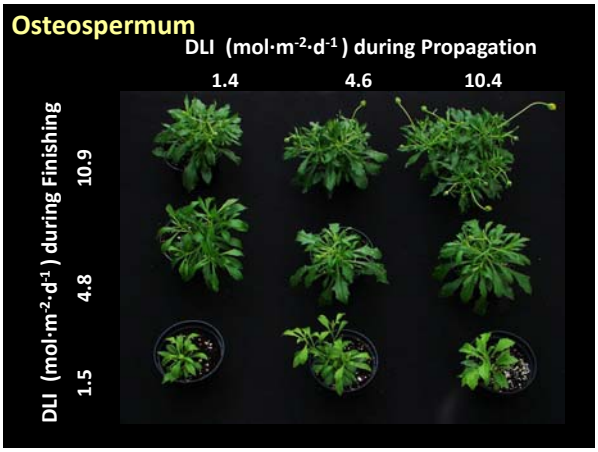

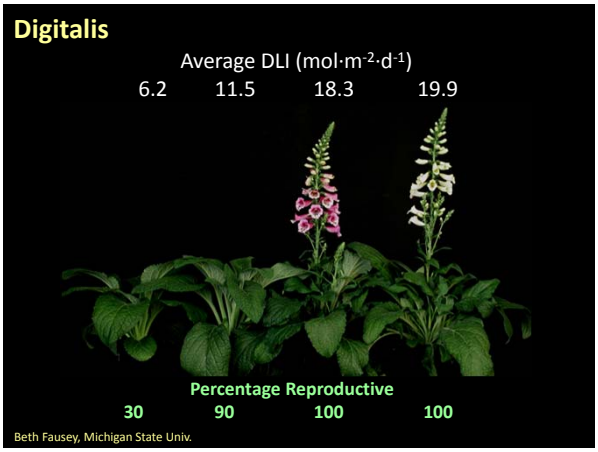

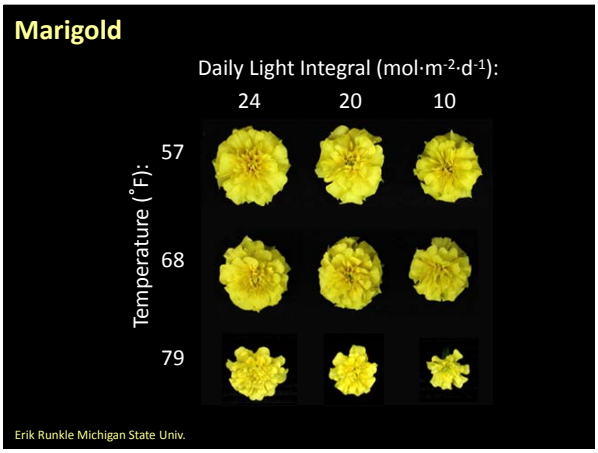

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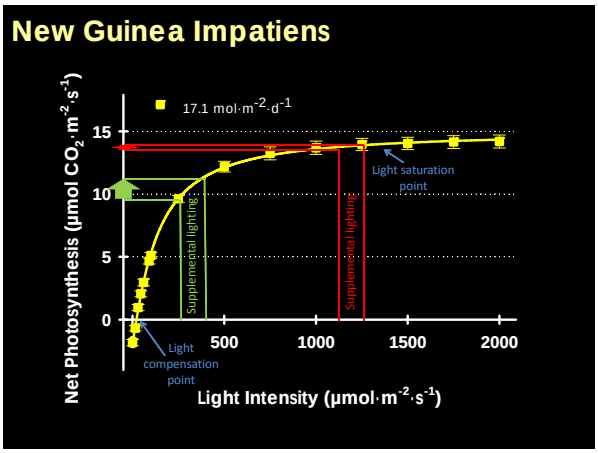

Greatest Benefit from Supplemental Lighting

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

Supplemental Lighting Guidelines

- 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 200 µmol·m^{-2}·s^{-1} for more than 5 minutes

  Off: Light intensity more than 400 µmol·m^{-2}·s^{-1} for more than 10 minutes

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 costs and return on investment
  - Light spectrum for desired plant responses

Supplemental Lighting Guidelines

- Light intensity and duration are both important
- Recommendation is to provide 50 to 75 µmol·m^{-2}·s^{-1} of photosynthetic light (PAR) at plant level, which adds 0.18 to 0.27 mol·m^{-2} each hour lamps are on. For example:

Supplemental Light Level	Supplemental DLI (mol·m^{-2}·d^{-1})				
µmol	12 hr.	15 hr.	18 hr.	21 hr.	24 hr.
35	1.5	1.9	2.3	2.7	3.0
50	2.2	2.7	3.2	3.8	4.3
65	2.8	3.5	4.2	4.9	5.6
80	3.5	4.3	5.1	6.1	6.9
95	4.3	5.4	6.6	7.6	8.6

High-Intensity Lighting Efficiency

Lamp type	PPF efficiency (µmol/W)
HPS, magnetic, 400 W	0.94
HPS, magnetic, 1000 W	1.16
HPS, electronic, 1000 W	1.30
HPS, electronic, 1000 W, double ended	1.70
Ceramic metal halide, 315 W	1.34–1.44
Red + Blue LED fixtures	0.89–1.70

Nelson J.A. and B. Bugbee. 2014. Economic analysis of greenhouse lighting: Light emitting diodes vs. high intensity discharge fixtures. PLoS ONE 9(6):e99010.

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Operation Costs

- Operation costs are primarily electrical
- At 10.3 cents per KWH and a lighting level of 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

Acknowledgments

- We thank former graduate student research assistants and technicians who have performed experiments to generate this information
- We also thank private horticulture and lighting companies that financially support MSU and Purdue floriculture research including:

HORT AMERICAS
PHILIPS sense and simplicity
USDA United States Department of Agriculture National Institute of Food and Agriculture
P.L. LIGHT SYSTEMS

DLICALC

- Supplemental light calculator
- http://extension.unh.edu/Grower-Tools/Web-Based

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LED Website and Conferences

http://leds.hrt.msu.edu

- **LED Webinar: Uncovering the Potential uses LEDs in Greenhouses and Indoor Production of Ornamental and Vegetable Crops**
  - February 13, 2015
  - 1 hour free webinar - Sponsored by Philips Lighting
  - Register: http://e-gro.org
- **LED Symposium: Developing LED Lighting Technologies and Practices for Sustainable Specialty-Crop Production**
  - February 19 (tour/reception) and 20 (full day), 2015
  - Tucson, AZ and online
  - $40 online; $70 onsite
  - Register: http://leds.hrt.msu.edu/meeting

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