Light Consists of Three Dimensions

1. Light duration (photoperiod)
   - Flowering, dormancy

2. Light quality (distribution)
   - Stem extension and flowering

3. Light quantity (intensity)
   - Root and shoot growth, branching, flowers and fruit
Regulating Flowering with Photoperiod

Campanula ‘Merrybell Bright Blue’
Photoperiod (hours):
13 14 15 16

Lighting Technologies

- Incandescent bulb
- Compact fluorescent bulb
- LED emitter

- Purchase price increases
- Electrical efficiency increases
- Lamp lifetime increases
Developing Effective R:FR

Objective: Determine how the red : far-red (R:FR) influences flowering and extension growth of photoperiod-sensitive crops to facilitate the development and use of effective LEDs for flowering applications.

Efficacy of R:FR for NI Lighting

<table>
<thead>
<tr>
<th>Long-day plants:</th>
<th>Short-day plants:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petunia 'Shock Wave Ivory'</td>
<td>Chrysanthemum 'Adiva Purple'</td>
</tr>
<tr>
<td>Petunia 'Easy Wave White'</td>
<td>Tagetes 'Antigua Yellow'</td>
</tr>
<tr>
<td>Petunia 'Wave Purple Improved'</td>
<td>Dahlia 'Figarò Mix'</td>
</tr>
</tbody>
</table>

The diagram illustrates the estimated $P_{FR}/P_{R+FR}$ for different plant species under FR only and R only conditions.
"Flowering Lamps" by Philips

Question: Are the R+W+FR lamps more effective than the R+W lamps, as would be predicted?

Chrysanthemum ‘Aideen Red Fire’

After 7 weeks at 20 °C, DLI = 5.7 mol·m⁻²·d⁻¹

9-hour short day

<table>
<thead>
<tr>
<th>Incan.</th>
<th>R+W</th>
<th>R+W+FR</th>
</tr>
</thead>
</table>

9-hour day with 4-hour night interruption
Ageratum ‘Hawaii Blue’

After 7 weeks at 20 °C, DLI = 5.7 mol·m⁻²·d⁻¹

<table>
<thead>
<tr>
<th>9-hour short day</th>
<th>9-hour day with 4-hour night interruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incan.</td>
<td>R+W</td>
</tr>
<tr>
<td>R+W+FR</td>
<td></td>
</tr>
</tbody>
</table>

Dianthus ‘Super Parfait Strawberry’

After 9 weeks at 20 °C, DLI = 5.7 mol·m⁻²·d⁻¹

<table>
<thead>
<tr>
<th>9-hour short day</th>
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<tbody>
<tr>
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<td></td>
</tr>
</tbody>
</table>
Petunia ‘Wave Purple Classic’

After 6 weeks at 20 °C, DLI = 5.7 mol·m⁻²·d⁻¹

<table>
<thead>
<tr>
<th>9-hour short day</th>
<th>9-hour day with 4-hour night interruption</th>
</tr>
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<tbody>
<tr>
<td>Incan.</td>
<td>R+W</td>
</tr>
<tr>
<td></td>
<td>R+W+FR</td>
</tr>
</tbody>
</table>

Conclusion: The influence of the R:FR of night-interruption lighting diminishes as the daily light integral increases.
Objective: To investigate the effects of NI lighting with different combinations of low-intensity B, R, and/or FR light provided by LEDs and from W LEDs on flowering of photoperiodic ornamentals.
Treatments
- Short-day photoperiod (SD)
- NI from incandescent lamps
- NI from LEDs (6 combinations):
  - W
  - B
  - B+R
  - B+FR
  - B+R+FR
  - R+FR

Experimental Protocol
2 µmol·m^{-2}·s^{-1} between 400-800 nm

Days to flower at 20 °C
- None
- INC
- W
- B
- B+R
- B+FR
- B+R+FR
- R+FR

Flowering percentage
- 69 NS
- 69 NS
- 69 NS
- 67 NS

Role of B Light as Night Interruption

Rudbeckia ‘Tiger Eye Gold’
9-hour day with 4-hour night-interruption at 2 µmol·m^{-2}·s^{-1} from:

Days to flower at 20 °C
- 69 NS
- 69 NS
Role of B Light as Night Interruption

Petunia ‘Wave Purple Classic’
9-hour day with 4-hour night-interruption at 2 µmol·m⁻²·s⁻¹ from:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days to Flower</th>
<th>Flowering Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>44 b</td>
<td>100</td>
</tr>
<tr>
<td>INC</td>
<td>52 a</td>
<td>100</td>
</tr>
<tr>
<td>W</td>
<td>50 a</td>
<td>65</td>
</tr>
<tr>
<td>B</td>
<td>60 a</td>
<td>80</td>
</tr>
<tr>
<td>B+R</td>
<td>41 b</td>
<td>100</td>
</tr>
<tr>
<td>B+FR</td>
<td>43 b</td>
<td>100</td>
</tr>
</tbody>
</table>

Days to flower at 20 °C

Role of B Light as Night Interruption

Chrysanthemum ‘Golden Cheryl’
9-hour day with 4-hour night-interruption at 2 µmol·m⁻²·s⁻¹ from:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days to Flower</th>
<th>Flowering Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>44 e</td>
<td>107 c</td>
</tr>
<tr>
<td>INC</td>
<td>140 a</td>
<td>96 d</td>
</tr>
<tr>
<td>W</td>
<td>44 e</td>
<td>96 d</td>
</tr>
<tr>
<td>B</td>
<td>120 b</td>
<td>47 e</td>
</tr>
<tr>
<td>B+R</td>
<td>118 b</td>
<td>47 e</td>
</tr>
</tbody>
</table>

Days to flower at 20 °C
Managing Greenhouse Light

For specific information on light responses of various horticultural plants, click on those topics. To learn more about light-emitting diodes (LEDs), visit our website focused on Developing LED Lighting Technologies and Practices for Sustainable Specialty-Crop Production.

LED Team Website

www.leds.hrt.msu.edu

Developing LED Lighting Technologies and Practices for Sustainable Specialty-Crop Production

In 2004, approximately 2.9% of farmland in the United States was used for high-value specialty crops yet they accounted for 39.5% of total farmland revenue. In many areas of the United States, particularly in temperate regions, growers produce high-value fruits, vegetables, and ornamentals in protected environments such as greenhouses and high tunnels. In a range of climates, growers often rely on horticultural high-intensity discharge (HID) lighting for supplemental lighting required at many stages of the growing process.

Much of the energy used to power HID lighting is unfortunately wasted in light that plants do not require to grow and in heat generated by the ballasts. In addition, there are negative environmental impacts created by HID lighting and compact fluorescent lighting found in many consumer applications.

Light-emitting diode (LED) technologies are energy-efficient, long-lasting, and flexible in use. LEDs provide potential solutions to many of these problems. However, for this application and the light frequencies required for plant growth, the initial expense and lack of extensive field trials have led to...
Acknowledgments

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[Logos of USDA, Michigan State University AgBioResearch, Philips, Project GREEN, and Raker]