What’s New and Noteworthy about LED Lighting for Plant Applications

Erik Runkle
November, 2015

MSU Floriculture Research

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50% Extension

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75% Research
25% Teaching

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45% Research
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75% Research

Robert Lopez
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Does Blue Light Regulate Flowering?

Objective: To investigate the effects of NI lighting from combinations of B, R, and/or FR LEDs and W LEDs on flowering of photoperiodic ornamentals

Blue and White Light on Flowering

Objective: To investigate the effects of NI lighting from combinations of B, R, and/or FR LEDs and W LEDs on flowering of photoperiodic ornamentals

MSU Floriculture Research, 2014-2015

• Understanding the genetic control of crop quality and flowering time traits to help breeders develop improved cultivars
• Quantifying flowering time of new Wave petunias
• Comparing the efficacy of Configure and a similar experimental compound on branching
• Application of ribose to inhibit growth and potentially stimulate flowering of orchids
• Development of LED applications
  o To regulate flowering
  o For sole-source lighting
  o For supplemental greenhouse lighting

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:

None INC W B B+R B+FR B+R+FR R+FR

Days to flower at 68 °F

Flowering percentage

69 NS 69 NS 69 NS 69 NS

0 100 100 0 100 0 100 100
Marigold ‘American Antigua Yellow’

9-hour day with 4-hour night-interruption:

<table>
<thead>
<tr>
<th>R+FR</th>
<th>R+FR+B₁</th>
<th>R+FR+B₁₅</th>
<th>R+FR+B₃₀</th>
<th>B₃₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 b</td>
<td>54 a</td>
<td>55 a</td>
<td>54 a</td>
<td>53 a</td>
</tr>
</tbody>
</table>

Days to flower at 68 °F

R+FR light delivered by R+W+FR LEDs at 2 μmol·m⁻²·s⁻¹

Value following B indicates intensity of blue light (in μmol·m⁻²·s⁻¹)

Calibrachoa ‘Callie Yellow Improved’

9-hour day with 4-hour night-interruption:

<table>
<thead>
<tr>
<th>R+FR</th>
<th>R+FR+B₁</th>
<th>R+FR+B₁₅</th>
<th>R+FR+B₃₀</th>
<th>B₃₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>85 a</td>
<td>24 b</td>
<td>27 b</td>
<td>26 b</td>
<td>26 b</td>
</tr>
</tbody>
</table>

Days to flower at 68 °F

R+FR light delivered by R+W+FR LEDs at 2 μmol·m⁻²·s⁻¹

Value following B indicates intensity of blue light (in μmol·m⁻²·s⁻¹)

Coreopsis ‘Early Sunrise’

9-hour day with 4-hour night-interruption lighting from (intensity, in μmol·m⁻²·s⁻¹):

<table>
<thead>
<tr>
<th>R+W+FR</th>
<th>Blue (2)</th>
<th>Blue (5)</th>
<th>Blue (15)</th>
<th>Blue (30)</th>
</tr>
</thead>
</table>

High-intensity B Light Night Interruption

4-h NI lighting from LEDs:

R B+R Cool-W Warm-W R+W+FR

Efficacy of White LEDs at NI Lighting

8 am 5 pm 10:30 pm 2:30 am 8 am

R B+R Cool-W Warm-W R+W+FR

Calibrachoa ‘Callie Yellow Improved’

68 °F with a truncated 9-h day

4-night-interruption lighting from:

<table>
<thead>
<tr>
<th>R</th>
<th>B+R</th>
<th>Cool-W</th>
<th>Warm-W</th>
<th>R+W+FR</th>
</tr>
</thead>
</table>

100% flowering under all treatments.

Days from transplant to first flower

R:F = 600–700 nm; 700–800 nm; B:R = 400–500 nm; 600–700 nm.

PPE = Estimated phytochrome photoequilibria from Sager et al., 1988.
Coreopsis ‘Early Sunrise’

68 °F with a truncated 9-h day
4-h night-interruption lighting from:

<table>
<thead>
<tr>
<th>R</th>
<th>B+R</th>
<th>Cool-W</th>
<th>Warm-W</th>
<th>R+W+FR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNF</td>
<td>74 a</td>
<td>79 a</td>
<td>75 a</td>
<td>75 a</td>
</tr>
</tbody>
</table>

Days from transplant to first flower

Snapdragon ‘Liberty Classic Yellow’

68 °F with a truncated 9-h day
4-h night-interruption lighting from:

<table>
<thead>
<tr>
<th>R</th>
<th>B+R</th>
<th>Cool-W</th>
<th>Warm-W</th>
<th>R+W+FR</th>
</tr>
</thead>
<tbody>
<tr>
<td>64 ab</td>
<td>64 a</td>
<td>66 a</td>
<td>63 b</td>
<td>63 ab</td>
</tr>
</tbody>
</table>

100% flowering under all treatments

Sole-Source (Indoor) Lighting

- Objective: To compare growth of seedlings under white or red+blue light from LEDs
- Treatments: 18-hour photoperiod with PPF = 160 μmol·m⁻²·s⁻¹ from:

<table>
<thead>
<tr>
<th>Treatment #1</th>
<th>Treatment #2</th>
<th>Treatment #3</th>
<th>Treatment #4</th>
<th>Treatment #5</th>
<th>Treatment #6</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW₁₀₀</td>
<td>MW₁₀₀⁺R₂₅</td>
<td>MW₁₀₀⁺R₅₅</td>
<td>MW₁₀₀⁺R₇₅</td>
<td>R₈₅⁺B₁₅</td>
<td>R₄₀⁺G₄₀⁺B₂₀</td>
</tr>
</tbody>
</table>

B=blue (peak=451 nm); G=green (peak=521 nm); R=red (peak=660 nm); MW=mint white (peak=552 nm). Values after each LED type indicate its percentage of the total PPF in each treatment.

Geranium ‘Pinto Premium Deep Rose’

Seedlings grown at 68 °F for 25 days under LEDs (33 days after sow)
18-hour photoperiod with PPF = 160 μmol·m⁻²·s⁻¹

<table>
<thead>
<tr>
<th>MW₁₀₀</th>
<th>MW₁₀₀⁺R₂₅</th>
<th>MW₁₀₀⁺R₅₅</th>
<th>MW₁₀₀⁺R₇₅</th>
<th>R₈₅⁺B₁₅</th>
<th>R₄₀⁺G₄₀⁺B₂₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.6 ab</td>
<td>5.7 ab</td>
<td>5.3 abc</td>
<td>5.9 a</td>
<td>4.8 c</td>
<td>5.1 bc</td>
</tr>
<tr>
<td>Leaf area (cm²)</td>
<td>30.4 a</td>
<td>31.8 a</td>
<td>29.8 a</td>
<td>32.3 a</td>
<td>25.5 b</td>
</tr>
</tbody>
</table>

Petunia ‘Wave Blue’

Seedlings grown at 68 °F for 19 days under LEDs (31 days after sow)
18-hour photoperiod with PPF = 160 μmol·m⁻²·s⁻¹

<table>
<thead>
<tr>
<th>MW₁₀₀</th>
<th>MW₁₀₀⁺R₂₅</th>
<th>MW₁₀₀⁺R₅₅</th>
<th>MW₁₀₀⁺R₇₅</th>
<th>R₈₅⁺B₁₅</th>
<th>R₄₀⁺G₄₀⁺B₂₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf area (cm²)</td>
<td>32.1 a</td>
<td>31.1 a</td>
<td>33.4 a</td>
<td>29.4 ab</td>
<td>26.5 b</td>
</tr>
</tbody>
</table>
**Petunia ‘Wave Blue’**

Seedlings grown at 68 °F for 45 days under LEDs (57 days after sow)
18-hour photoperiod with PPF = 160 μmol·m⁻²·s⁻¹

**Sole-Source Lighting with Far Red**

<table>
<thead>
<tr>
<th>Treatment #1</th>
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<th>Treatment #3</th>
<th>Treatment #4</th>
<th>Treatment #5</th>
<th>Treatment #6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment #1</td>
<td>Treatment #2</td>
<td>Treatment #3</td>
<td>Treatment #4</td>
<td>Treatment #5</td>
<td>Treatment #6</td>
</tr>
</tbody>
</table>

**Geranium ‘Pinto Premium Orange Bicolor’**

Preliminary Results

Seedlings grown at 68 °F for 22 days under LEDs (29 days after sow)
18-hour photoperiod all with B₃₂

Preliminary Results

Seedlings grown at 68 °F for 24 days under LEDs (31 days after sow)
18-hour photoperiod all with B₃₂

**Preliminary Results**

Seedlings grown at 68 °F for 24 days under LEDs (31 days after sow)
18-hour photoperiod all with B₃₂

**Indoor Leafy Green Production**

Photo taken 33 days after transplant at 68 °F with a 16-hour photoperiod.

Erik Runkle, Michigan St. Univ.

Floriculture Research Alliance 2015 annual meeting
**Indoor Leafy Green Production**

Seedlings grown at 72 °F with continuous light from (μmol·m⁻²·s⁻¹):

- Butterhead Lettuce ‘Rex’
  - B30R150B30R150FR30R180FR30B30R90FR30B180FR30

- Red-leaf Lettuce ‘Cherokee’
  - E30R150B30R150FR30R180FR30E90R90B90R90FR30B180FR30

**Supplemental (Greenhouse) Lighting**

- Supplemental lighting delivered at 90 μmol·m⁻²·s⁻¹ from:
  - HPS
  - B11R89
  - B21R79
  - B6W5R87
  - B14W5R81

- Control: 10 μmol·m⁻²·s⁻¹ from HPS lamps

**Tomato ‘Supersweet’**

Greenhouse supplemental lighting as needed from 0600 to 2200 HR at a PPF (μmol·m⁻²·s⁻¹) of:

- HPS = high-pressure sodium lamps.
  - B=blue (peak=453 nm), R=red (peak=660 nm), W=white (peak=560 nm) LEDs. Values after each LED type indicate its percentage of the total PPF in each treatment.

- Photo taken after 21 days at 68 °F, DLI = 7.7 mol·m⁻²·d⁻¹
HPS = high-pressure sodium lamps. B=blue (peak=453 nm), R=red (peak=660 nm), W=white (peak=560 nm) LEDs. Values after each LED type indicate its percentage of the total PPF in each treatment.

Photo taken after 37 days at 68 °F, DLI = 8.2 mol·m⁻²·d⁻¹

<table>
<thead>
<tr>
<th></th>
<th>HPS</th>
<th>B₂₁R₁₉</th>
<th>B₂₁R₉₉</th>
<th>B₆W₄R₆₇</th>
<th>B₁₄W₄R₆₁</th>
<th>HPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPF</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

### Petunia ‘Wave Misty Lilac’

Greenhouse supplemental lighting as needed from 0600 to 2200 HR at a PPF (μmol·m⁻²·s⁻¹) of:

### CE Lighting Lab (CELL) at MSU

Anticipated completion: Spring, 2016

### ISHS International Lighting Symposium

May 22-26, 2016 - East Lansing, Michigan

www.lightsym16.com

### New Book on Plant Lighting

- Updated and expanded from 2004 Lighting Up Profits book edited by Fisher and Runkle
- New book with 18 chapters, edited by Lopez and Runkle
- 19 chapter authors including FRA partners Dole, Faust, Fisher, and Warner
- Published by Meister Media (parent company of Greenhouse Grower)
- Available in print and digital versions in summer, 2016

### Acknowledgments

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Erik Runkle, Michigan St. Univ.