Testing of LEDs for Supplemental Lighting of Greenhouse-grown Tomatoes for a Northern Climate

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The greenhouse environment

- Semi-controlled environment for extensive production
- More affordable than completely controlled environments
- Take profit from natural solar radiation
Rationale

• Energy is second only to labor as the most expensive indirect costs of greenhouse production (Frantz et al., 2010).

• The industry wants:
  • Cost effectiveness
  • Energy efficiency

• High-intensity discharge (HID) lamps:
  • High investment and installation costs
  • Short life-span
  • Problem for disposal (mercury and sodium vapors)
  • Inefficient at converting electrical energy into photosynthetically active radiation (PAR)
Mutual shading...
Traditional overhead HPS lighting

Bushel Boy Farms, Owatonna, MN
Light-emitting Diodes (LEDs)

- Low wattage consumption
- Robust
- Long-lasting
- Narrow-band wavelengths
- Can be dimmed
- LEDs are being tested as supplemental lighting in greenhouses in the US
LEDs
Cool surface
Close to plant tissue
Adequate PPF
Low energy consumption

Lighting system built by ORBITEC, Madison, WI
Young tomato plants with LED lighting (temporarily positioned overhead) (experiment 2009/2010 at WUR) (Netherhoff 2010).
Objectives

• Compare year-round tomato production with no supplemental lighting vs. traditional overhead HPS lighting vs. overhead/side-/intracanopy-lighting arrays with high-intensity red and blue LEDs.
• Develop protocols for the use of LEDs arrays for greenhouses.
• Ultimately, enable US greenhouse growers to transition from HPS lighting sources to LED technologies.
Objective 1. Compare transplant quality across seasons using LEDs vs. HPS as supplemental lighting.

Objective 2. Evaluate transplant production of different cultivars under LEDs vs. HPS vs. no supplemental lighting across seasons.
Hypothesis

Tomato seedlings grown under LEDs will achieve equal or greater transplant quality compared to those grown with HPS or no supplemental light while reducing electrical energy consumption in greenhouses.
Greenhouse tomatoes being tested (Indeterminate cultivars)

1. ‘Maxifort’- Rootstock
2. ‘Komeett’- generative scion
3. ‘Success’- vegetative scion
4. ‘Liberty’ - beef, scion
5. ‘Sheva-sheva’ - Roma, scion
6. ‘Felicity’- round cherry, scion
## Supplemental lighting treatments

<table>
<thead>
<tr>
<th>Treatments*</th>
<th>Supplemental PPF ($\mu$mol·m$^{-2}$·s$^{-1}$)</th>
<th>Photoperiod (h/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control, natural light</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>HPS (100 W)</td>
<td>61</td>
<td>23</td>
</tr>
<tr>
<td>LEDs 100% red</td>
<td>61</td>
<td>23</td>
</tr>
<tr>
<td>LEDs 95% red + 5% blue</td>
<td>61</td>
<td>23</td>
</tr>
<tr>
<td>LEDs 80% red + 20% blue</td>
<td>61</td>
<td>23</td>
</tr>
</tbody>
</table>

*DLI (5.05 mol·m$^{-2}$·d$^{-1}$).
100 W HPS
Control

95% red - 5% blue

Lighting system built by ORBITEC, Madison, WI
Lighting system built by ORBITEC, Madison, WI
Growing conditions

• Plants are propagated and grown in a glass-glazed greenhouse.

• Cumulative DLI is collected for each lighting treatment using LI-COR 190 SB quantum sensors interfaced to a Campbell Sci. CR1000 datalogger.

• The experiment is being repeated monthly for 21 days (expected start and end dates: ~5\textsuperscript{th} and ~26\textsuperscript{th} of each month, respectively) for at least 12 months.
Data collected

- Hypocotyl and epicotyl length (cm)
- Hypocotyl and epicotyl caliper (mm)
- Node number
- Leaf span (cm)
- Leaf area (cm²)
- Shoot DW (g)

- Shoot biomass per kWh of energy consumed is compared for the different treatments.
Results obtained with ORBITEC’s overhead, open-bar LED arrays
Preliminary Results

• Supplemental lighting is needed for adequate transplant growth during light-limited times of year.
• Blue light addition may be beneficial for plant growth in light-limited climates.
GROW-OUT STAGE
Hypothesis

Tomatoes grown with side/intracanopy LED lighting will achieve equal or higher yields than plants grown with HPS or no supplemental light while reducing electrical energy consumption in greenhouses.
LED lighting system built by ORBITEC, Madison, WI
LEDs

Lighting system built by ORBITEC, Madison, WI
Crop-response metrics to be measured

- **Yield/productivity metrics:**
  - Fruit number
  - Fruit weight
  - Stem growth (diameter/length)
  - Leaf length
  - Shoot dry weight

- **Physiological metrics:**
  - Chlorophyll (SPAD)
  - Chlorophyll fluorescence
  - Leaf/fruit temperature
  - Leaf photosynthetic rates

- **Fruit quality metrics:**
  - Organoleptic
    - Sweetness
    - Acidity
    - Texture
    - Color

- **Physico/chemical:**
  - Total soluble solids
  - Titratable acidity
  - Lycopene content
  - Antioxidant content
Plant responses to...

- Light source
- Cultivar
- Season
- Position of leaves in the plant canopy