LED Lighting

Review of practical experience and results of trials in different cut flower crops

Marco de Groot
Crop consultant Gerbera and Alstroemeria
marco@floriiconsultgroup.nl
LED developments Gerbera and Alstroemeria

Full LED
LED 2.7 μmol/Watt el
Gerbera

- In The Netherlands, Gerbera is the third cut flower crop after Chrysanthemum and Rose
- It is a quantitative short day plant (darkening screens needed in summer)
- Electricity is needed to overcome the low light levels in Dutch winter
- Lighting hours increasing to 2800 hours/year
- Light intensity standard: 180-200 umol/m²
- Light intensity mini: 100-125 umol/m²
Energy = high production costs

Energy use in gerbera cultivation in The Netherlands accounts for up to 27% of total production costs. Developing and implementing strategies to reduce the use of energy in gerbera cultivation has been an important research topic in the last few years.
LED developments

Hybrid
HPS 1.85 μmol/Watt el + LED 2.7 μmol/Watt el
Light spectra

Hybrid just HPS

LED only

Hybrid just LED

Hybrid LED + HPS
# Light comparison

<table>
<thead>
<tr>
<th>HSE NXTII 1000W</th>
<th>HSE HortiLED R/B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Return</strong></td>
<td></td>
</tr>
<tr>
<td>• 2.10 μmol/W</td>
<td>• 2,6-2,7 μmol/W</td>
</tr>
<tr>
<td>• Used for full power</td>
<td>• Cooling for full power</td>
</tr>
<tr>
<td><strong>Heat radiant heat/positioning</strong></td>
<td></td>
</tr>
<tr>
<td>• Use radiant heat</td>
<td>• No radiant heat, growth tube</td>
</tr>
<tr>
<td>• Fixed position in the greenhouse</td>
<td>• Above, in between, underneath crop</td>
</tr>
<tr>
<td>• Multi-layer min. 1, 25mtr</td>
<td>• Multi-layer cultivation 30 cm</td>
</tr>
<tr>
<td><strong>Spectrum</strong></td>
<td></td>
</tr>
<tr>
<td>• Wide spectrum/all colors</td>
<td>• 95 % red, 5 % blue (and/or 1 % white)</td>
</tr>
<tr>
<td>• Good crop recognition</td>
<td>• Crop recognition difficult (workers)</td>
</tr>
<tr>
<td>• Life 30,000 hours/10.000uur</td>
<td>• Life span 50,000 hours (economical ?)</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td></td>
</tr>
<tr>
<td>• Development</td>
<td>• Development on going</td>
</tr>
<tr>
<td>• Relatively few fixtures/m²</td>
<td>• Relatively more fixtures/m²</td>
</tr>
</tbody>
</table>
LED trials

Gerbera

- Implementing light integration - 5%
- LED lichting - 20%
- 80 instead 100 μmol - 20%
- => maximum saving - 45%
- Interlighting = photoperiodical (stear) and growth light
- Stimulating side shoot development inside rows
- Better LUE (more production per mol light)
LED trials

3 compartments
● 100 μmol LED
● 80 μmol HPS
● 60 + 20 μmol (inter lighting)
Results: Flower production

HPS, Flowers/m² (cumulative)

- 4%
- 9.4%

Interlight vs. Top
Results: Flower production

Interlight vs. Top

LED instead of HPS: -2.3 %

LED 60+20
LED 80
LED 100

-3.9 %
-9 %

LED instead of HPS: -2.3 %
LED trials

Difference in production between SON-T and LED (-2.3% for LED).
LED trials

Flowers underneath LED treatment in winter taller and more heavy
No difference in flower diameter
LED trials

Light response graph

Very little difference between LED and HPS with respect to light response
No linear relation above 120 umol PAR in winter
LED trials

Max photosynthesis at 800 ppm CO2. No difference between LED and HPS
LED trials

<table>
<thead>
<tr>
<th>Energy saving by</th>
<th>goal</th>
<th>results</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Light integration</td>
<td>- 5%</td>
<td>-1.5 % energy</td>
</tr>
<tr>
<td>• LED lighting</td>
<td>- 20%</td>
<td>&lt; -2 tot -4% prod</td>
</tr>
<tr>
<td>• 80 instead of 100 μmol</td>
<td>- 20%</td>
<td>&lt; -5% prod</td>
</tr>
<tr>
<td>• maximale besparing</td>
<td>- 45%</td>
<td>41.5% &lt; -9% stem</td>
</tr>
</tbody>
</table>

Note: There has been more heat demand due to more bottom heat
• Lower light levels (< 100 umol) may improve LUE.
• Valid for HPS and LED
• More length underneath LED in winter (higher pipe temperature)
• No more issues with e.g. Botrytis in crop or flowers
• No effects on vase life
LED trials

**Gerbera**

LED trial 2015-2016

- Gerbera cv. Kimsey plants were placed in 3 greenhouses with the differences in climatic factors shown in Table 1, aimed to be in balance with the lighting systems: LED, HPS and a hybrid HPS/LED.

- Flower production, flower quality and energy use was closely monitored throughout the experiment from Oct.1, 2014 to May 1, 2015.
LED trials

Gerbera


<table>
<thead>
<tr>
<th>Treatement concept</th>
<th>Licht-intensiteit (μmol/m²/s)</th>
<th>Daglengte (uren)</th>
<th>Kastemp (°C, D/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>90</td>
<td>10.5</td>
<td>18/16</td>
</tr>
<tr>
<td>Hybride</td>
<td>100</td>
<td>9.5-12</td>
<td>17/15</td>
</tr>
<tr>
<td>SON-T</td>
<td>90</td>
<td>13 (11)</td>
<td>16/14</td>
</tr>
</tbody>
</table>

Treatment with day length and intensity leads to equal PAR sum for every concept.
LED trials

Gerbera

Idea: relationship between day length and average temperature for optimal flower production.

Low average (15°C) max day length 13 hours
High average (17°C) max day length 10.5 hours

<table>
<thead>
<tr>
<th>Teelt concept</th>
<th>Etmaal (°C)</th>
<th>RV (%)</th>
<th>CO₂ (ppm)</th>
<th>Lichtsom (mol/m²/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>16.6</td>
<td>85</td>
<td>761</td>
<td>6.2</td>
</tr>
<tr>
<td>Hybride</td>
<td>15.9</td>
<td>85</td>
<td>718</td>
<td>5.9</td>
</tr>
<tr>
<td>SON-T</td>
<td>15.3</td>
<td>83</td>
<td>724</td>
<td>6.2</td>
</tr>
</tbody>
</table>
LED trials

Gerbera

# side shoots per plant.

![Bar chart showing Scheuten/plant for LED, Hyb, and SON-T with different colors for 'jan' and 'mei' categories.]
LED trials

Gerbera

Days of development bud till harvest

Underneath full LED lower plant/flower temperature -> slower growth!
LED trials

Gerbera

Results till end of April

<table>
<thead>
<tr>
<th>Belichting</th>
<th>Bloemen/m² (cum)</th>
<th>Taklengte (cm)</th>
<th>Takgewicht (g)</th>
<th>Diameter (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>RWB 227</td>
<td>64.6</td>
<td>21.9</td>
<td>8.7</td>
</tr>
<tr>
<td>R</td>
<td>221</td>
<td>63.7</td>
<td>22.1</td>
<td>8.8</td>
</tr>
<tr>
<td>Hybr</td>
<td>RB 233</td>
<td>62.1</td>
<td>22.8</td>
<td>8.8</td>
</tr>
<tr>
<td>R</td>
<td>225</td>
<td>62.5</td>
<td>22.8</td>
<td>8.8</td>
</tr>
<tr>
<td>SON-T</td>
<td>236</td>
<td>64.9</td>
<td>24.3</td>
<td>8.8</td>
</tr>
</tbody>
</table>

HPS lighting highest production and heaviest stem weight (also per cm)
HPS + extra red LED light is no advantage with respect to production
LED trials

Gerbera

• The most flowers/m2 were produced in the HPS treatment.
• Development time from bud to harvestable flower was 34 d under HPS, 31.5 under hybrid and 31 under LEDs, most likely as a result of increasing greenhouse temperature.
• Stem lengths in LED and HPS were similar and both longer than in the hybrid treatment, but the stems in the HPS treatment were heavier, likely due to a longer development time from bud to flower.
LED trials

Gerbera conclusions

• HPS lighting systems with radiative heat allows Gerbera crops to grow and produce well at temperatures lower than growers are accustomed to using.
• A longer day length combined with a lower temperature in the lighting season results in a stronger crop, producing more flowers with higher quality.

Source: Wageningen UR Glastuinbouw
Light Use Efficiency: most efficient with HPS
LED trials

Gerbera conclusions

- HPS lighting for Gerbera still most efficient looking to production and quality
- LED lighting additionally improves quality due to limited crop and greenhouse temperature
- Full LED demands more energy by heating
- Lower plant and flower temperature underneath full LED
- Slower development of shoots and flowers in winter under full LED!
- Saving energy with HPS possible with lower average greenhouse temperature and longer day length
- Advantage is better quality due to more PAR light and lower T
- Hybrid system interesting with limited Cogen capacity or heat surplus
Results: development time

- 100 µmol, HPS 1 day shorter time from 2 cm to harvest than LED, probably caused by higher crop temperature (cycle mean 7h-10h = 0.5°C)
Alstroemeria

• In The Netherlands, Alstroemeria area is 45 ha
• It is a quantitative long day plant
• Average greenhouse temperature winter: 17°C
• Electricity is needed to overcome the low light levels in Dutch winter
• Lighting hours increasing to 3200 hours/year
• Light intensity: 100-125 umol/m²
LED trials

Alstroemeria

- 2 Alstroemeria growers executed LED trials in their greenhouses
- Valoya top lights (Valoya R300 AP67) 2.4 µmol/W el
- Philips top lights (High Output LED lamp) 2.7 µmol/W el
- Both implemented as LED and hybrid system
- Lighting hours Alstroemeria up to 3200 per year
- Relatively low use of Cogen power due to lower temperature demand
- Leaf quality can be an issue in winter:
  - White spots and stripes in the leaves
  - Red/purple tips
LED trials

LED trial 2016 at Vreugdenhil Alstroemeria
Project goals: energy saving with the use of LED. Monitoring production and quality

79 μmol full LED
+ 27 % ref

61 μmol HPS
+ 21 umol LED
+ 32 % ref

Source: Wageningen University and Research
LED trials

Alstroemeria production results

LED
HPS

Variety: Virginia
Equal production
November – March

PAR sum = PAR sum
LED trials

Alstroemeria production results

Cumulative production 30 January till 31 May

<table>
<thead>
<tr>
<th></th>
<th>LED</th>
<th>HYBRIDE</th>
<th>HPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>243 (-14%)</td>
<td>267 (-6%)</td>
<td>284</td>
</tr>
</tbody>
</table>
## LED trials

### Alstroemeria light use efficiency

<table>
<thead>
<tr>
<th>behandeling</th>
<th>Production kg/m²</th>
<th>Lightsum mole/m²</th>
<th>Electra kwh/m²</th>
<th>Light use gr/mole</th>
<th>Electra use gr/Kwh</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYBRIDE</td>
<td>12.1</td>
<td>2482</td>
<td>51.2</td>
<td>4.86</td>
<td>236.3</td>
</tr>
<tr>
<td>LED</td>
<td>10.0</td>
<td>2430</td>
<td>42.4</td>
<td>4.12</td>
<td>235.8</td>
</tr>
<tr>
<td>HPS</td>
<td>11.7</td>
<td>2384</td>
<td>41.4</td>
<td><strong>4.92</strong></td>
<td><strong>282.6</strong></td>
</tr>
</tbody>
</table>

LUE still the highest underneath HPS

Source: Wageningen UR Glastuinbouw
LED trials

Alstroemeria plant temperature

Plant temperature in cold night strongly under greenhouse temperature
(temp of the sky -10 ° c)
Plant temperature Alstroemeria winter

Source: Wageningen University and Research
Hybrid in practice Gerbera

- Reijm Nieuwerkerk B.V.
- hybrid system in Gerbera on 1 ha
- Total light level 110 μmol/m2/s
- 60% LED 1000 Watt
- 40% HPS 1000 Watt
- Spectrum DR/B-LB
- LED toplighting module
- DR/W LB 400V HO
Hybrid in practice Alstroemeria

- Hoogenboom Alstroemeria B.V.
- hybrid system in Alstroemeria on 1,5 ha
- Total light level 150\(\mu\text{mol/m2/s}\)
- 33% LED 1000 Watt
- 66% HPS 1000 Watt
- Spectrum DR/B-LB
- LED toplighting module
- DR/W LB 400V HO
- Start sept. 2016
Light use efficiency Alstroemeria HPS vs hybrid

![Bar chart showing light use efficiency for Virginia HPS, Rome HPS, Virginia hybrid, and Rome hybrid.]
HPS lighting vs LED

HPS for cut flowers still basic lighting!

Radiation heat of HPS lights is necessary for Canadian and North-West European flower cultivation.

LED lighting only supplemental lighting above 80-100 umol HPS light intensity as a hybrid system

Full LED in Rose trial: issues with bud quality and growth. Light spectrum?

Hybrid lighting in Chrysanthemums: more weight and more even flower