Growth Chambers on the International Space Station for Large Plants

Gioia D. Massa\(^1\), Raymond M. Wheeler\(^1\), Robert C. Morrow\(^2\), and Howard G. Levine\(^1\)

\(^1\) NASA, Kennedy Space Center, FL \(^2\) ORBITEC, Madison, WI

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An easily stowable, simple, low resource plant growth system capable of supporting plant growth for improving crew habitability.
Veggie Components

- LED Light Cap
- EXPRESS Rack Mounting Plate
- Transparent Bellows
- Root Mat Reservoir
- Flexible Support Arms

Image courtesy of Felix Joe, NASA
Plant Pillow Concept

- Different sizes for variety of plant types
  - 1, 2, 3 or 6 per Veggie
- Media and fertilizer containment
- Plant/glue seeds dry
- Hydrate on orbit
- Passive wicking from reservoir
- Minimal crew time
- Single use, disposable

Watering concept being revisited based on microgravity performance
Veggie Specifications

• **LED Light Cap:** Red (630 nm): low, med, high
  
  Blue (455 nm): low, med, high
  
  Green (530 nm): on/off

• **Cabin Air Fan:** Low / High / Off

• **Temperature/RH:** monitored by data logger

• **Footprint:**
  
  Baseplate: 29.2 cm x 36.8 cm
  
  Root mat: 21.6 cm x 35.6 cm

• **Max. Height:** 47 cm empty; 41.9 cm w/ root mat
Environment Inside Veggie during VEG-01

- **Humidity (%)**
- **Temperature (°C)**

- HOBO Data Logger installed left-back on 5/8/2014
- HOBO Data Logger moved to right-back on 5/21/2014

Possible pillow overfill?

Harvest

- HOBO Data Logger moved to right side
## Veggie LED Capabilities

<table>
<thead>
<tr>
<th>Light Setting</th>
<th>630 nm (red)</th>
<th>455 nm (blue)</th>
<th>530 nm (green)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>120 ± 10%</td>
<td>30 ± 10%</td>
<td>-</td>
</tr>
<tr>
<td>Medium</td>
<td>240 ± 10%</td>
<td>60 ± 10%</td>
<td>-</td>
</tr>
<tr>
<td>High</td>
<td>360 ± 10%</td>
<td>90 ± 10%</td>
<td>-</td>
</tr>
<tr>
<td>On</td>
<td>-</td>
<td>-</td>
<td>30 ± 5%</td>
</tr>
<tr>
<td>Custom (max levels)</td>
<td>550</td>
<td>150</td>
<td>100</td>
</tr>
</tbody>
</table>

Levels in μmol m\(^{-2}\) s\(^{-1}\) ± % at 10 cm beneath light cap. Wavelength requirements are ± 10 nm.
• 180-point light mapping conducted without bellows at different heights
• Bellows provides avg. increase of 5.7 µmol m$^{-2}$ s$^{-1}$ ($\pm$1.4)
Veggie Light Map - Med @ 32.5 cm
Advanced Plant Habitat
Chamber slides out 10” from main unit for viewing through the top window.
APH Growth Chamber

- USB Camera within Growth Light Assembly (Top Down Color View)
- Wide Angle Color Camera (Side View)
- Near Infra Red Camera (Black & White Side View)
- Air Intake Particulate Filters
- Air Output Vents
Base Science Carrier
Dwarf Wheat in Science Carrier in APH EDU
APH Specifications

- **Growth Light**
  - Assembly: 0-1000 μmol m\(^{-2}\) s\(^{-1}\) PPF set in increments of 50

- **Colors:**
  - Red, Blue, Green, White, Far Red

- **Uniformity:**
  - ±15% (15 cm below GLA, 5 cm from wall)

- **Temperature:**
  - 18°C-30°C (±1°C)

- **RH:**
  - Controlled / monitored: 50-90% (±5%)

- **CO₂:**
  - Controlled / monitored: 400 ppm-5000 ppm (±50 ppm or 3%)
APH Specifications (Cont.)

- Ethylene: Scrubbed to <25 ppb
- Air Flow: Controlled between 0.3-1.5 m/s
- Leak Rate: \( \leq 10\% \) by volume a day
- Root Zone Moisture: Monitored 25%-100\% (±10\%) and controlled by flow rate

Growth Chamber
- Shoot zone: 0.19 m\(^2\)
- Height: 50 cm total
  max. shoot height 45 cm
APH Lightcap
### APH LED Capabilities

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>PPF (μmol m(^{-2}) s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red (630 nm)</td>
<td>0-600</td>
</tr>
<tr>
<td>Blue (450 ± 10 nm)</td>
<td>0-400</td>
</tr>
<tr>
<td>Green (525 ± 10 nm)</td>
<td>0-100</td>
</tr>
<tr>
<td>Broad Spectrum White (4100 K)</td>
<td>0-600</td>
</tr>
<tr>
<td>Far Red (730 nm)</td>
<td>0-50</td>
</tr>
<tr>
<td>No light</td>
<td>≤0.02</td>
</tr>
</tbody>
</table>

Max allowable light level is 1000 μmol m\(^{-2}\) s\(^{-1}\)
Imaging

• Top Down and Side Viewing
• Light and Dark Cycle (IR)

Side view, near IR, narrow angle

Top Down view, color

Side view, color, wide angle
APH Additional Features

- Plant experiments up to 135 days
- Removable Science Carrier Tray – base design – 5 cm
- Door plus sleeve ports
- Window
- PAR sensor
- O₂ Sensor-Root & shoot
- CO₂ Sensor
- CO₂ draw-down capability
- Leaf Temperature Sensor
- Air pressure monitored and maintained
- RH condensate recycling
- Condensate measuring
- Air filtration
- Ionizing radiation measurements
- Water and nutrient delivery
  - Porous tubes, solid media
  - Liquid NDS or solid fertilizer
- Sample ports- air, water
Opportunities to Experiment

• For US investigators:
  – NASA Research Announcements
    (https://nspires.nasaprs.com/external/)
  – Center for the Advancement of Science in Space
    (http://www.iss-casis.org/)

• For International Investigators:
  – International Life Science Research Announcements
  – Local Space Agencies (ESA, CSA, JAXA, Roscosmos, etc.)
Thank you!

- Veggie and APH teams at Kennedy Space Center and ORBITEC
- Science advisory teams and engineering design review boards
- NASA’s Space Life and Physical Sciences and International Space Station Programs