Growth Chambers on the International Space Station for Large Plants

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Veggie on the ISS

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

PAR: 05/21/2014 14:59:48 GMT

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$^{-1}$ (±1.4)
Veggie Light Map - High @ 43.5 cm

RGB PAR (µmol/m²/s)

- 130-135
- 120-130
- 110-120
- 100-110
- 90-100
- 80-90

Blue PAR (µmol/m²/s)

- 23-24
- 21-23
- 19-21
- 17-19
- 15-17
- 13-15

Red PAR (µmol/m²/s)

- 100-105
- 95-100
- 90-95
- 85-90
- 80-85
- 75-80
- 70-75
- 65-70
- 60-65

Green PAR (µmol/m²/s)

- 10-11
- 9-10
- 8-9
- 7-8
- 6-7
- 5-6
- 4-5
Veggie Light Map-Med @ 32.5 cm

- **RGB PAR (µmol/m²/s)**
  - 130-135
  - 120-130
  - 110-120
  - 100-110
  - 90-100
  - 80-90
  - 75-80
  - 70-75
  - 65-70
  - 60-65

- **Blue PAR (µmol/m²/s)**
  - 23-24
  - 21-23
  - 19-21
  - 17-19
  - 15-17
  - 13-15

- **Red PAR (µmol/m²/s)**
  - 100-105
  - 95-100
  - 90-95
  - 85-90
  - 80-85
  - 75-80
  - 70-75
  - 65-70
  - 60-65

- **Green PAR (µmol/m²/s)**
  - 10-11
  - 9-10
  - 8-9
  - 7-8
  - 6-7
  - 5-6
  - 4-5
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 in from wall)
- **Temperature:** 18°C-30°C (±1°C)
- **RH:** Controlled / monitored: 50-90% (±5%)
- **CO\(_2\):** Controlled / monitored: 400 ppm-5000 ppm (±50 ppm or 3%)
• Ethylene: Scrubbed to <25 ppb
• Air Flow: Controlled between 0.3-1.5 m/s
• Leak Rate: ≤10% by volume a day
• Root Zone Moisture: Monitored 25%-100% (±10%) and controlled by flow rate

Growth Chamber
• Shoot zone: 0.19 m²
• 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</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
- $O_2$ Sensor-Root & shoot
- $CO_2$ Sensor
- $CO_2$ 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