Dimensioning and planning crop production in a simulated space expedition

Esther Meinen, Frank Kempkes, Tom Dueck, Cecilia Stanghellini

Wageningen University & Research, Greenhouse Horticulture
Background EDEN-ISS project

Aim: Growing fresh food for future space missions

Designing growing recipes:

- to produce tasty ‘ready-to-eat’ fresh food
- with limiting factors (space, light, temperature, energy)
Context EDEN-ISS

Space missions: future

‘Earthly’ test: Antarctica: 2018

Tasks Wageningen:
- Tests for designing growing recipes
- Training space engineer
- Remote plant health monitoring
Future exploration greenhouse
Tests growing recipes (Wageningen)

- Selection crops
- Maximize fresh food production
- Determine resource requirements
- Continuous production by careful planning of seeding and harvesting
- Growing handbook: cultivation recipes
Selected crops

- Lettuce: crispy, red romaine, batavia
- Leafy greens: Swiss chard, red mustard, rocket, spinach
- Radish
- Herbs: parsley, chives
- Fruit vegetables: tomato, cucumber, pepper
Climate chambers in Wageningen
Experiments

- 4 light intensities (200, 300, 450, 600 μmol m\(^{-2}\) s\(^{-1}\))
- 2 temperatures: 21/19° and 25/23°C (day/night)
- Space use efficiency: single and spread harvest
Effect of light intensity

Biomass production (g FW m⁻²)

Light intensity (µmol m⁻² s⁻¹)

- Crispy Green
- Outredgeous
- Radish taproot
- Radish leaves
Effect of light intensity: quality

200 \quad 300 \quad 450 \quad 600

[\mu\text{mol m}^{-2} \text{s}^{-1}]
Effects of temperature (21 and 25°C)

- 25°C increased production of some crops (red mustard, rocket, chives)
- 25°C decreased production of radish
- Herbs: poor regrowth at 25°C

Parsley

Cumulative fresh weight (kg m⁻²)

Days after sowing
Space use efficiency

![Graph showing space use efficiency for different types of lettuce. The x-axis represents single harvest, g m⁻² day⁻¹, and the y-axis represents spread harvest, g m⁻² day⁻¹. Points are marked for Crispy green, Outridgeous, Batavia, and Spinach. A note indicates that the spread harvest is about four times higher.]

- Crispy green
- Outridgeous
- Batavia
- Spinach

about four times higher
Cultivation scheme per crop

- Radish
- Leafy greens
- Lettuce
- Herbs
- Tomato
- Cucumber
- Pepper

Days after sowing

Growing phase
Spread harvest

1 endharvest
## Production per week

<table>
<thead>
<tr>
<th>Crop</th>
<th>FW (kg week$^{-1}$ tray$^{-1}$)</th>
<th>Trays</th>
<th>Plants tray$^{-1}$</th>
<th>Weekly FW (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lettuce (spread)</td>
<td>1.0</td>
<td>2</td>
<td>20</td>
<td>2.0</td>
</tr>
<tr>
<td>Tomato</td>
<td>0.4</td>
<td>4</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>Cucumber</td>
<td>0.6</td>
<td>5</td>
<td>2</td>
<td>2.9</td>
</tr>
<tr>
<td>Radish</td>
<td>1.0</td>
<td>1</td>
<td>66</td>
<td>1.0</td>
</tr>
<tr>
<td>Leafy greens</td>
<td>0.2</td>
<td>7</td>
<td>40 - 150</td>
<td>1.7</td>
</tr>
<tr>
<td>Herbs</td>
<td>0.3</td>
<td>2</td>
<td>150 - 450</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21</strong></td>
<td></td>
<td></td>
<td><strong>9.7</strong></td>
</tr>
</tbody>
</table>
Final advice cultivation recipe

- Cultivation at 21/19°C and 300 µmol m⁻² s⁻¹
- Radish and chives at 600 µmol m⁻² s⁻¹
- CO₂ 750 ppm
- Spread harvest for lettuce increases production (4 times)
- Fresh production per week: max 10 kg
Results Antarctic until 1 May 2018

- Sowing 7 February
- First harvest 14 March: lettuce (single harvest)
- 42 kg edible fresh food (< 6 weeks full production)
- Cucumber (17 kg), lettuce (10 kg), leafy greens, radish, herbs

Good work Paul!
Thanks to...

- The EU-H2020 grant
- The Dutch Ministry of Agriculture, Nature and Food Quality
- ...and you all for your attention