# Sustained Veggie: Considerations for Consistent On-Orbit Leafy Green Production

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## Background

- The Veggie plant growth system on the International Space Station (ISS) intermittently supplements the crew diet with fresh, leafy green crops.
- For 120 days, the ground based "Sustained Veggie" test assessed the potential of continuous on-orbit crop production.
- Crops grown in Veggie have been grown concurrently, but Sustained Veggie staggered plant initiation and harvest to provide more constantly available produce.
- The objective of this preliminary study was to compare two growth schemes to determine methodology for required inputs, optimal yield, food safety, and crew considerations.

## Materials & Methods

- 2 Veggie plant chamber ground units: single harvest (28 days after initiation; DAI) treatment in one unit vs multiple "cut-and-come-again" harvest (28, 42, 56 DAI) in second unit
- Crops selected from prior or planned Veggie on-orbit studies
  - 2 crops grown together in each unit for first 56 days
    Crop A: 'Amara' mustard  Crop B: 'Red Russian' kale
  - Rotated in 2 other crops for latter experiment half
    Crop A: 'Shungiku ' Asian green  Crop B: 'Extra dwarf' pak choi
- Staggered plant growth for continuous production: 1A/B plant pillows (rooting packets) initiated in each facility on 0 DAI, 2A/B initiated 7 DAI, and 3A/B initiated 14 DAI **(Figure 1)**
- Data collected: plant yield and health metrics, food safety microbial analyses (Yeast and Mold Count on Inhibitory Mold Agar [IMA] and Aerobic Plate Count [APC])
- Linear mixed-effects model ANOVA ($P < 0.05$) and Tukey HSD test conducted in R Version 3.5.1

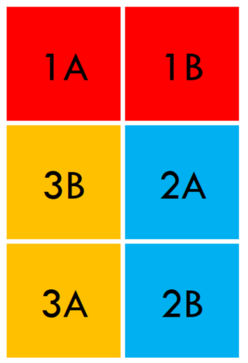


***Figure 1.*** *Crop and pillow initiation layout.*

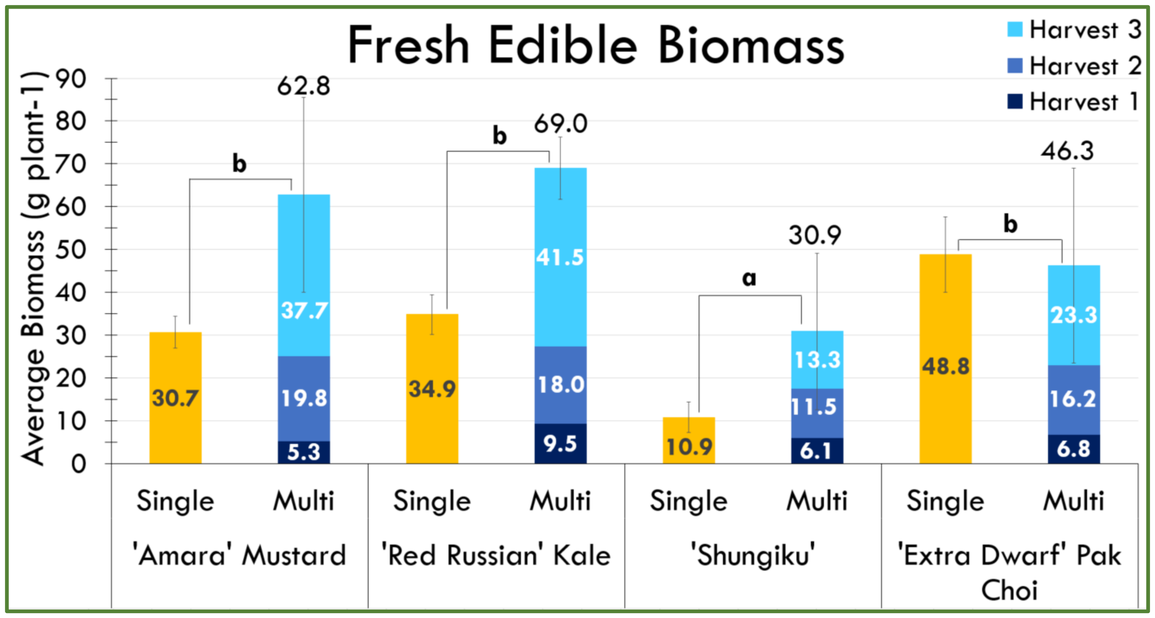


***Figure 2.*** *Fresh edible biomass (g plant$^{-1}$) for single and multiple "multi" harvest treatments. For "multi," biomass shown for each harvest and overall plant (above standard error bars). Tukey letters presented at crop level.*

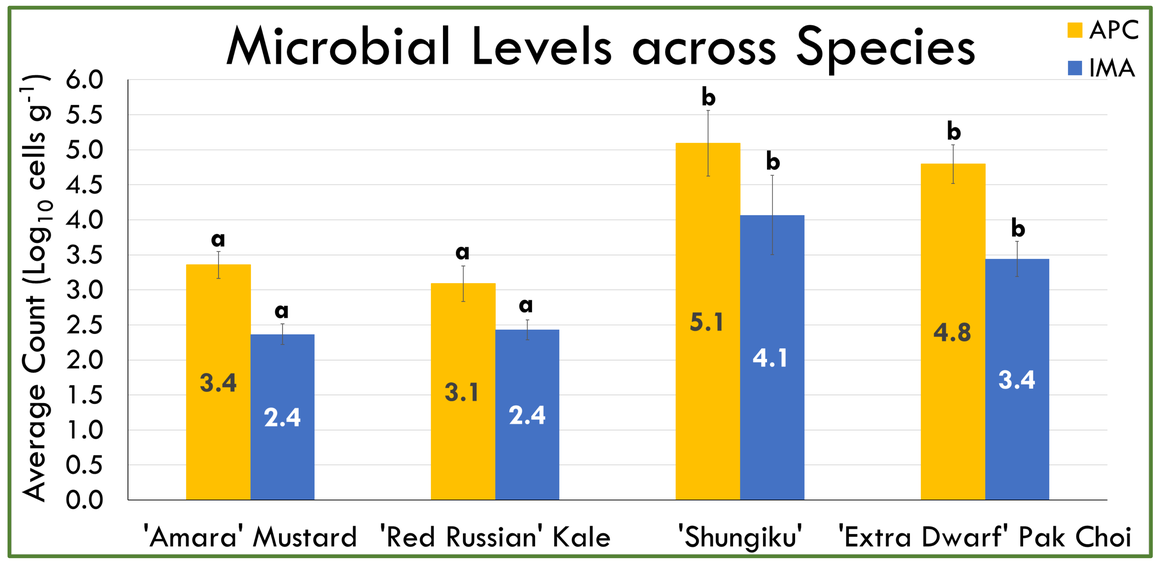


***Figure 4.*** *Average microbial counts (Log$_{10}$ cells g$^{-1}$) by crop from APC and IMA testing. Tests were analyzed separately. Tukey letters presented for each test above standard error bars at crop level.*

## Results

**REQUIRED INPUTS**

- Single harvest: 24 pillows (including 2 failed pillows)
- Multiple harvest: 13 pillows (including 1 failed pillow)

**OPTIMAL YIELD**

- Average per plant fresh edible biomass higher in multiple harvest than single harvest for all crops but 'Shungiku' ($P < 0.002$; **Figure 2**), but no significant harvest treatment by crop interaction.
- Larger error bars in multiple harvest treatment (**Figure 3**):
  - Likely caused by competition between plants at different growth stages, especially when 'Extra Dwarf' pak choi was phased into the Veggie facility next to larger, older plants.
  - Potential drawback of staggering pillow initiation for continuous production goal

**FOOD SAFETY**

- Microbial load was more dependent on experiment age than individual plant or cultivar age.
  - APC ($P < 0.001$) and IMA ($P < 0.001$) test results from 'Shungiku' and 'Extra Dwarf' pak choi samples higher than 'Amara' mustard and 'Red Russian' kale samples across both harvest methods (**Figure 4**)
  - Harvest method showed no significant difference for microbial load (data not shown)

**CREW CONSIDERATIONS**

- Continuous production schemes aimed for weekly harvests.
  - 1 week without yield in multiple harvest treatment vs. 5 weeks in single harvest
- Careful organization required to accurately care for plants at staggered growth stages.

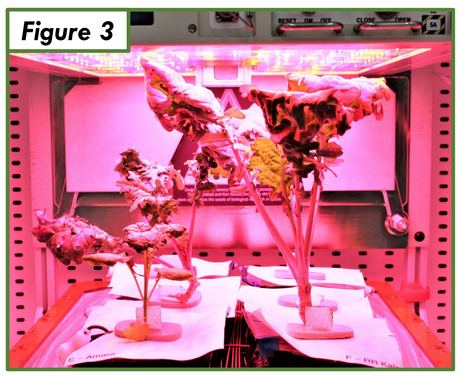


***Figure 3.*** *Height differences across growth stages caused shading of younger plants and plant competition.*


***Figure 5.*** *Visible stress in multiple harvest pak choi (nitrogen-deficient, yellow leaves & early flowering).*


***Figure 6.*** *Roots created thick mats on pillow bottoms in multiple harvest treatment.*

## Future Research & Acknowledgements

- Repeat study for microbiology, and test new crops and other layouts that could potentially reduce shading and plant competition **(Figure 3)**
- Mitigate plant stress and nutrient deficiencies for repeated harvest approach **(Figure 5)**
- Develop protocol for crop failures and periodic root mat cleaning **(Figure 6)**

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