

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

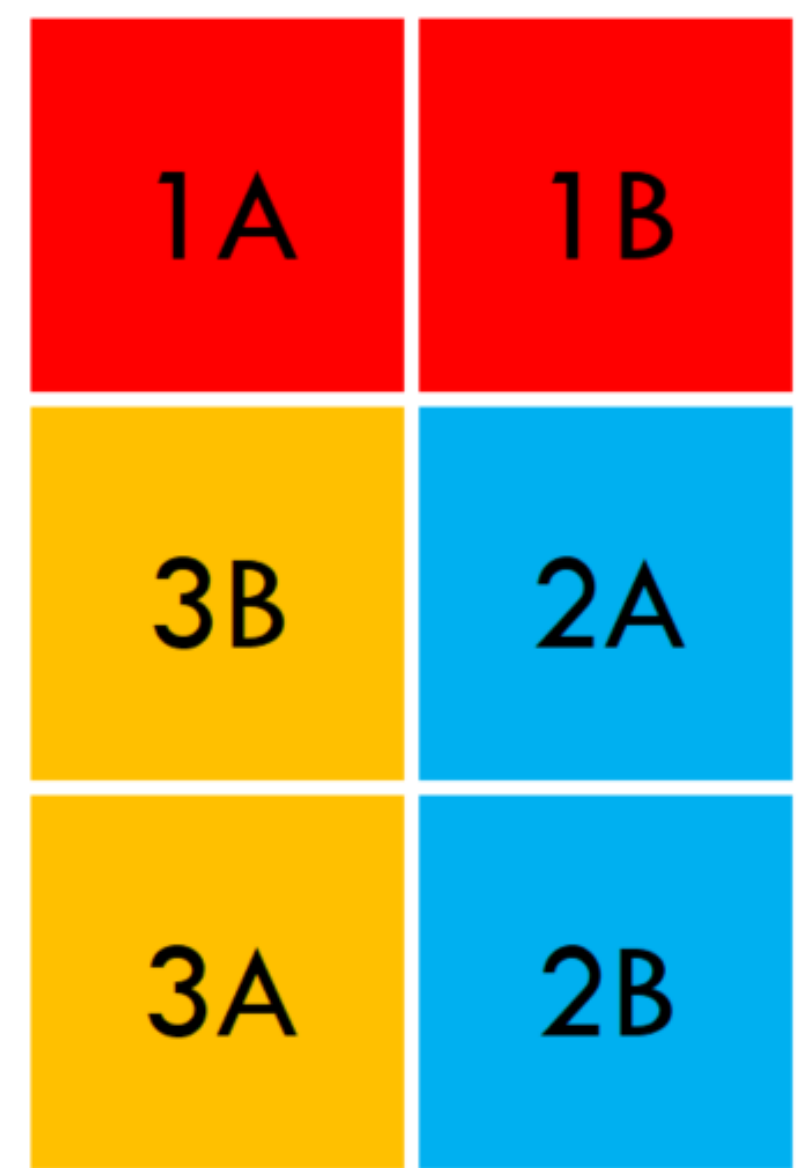


Figure 1. Crop and pillow initiation layout.

Fresh Edible Biomass

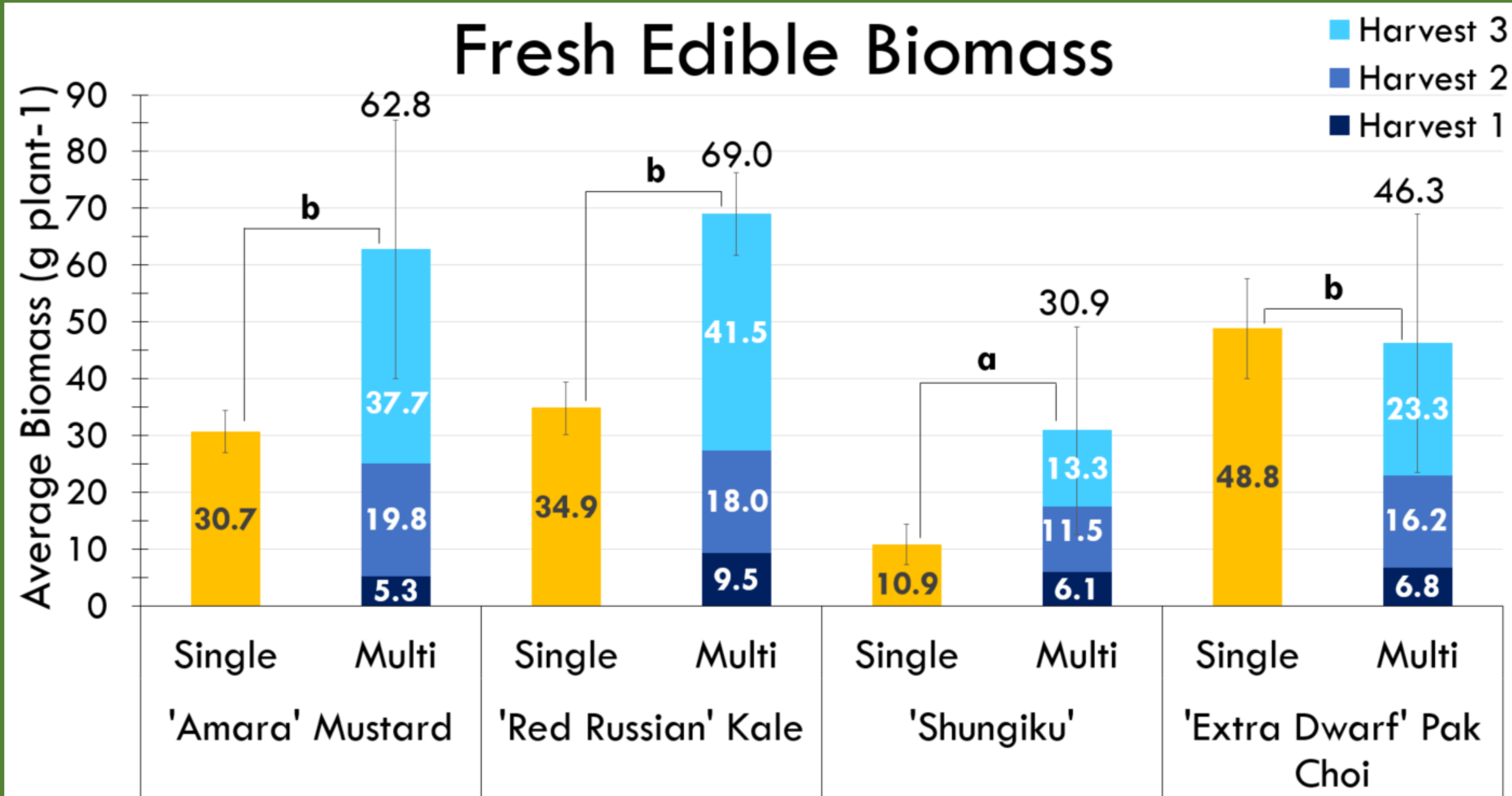


Figure 2. Fresh edible biomass (g plant⁻¹) for single and multiple “multi” harvest treatments. For “multi,” biomass shown for each harvest and overall plant (above standard error bars). Tukey letters presented at crop level.

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.

Microbial Levels across Species

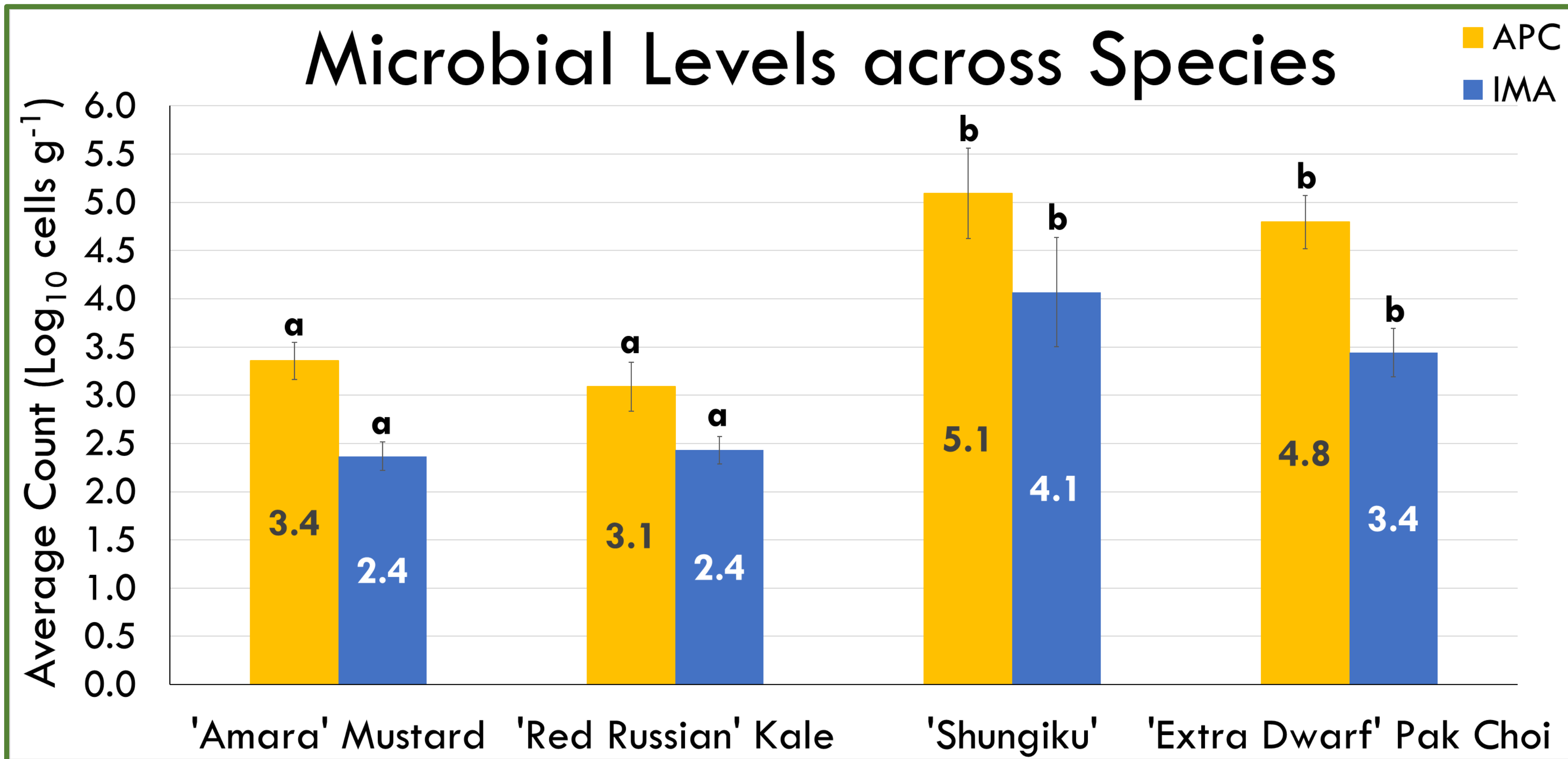


Figure 4. Average microbial counts (Log₁₀ cells g⁻¹) by crop from APC and IMA testing. Tests were analyzed separately. Tukey letters presented for each test above standard error bars at crop level.

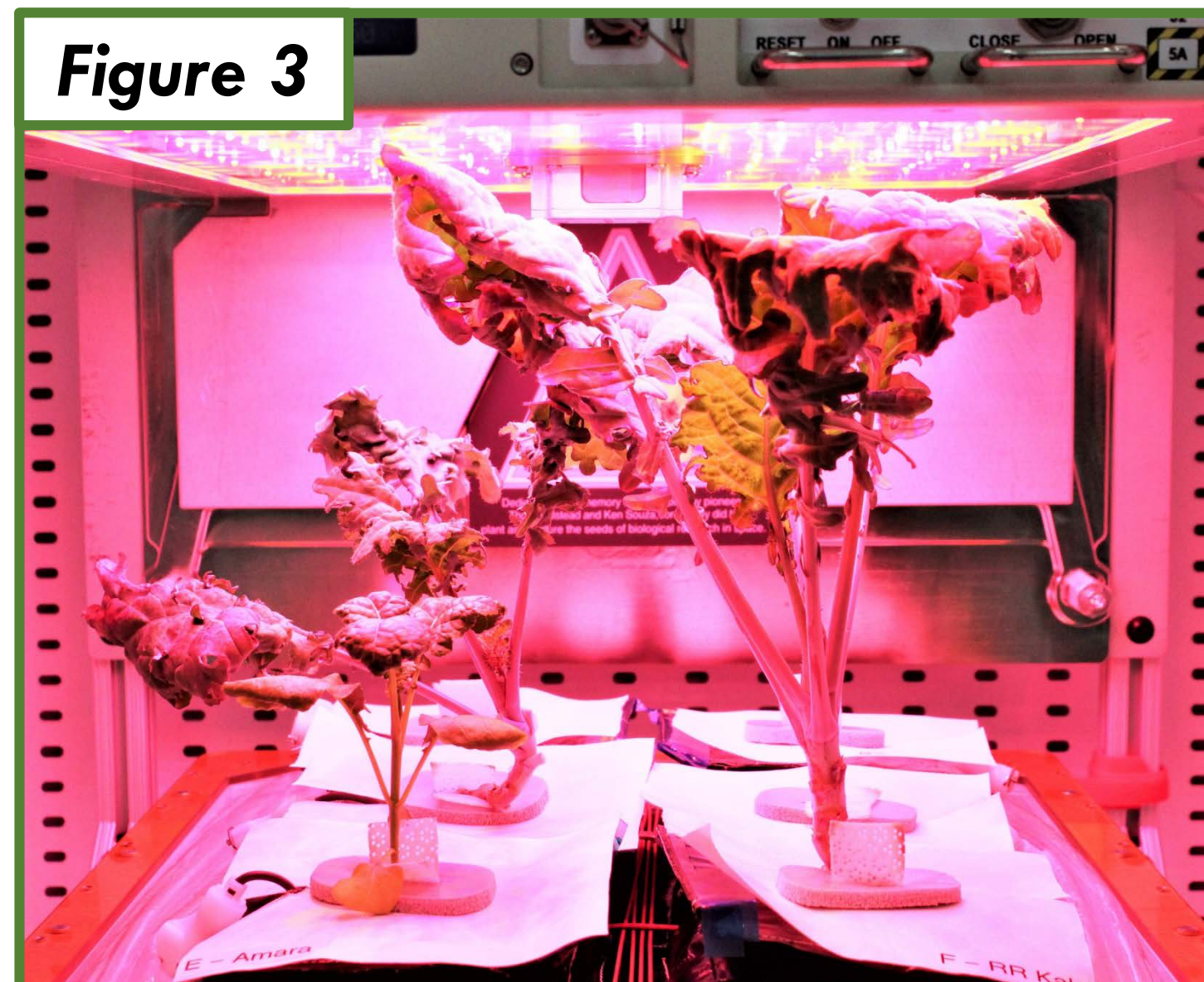


Figure 3. Height differences across growth stages caused shading of younger plants and plant competition.



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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