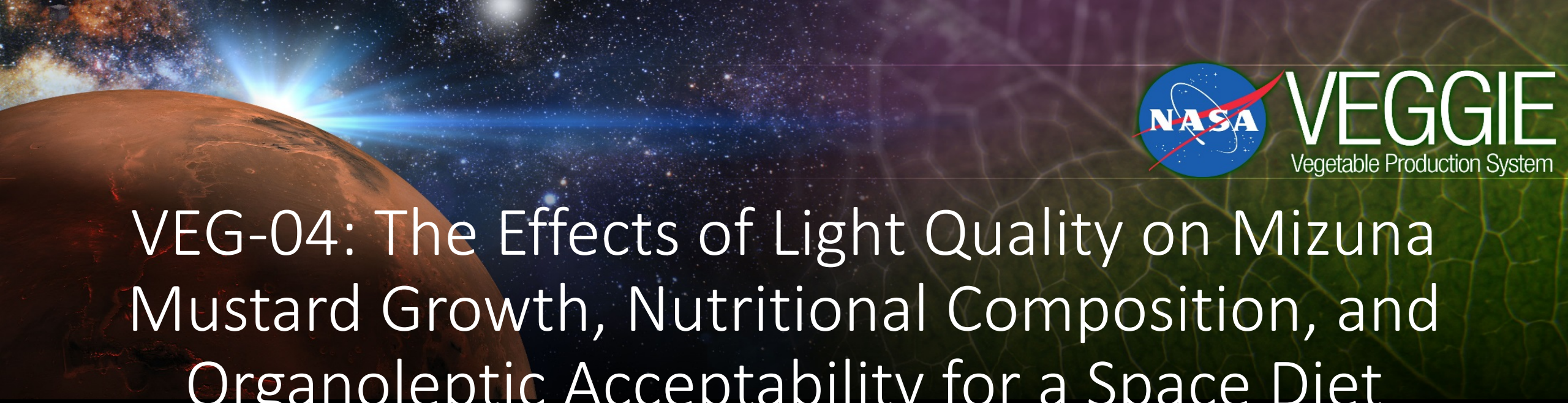



# VEG-04: The Effects of Light Quality on Mizuna Mustard Growth, Nutritional Composition, and Organoleptic Acceptability for a Space Diet

Gioia D. Massa[1], Jess M. Bunchek[1], Grace L. Douglas[2], Mary E. Hummerick[1], Cary A. Mitchell[3], Robert C. Morrow[4], Asmaa H. Morsi[3], Peter G. Roma[2], Matthew W. Romeyn[1], LaShelle E. Spencer[1], and Raymond M. Wheeler[1]

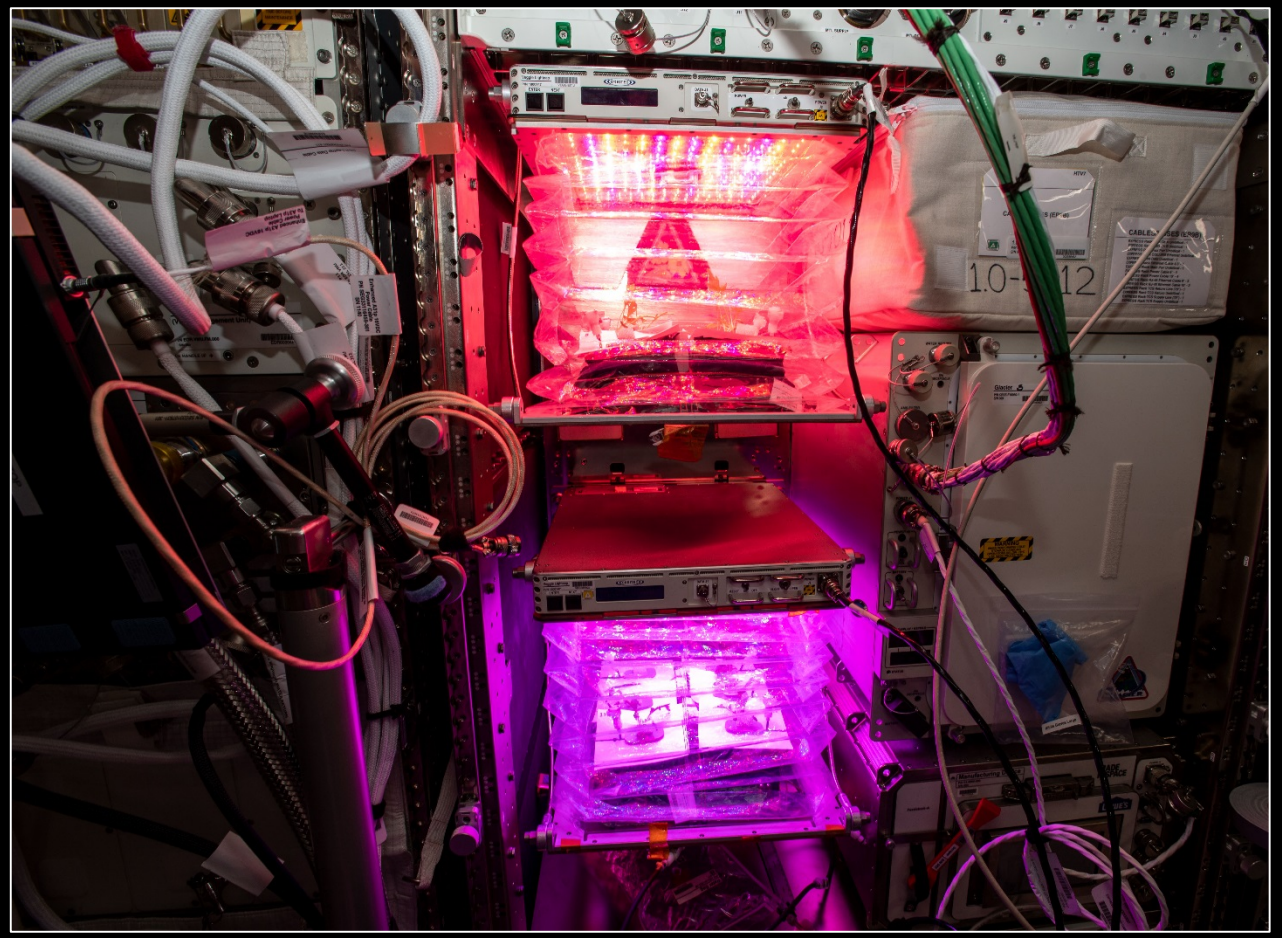
1. Kennedy Space Center 2. Johnson Space Center 3. Purdue University 4. ORBITEC-Sierra Nevada Corporation

# Pick-and-eat salad-crop productivity, nutritional value, and acceptability to supplement the ISS food system

**Aim:** To examine light quality and fertilizer formulation on crop morphology, edible biomass yield, microbial food safety, organoleptic acceptability, nutritional value, and behavioral health benefits.

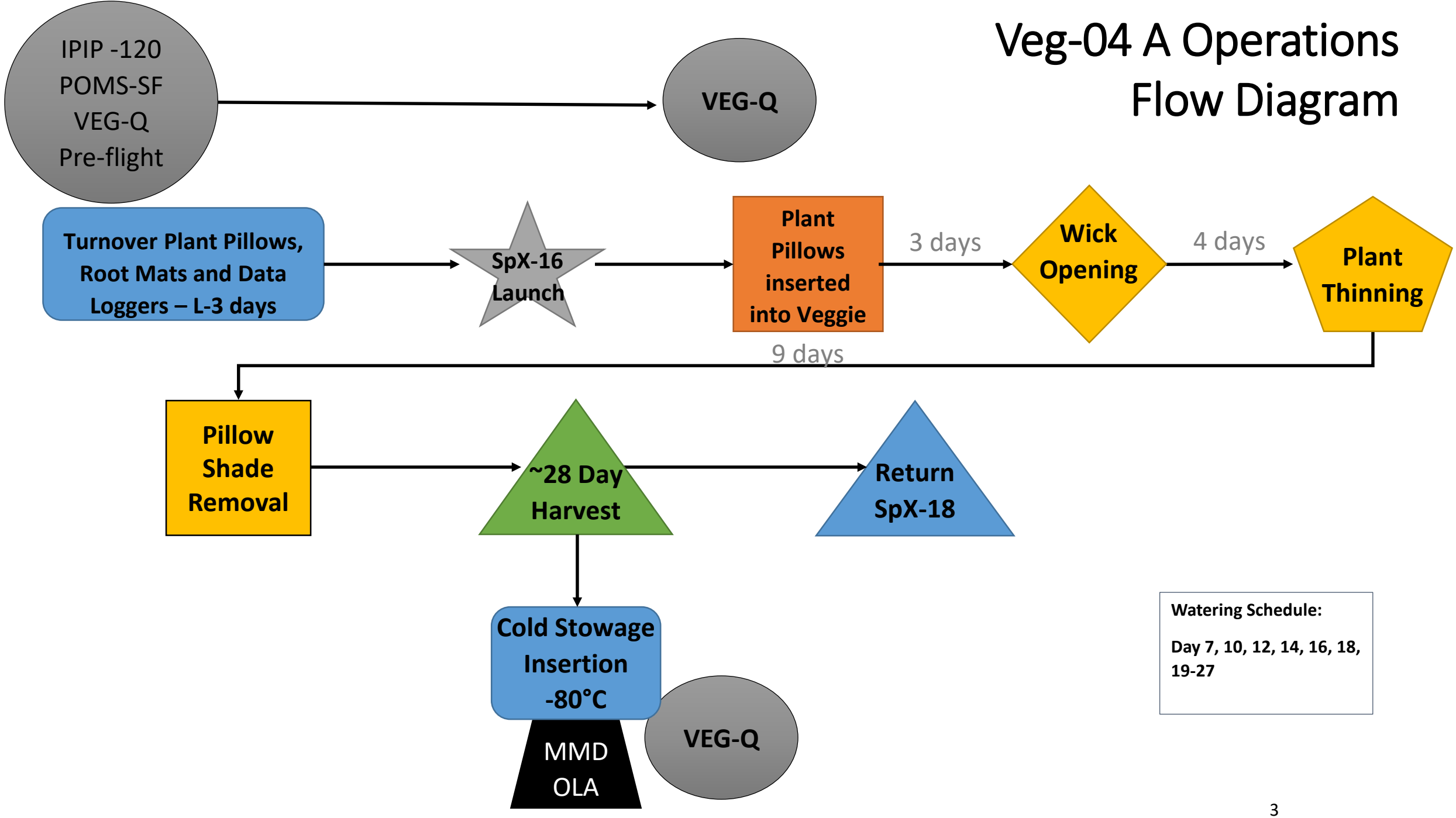
**Team Components:**

KSC: Crop Testing, Microbiology
JSC: AFT, BHP, Statistics
Purdue: Crop Testing
SNC-ORBITEC: Testing, Lighting, Software
Florikan: Fertilizer Consultants



**Veggie plant chambers currently on ISS in the Columbus module.**

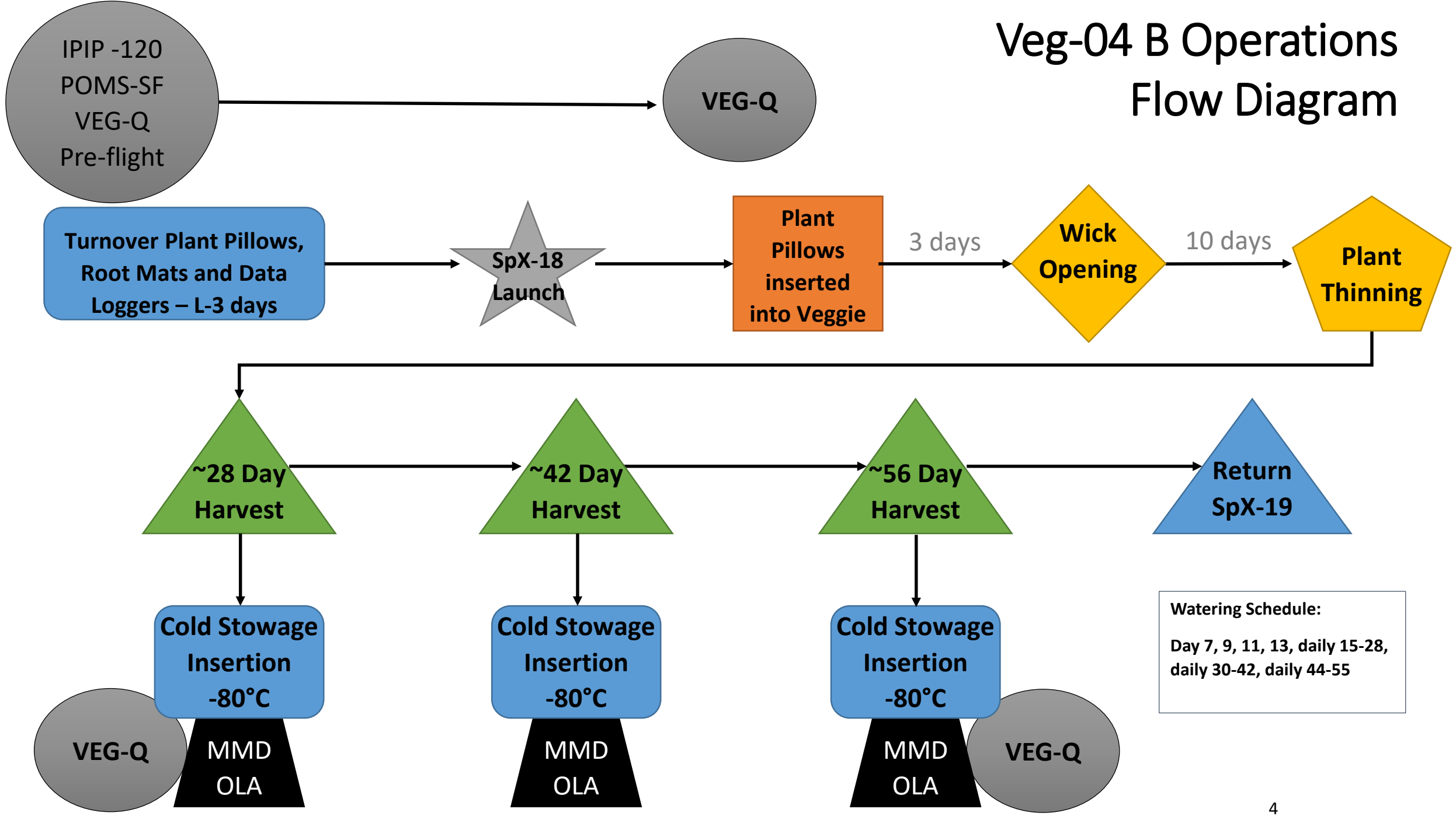
# Veg-04 A Operations Flow Diagram




**Watering Schedule:**

**Day 7, 10, 12, 14, 16, 18, 19-27**

# Veg-04 B Operations Flow Diagram



# Veggie Questionnaire (VEG-Q) for BHP

**In a typical week on orbit, how many servings of fresh fruit and vegetables do you consume (think of one serving as an apple)?**

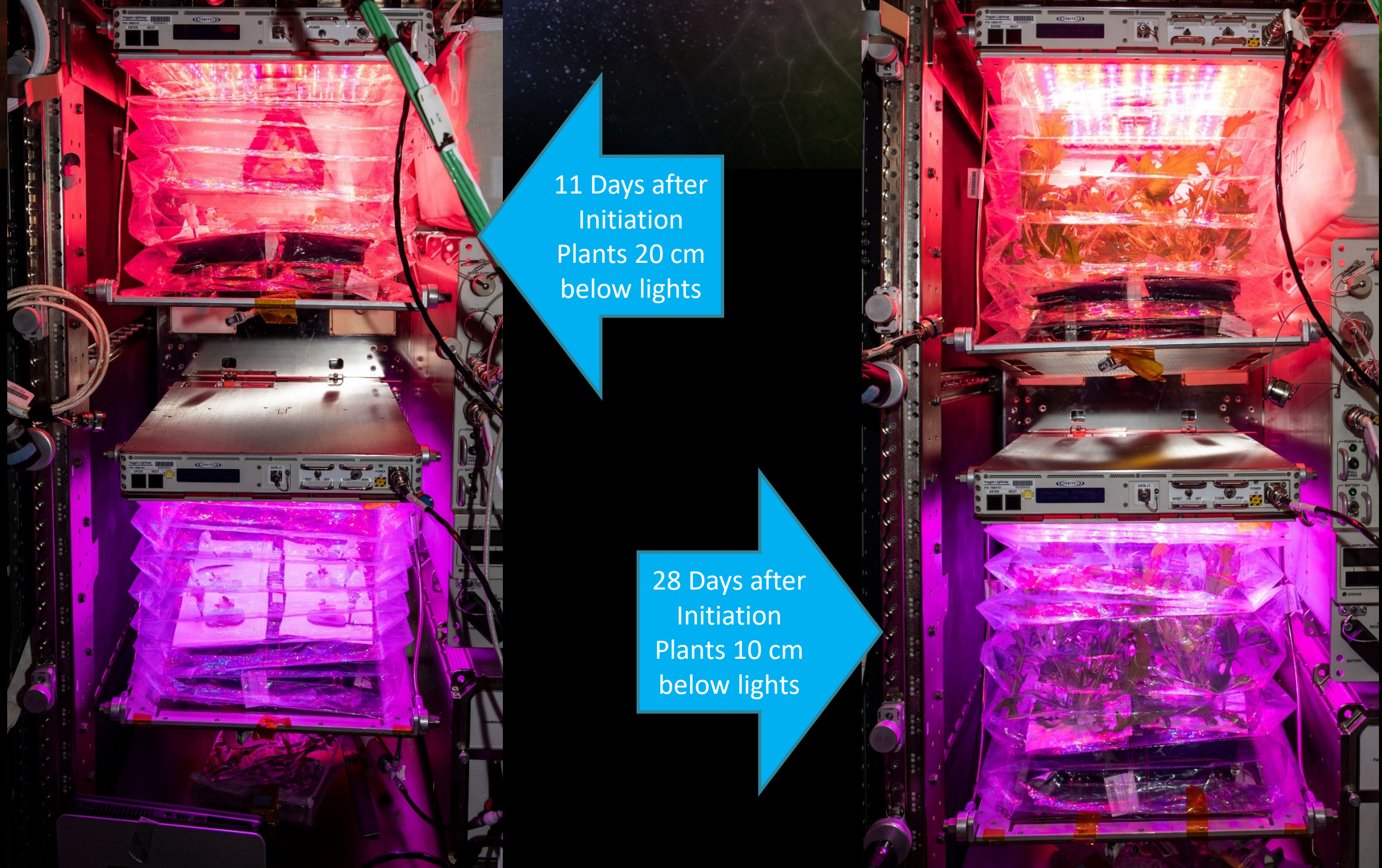
1-5

COMMON
DATA
COLLECTION
APPLICATION (CDCA)

Throughout the time since your last Veggie Questionnaire, interacting with Veggie was…

| | | |
|---|---|---|
| Diminished my well-being | 0 — 200 | Enhanced my well-being |
| Diminished my relationship with other crew members | 0 — 200 | Enhanced my relationship with other crew members |
| Diminished my connection to Earth | 0 — 200 | Enhanced my connection to Earth |
| Diminished my desire to harvest the plants | 0 — 200 | Enhanced my desire to harvest the plants |
| Diminished my desire to consume the plants | 0 — 200 | Enhanced my desire to consume the plants |

**If any of the plants struggled or died, please describe this experience:**


11 Days after Initiation Plants 20 cm below lights
28 Days after Initiation Plants 10 cm below lights

# VEG-04 Harvest

VEG-04A at 35 DAI

VEG-04B at 29 DAI

# Organoleptic Evaluation (OLA)

| | Not Crisp At All | Not Crisp Enough | Just About Right | Somewhat Too Crisp | Much Too Crisp |
|---|---|---|---|---|---|
| *7. Crispness | ☑ | ☐ | ☐ | ☐ | ☐ |

| | Not Tender At All | Not Tender Enough | Just About Right | Somewhat Too Tender | Much Too Tender |
|---|---|---|---|---|---|
| *8. Tenderness | ☐ | ☐ | ☐ | ☑ | ☐ |

| | Not Bitter At All | Not Bitter Enough | Just About Right | Somewhat Too Bitter | Much Too Bitter |
|---|---|---|---|---|---|
| *9. Bitterness | ☑ | ☐ | ☐ | ☐ | ☐ |

10. Please provide any comments you would like to share regarding the Mizuna sample. Mizuna comment1

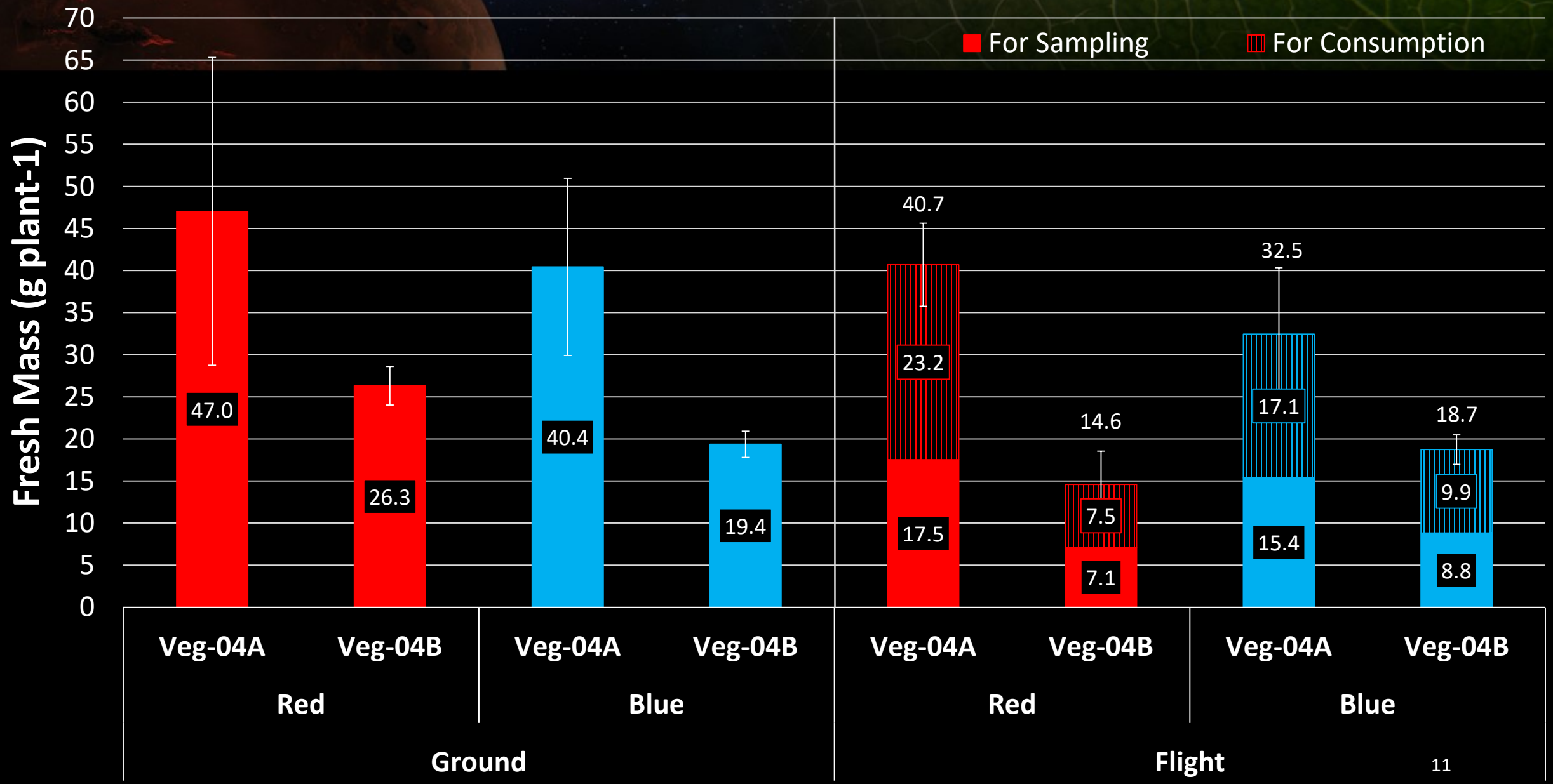
Select Next Page and return to Crew Procedure

Select Next Page to continue with survey

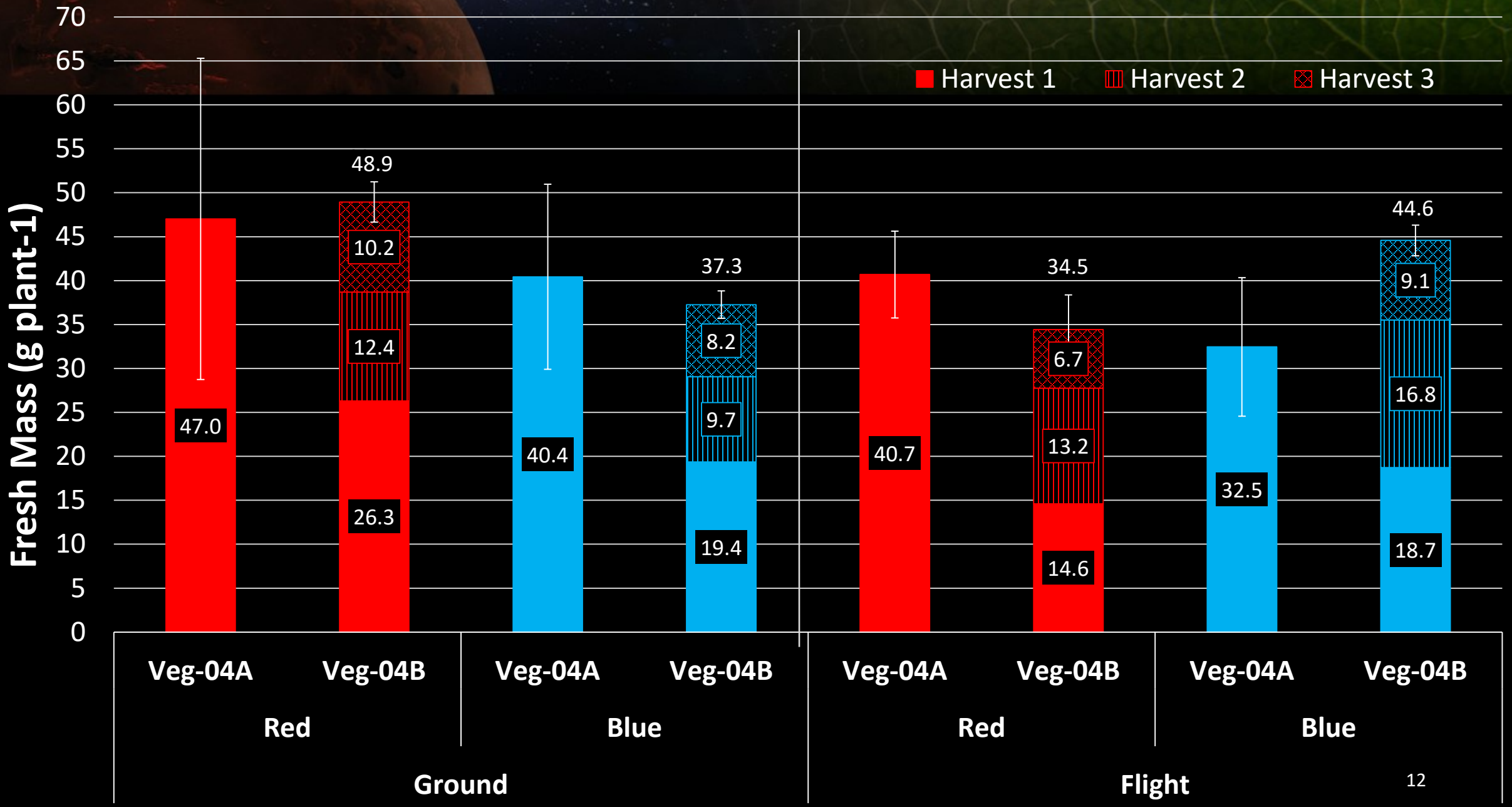
# Hazard Analysis Critical Control Points (HACCP) Plan

| Process Step/Control Point | Food Safety hazard | Methods to reduce hazard | CCP |
|---|---|---|---|
| **Ground processing-pillows** | Introduction of microbes via handling and materials. | Sterilize components, aseptic technique used while assembling | **1** |
| **Ground Processing-Seed** | Introduction of microbes via handling and indigenous microbes present on seeds | Disinfection. Certification of pathogen free seed. Use of sanitary handling practices | **2** |
| **Packing** | no | | |
| **Transport** | no | | |
| **Integrate with Veggie hardware** | Introduction of microbes via handling. | Use of sanitary handling. | **3** |
| **Watering** | Introduction of microbes via water supply or unsanitary handling | Water is potable quality and treated with biocide. | **4** |
| **Grow** | Potential contamination from air and human presence, increase in indigenous flora due to availability of nutrients. | Use of sanitary handling. Minimize handling of plants before harvest. | **5** |
| **Harvest** | Introduction of microbes due to harvest procedures/human handling. | Sanitized instruments should be used and gloves worn. | **6** |
| **Post-harvest** | Microbial presence established during plant growth and introduction via handling. | Crops should be sanitized before consumption following procedures. Veggie facility should be thoroughly sanitized. | **7** |

# Fresh Biomass at 1-month Harvests



# Fresh Biomass Across Veg-04 A & B



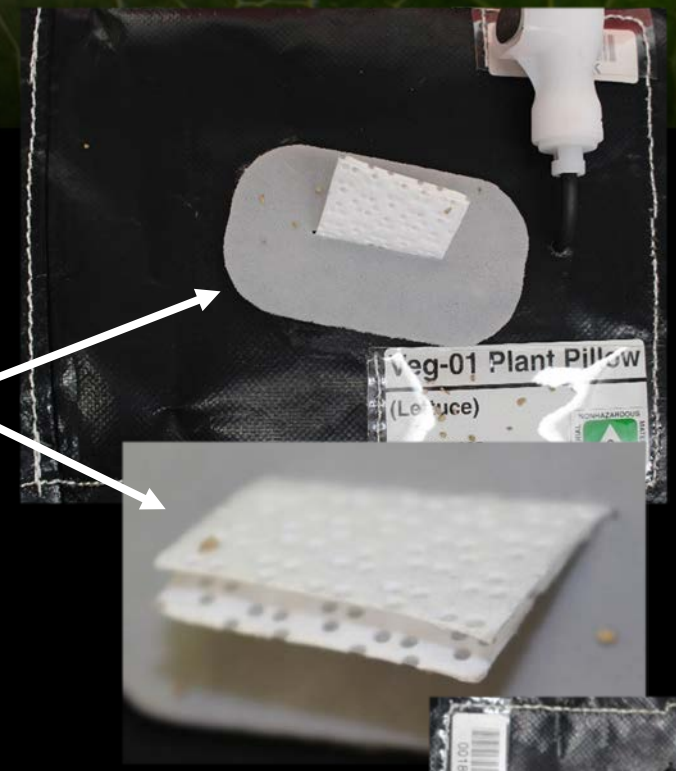
# Microbiology Methods

- Post harvest:
- Samples taken from both ground and flight
  - Plant surfaces, Root zone
  - Wicks and Substrate

- Heterotrophic bacterial & fungal plate counts

- Media specific screening
  - *E. coli*
  - *Salmonella sp*
  - *Staphylococcus aureus*

- Microbe Identification

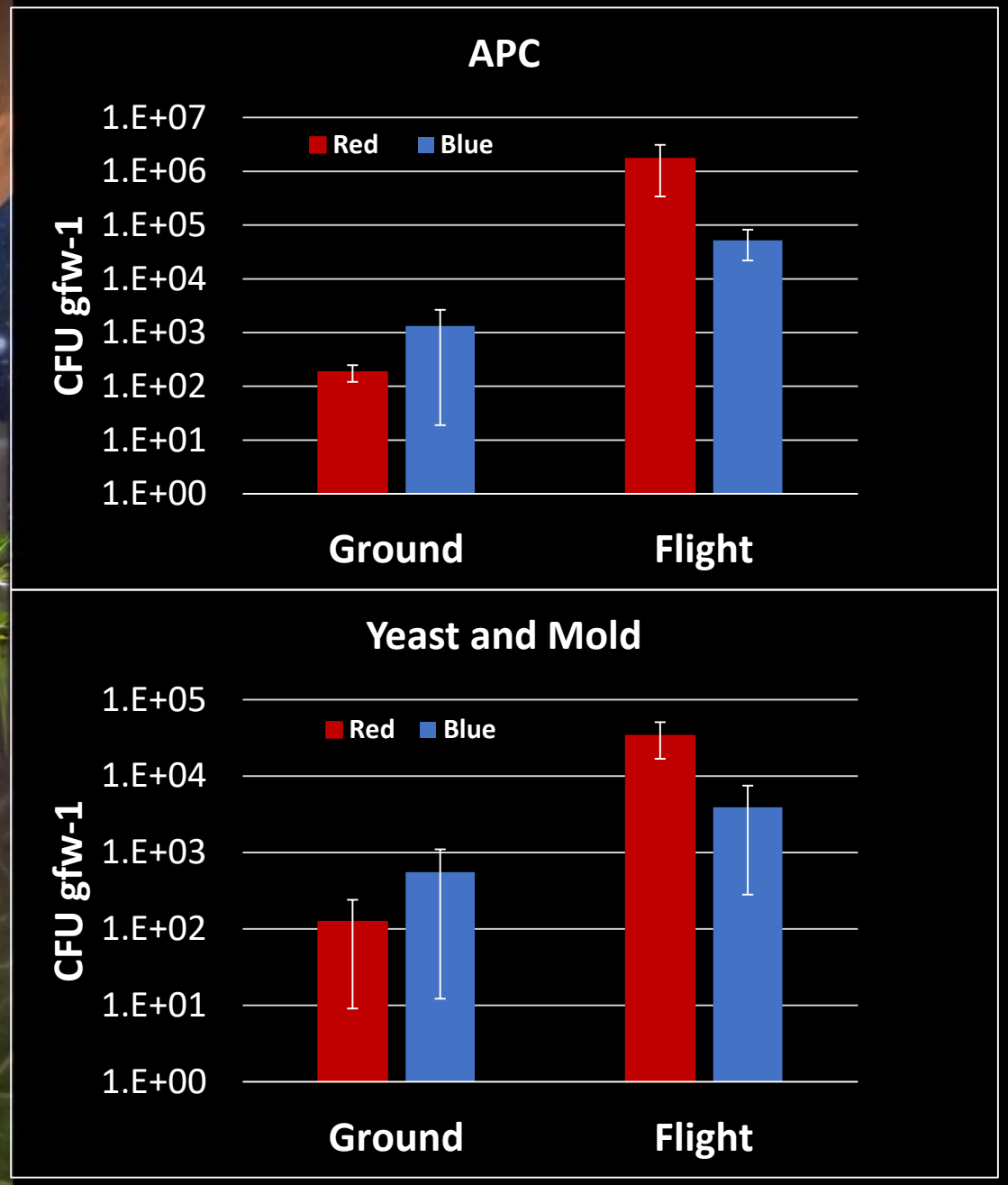



**Wick Material**



**Plant Leaves**

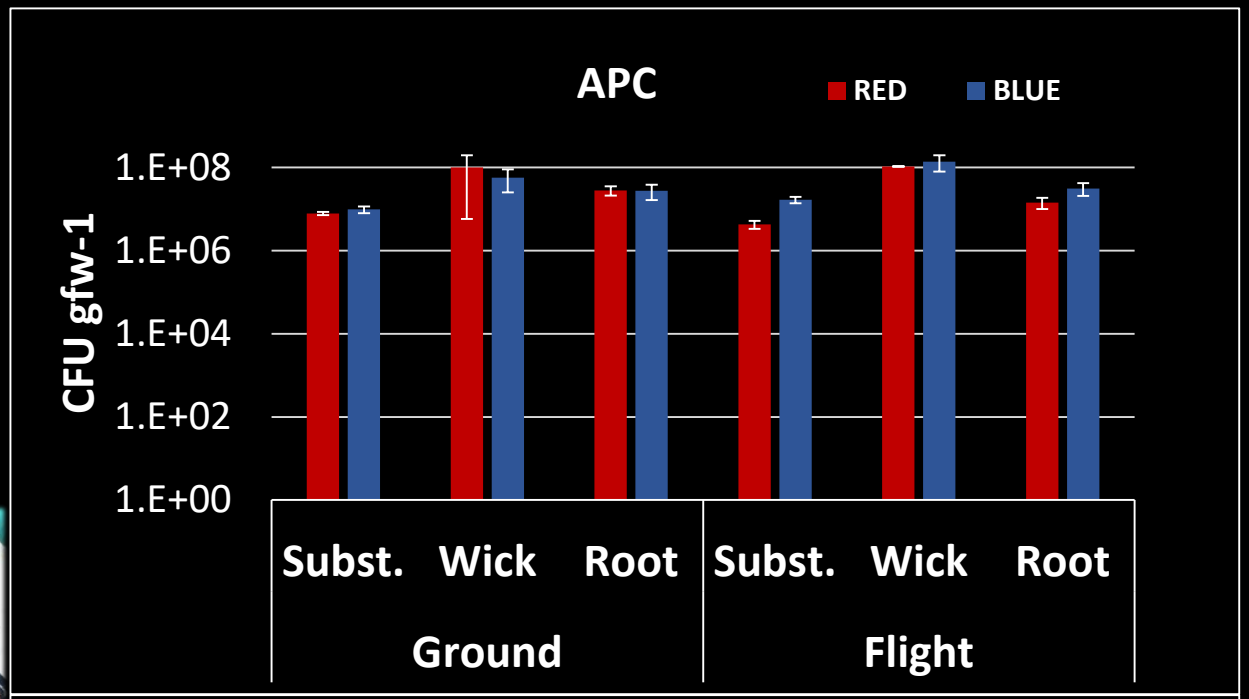
**Substrate & Root Zone**

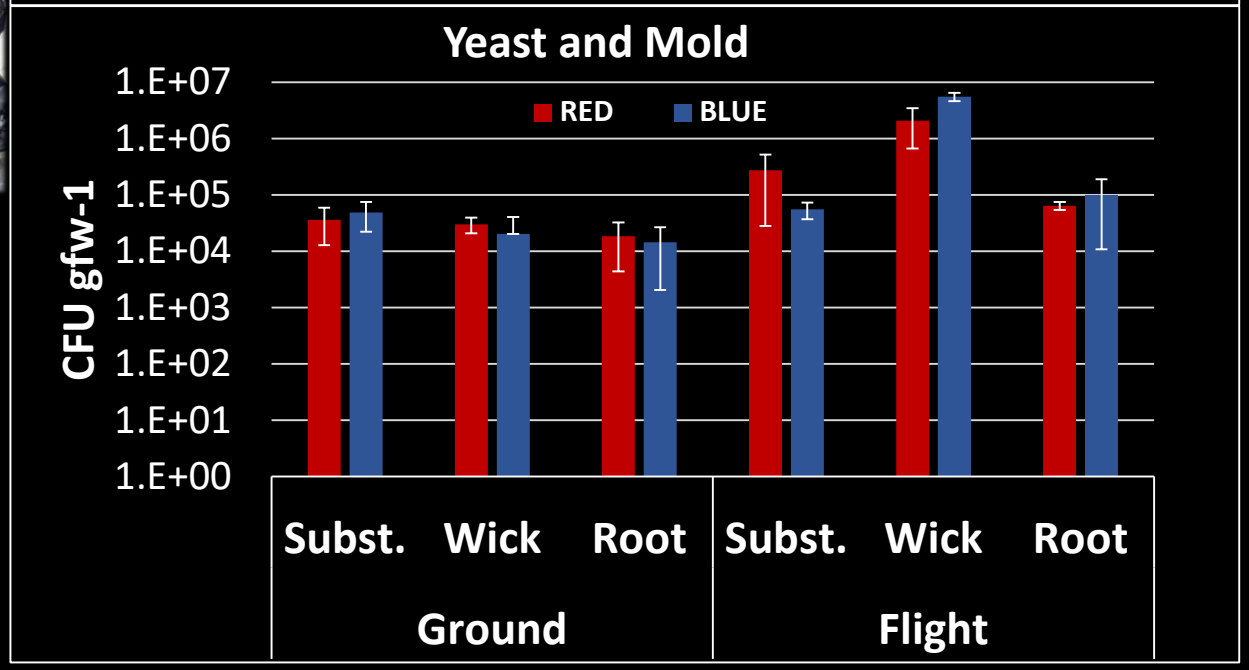



# VEG-04A Produce Microbiology from red-rich and blue-rich light treatments

Aerobic bacterial (APC) and yeast and mold plate counts on harvested **mizuna leaves**. (n=3 except n=5 for flight red-rich light treatment samples).

- Flight leaves have higher bacterial and fungal counts than ground ($p<0.01$).
- Flight leaves under red-rich light treatment have higher counts than all other sample sets ($p<0.01$).
- Bacterial and fungal counts exceed NASA limits for thermostabilized food but pathogen screening was below detection limit for *S. aureus, E. coli,* coliforms and *Salmonella sp*.




# VEG-04A Pillow Microbiology from red-rich and blue-rich light treatments

Aerobic bacterial (APC) and yeast and mold plate counts on Veggie **pillow component.**

- Fungal counts are higher on the wicks from the flight pillows

| | VEG-04 A Tissue Average Elemental Content (ug/g DW) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Al** | **B** | **Ca** | **Cu** | **Fe** | **K** | **Mg** | **Mn** | **Na** | **P** | **S** | **Zn** |
| **Red-Rich (Ground)** | 22 | 74 | 4,318 | 12 | 64 | 28,962 | 5,432 | ^*166 | 630 | 4,139 | 4,542 | 34 |
| **Red-Rich (Flight)** | 23 | 93 | 6,292 | 8 | 67 | 38,762 | 8,375 | *306 | 828 | 5,077 | 6,929 | 38 |
| **Blue-Rich (Ground)** | 24 | 85 | 5,175 | 10 | 62 | 26,873 | 6,408 | ^213 | 479 | 3,648 | 4,542 | 26 |
| **Blue-Rich (Flight)** | 23 | 124 | 5,645 | 11 | 85 | 34,029 | 7,476 | 248 | 613 | 5,154 | 6,922 | 40 |

Sample sizes: All are n=3 except Red-rich flight which is n=5

| | VEG-04 A Tissue Average Elemental Content (ug/g DW) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Al | B | Ca | Cu | Fe | K | Mg | Mn | Na | P | S | Zn |
| Red-Rich (Ground) | 22 | 74 | 4,318 | 12 | 64 | 28,962 | 5,432 | ^*166 | 630 | 4,139 | 4,542 | 34 |
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| Blue-Rich (Flight) | 23 | 124 | 5,645 | 11 | 85 | 34,029 | 7,476 | 248 | 613 | 5,154 | 6,922 | 40 |

Average elemental analysis, red and blue light treatments

- Manganese - *indicates significant difference between ground and flight Red-rich samples.

^indicates significant difference between Red-rich and Blue-rich ground samples.

| | VEG-04 A Tissue Average Elemental Content (ug/g DW) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Al | B | Ca | Cu | Fe | K | Mg | Mn | Na | P | S | Zn |
| **Red-Rich (Ground)** | 22 | 74 | 4,318 | 12 | 64 | 28,962 | 5,432 | ^*166 | 630 | 4,139 | 4,542 | 34 |
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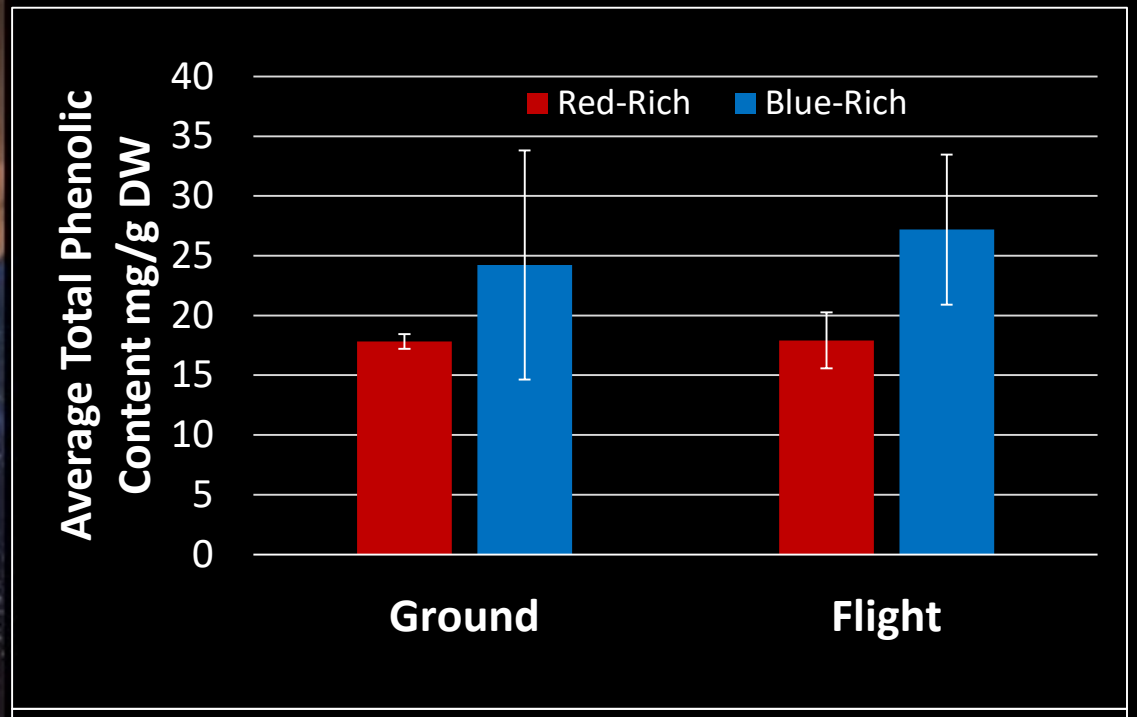
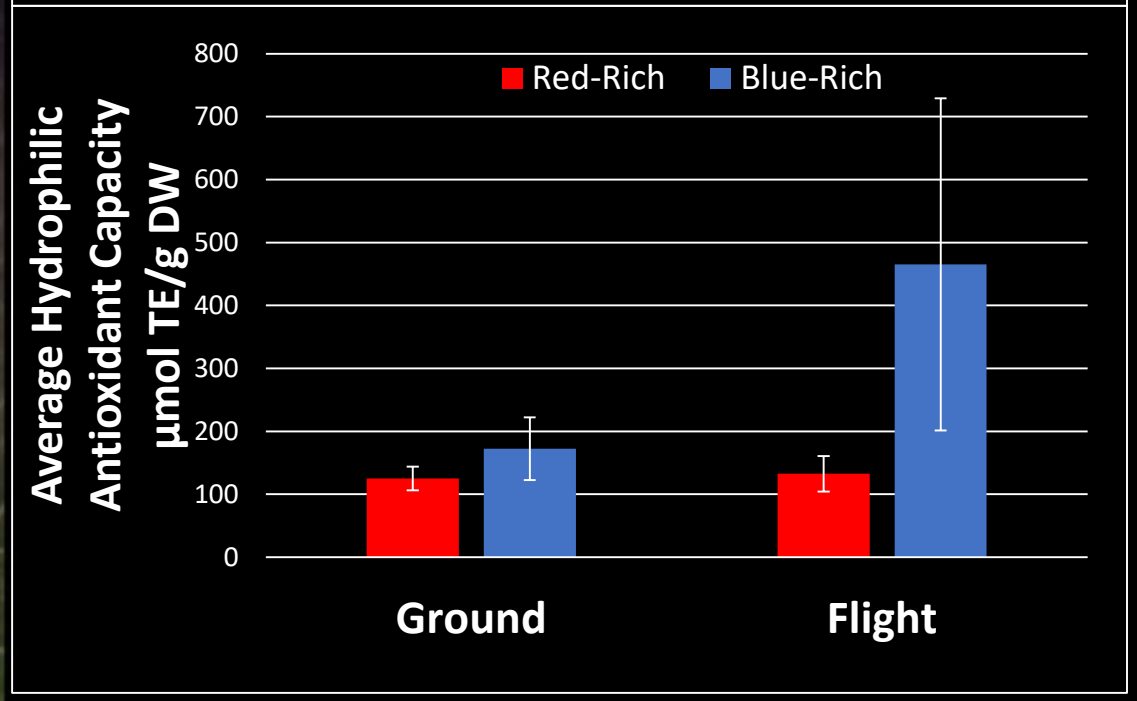
Sample sizes: All are n=3 except Red-rich flight which is n=5




# VEG-04A chemistry from red-rich and blue-rich light treatments

- Average Total Phenolic Content
  - Total phenolic content is higher in blue-rich light in both Ground and Flight plant samples. This difference is significant in flight samples.
- Average Hydrophilic Antioxidant Content
  - Blue flight samples (n=2) were re-analyzed to confirm this large variability.

    Sample sizes: All ground are n=3;
    Red-rich flight n=4
    Blue-rich flight n=2

# Next Steps

- Complete VEG-04B growth tests on ISS with the final harvest around Thanksgiving
- Identification of microorganisms from VEG-04A samples
- Continue chemistry of VEG-04A samples
- Continue crew surveys
- Samples from VEG-04B will be returned and analyzed following undock of SpaceX-19 (estimated January 2020)

# Thank you!

- Veggie and VEG teams at KSC, JSC, and SNC-ORBITEC
- Astronauts Christina Koch, David Saint-Jacques, Nick Hague, Jessica Meir, Drew Morgan, and Luca Parmitano
- Payload Operations and Integration Center
- This research was co-funded by NASA's Human Research Program and Space Biology in the ILSRA 2015 NRA call.