Fiscal Year:	FY 2021	**Task Last Updated:**	FY 08/02/2021
PI Name:	Massa, Gioia Ph.D.		
Project Title:	Pick-and-Eat Salad-Crop Productivity, Nutritional Value, and Acceptability to Supplement the ISS Food System		
Division Name:	Human Research, Space Biology		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HHC**:Human Health Countermeasures		
Human Research Program Risks:	(1) **Food and Nutrition**:Risk of Performance Decrement and Crew Illness Due to Inadequate Food and Nutrition		
Space Biology Element:	(1) Plant Biology		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	(1) Bioregenerative Life Support		
PI Email:	gioia.massa@nasa.gov	**Fax:**	FY
PI Organization Type:	NASA CENTER	**Phone:**	321-861-2938
Organization Name:	NASA Kennedy Space Center		
PI Address 1:	ISS Ground Processing and Research		
PI Address 2:	Mail Code UB-A-00		
PI Web Page:			
City:	Kennedy Space Center	**State:**	FL
Zip Code:	32899-0001	**Congressional District:**	8
Comments:			
Project Type:	FLIGHT	**Solicitation / Funding Source:**	2013-14 HERO NNJ13ZSA002N-ILSRA. International Life Sciences Research Announcement
Start Date:	09/01/2015	**End Date:**	09/30/2025
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:		**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	2	**Monitoring Center:**	NASA JSC
Contact Monitor:	Douglas, Grace	**Contact Phone:**	
Contact Email:	grace.l.douglas@nasa.gov		
Flight Program:	ISS		
Flight Assignment:	NOTE: End date changed to 9/30/2025 per HRP HHC element management (Ed., 8/10/21) NOTE: End date changed to 9/30/2021 per PI (Ed., 5/4/2020) NOTE: End date changed to 8/31/2020 per PI (Ed., 8/17/18) NOTE: Element change to Human Health Countermeasures; previously Space Human Factors & Habitability (Ed., 1/18/17) NOTE: Period of performance changed to 9/01/2015-8/31/2018 (previously 7/1/15-6/30/18) per G. Douglas/HRP (Ed., 4/3/16)		
Key Personnel Changes/Previous PI:	July 2021 report: Co-investigator Pete Roma departed the project in Feb. 2021, and Dr. Suzanne Bell and Dr. Sara Whiting were added as a Co-investigators for Behavioral Health and Performance (BHP). Meredith Russel was added as a participant to support the BHP work.		

COI Name (Institution):	Douglas, Grace Ph.D. (NASA Johnson Space Center) Hummerick, Mary M.S. (Amentum, Kennedy Space Center) Mitchell, Cary Ph.D. (Purdue University--grant NNX15AN78G) Morrow, Robert Ph.D. (Orbital Technologies Corporation) Wheeler, Raymond Ph.D. (NASA Kennedy Space Center) Young, Millennia Ph.D. (NASA Johnson Space Center) Spencer, LaShelle M.S. (Amentum, Kennedy Space Center) Romeyn, Matt M.S. (NASA Kennedy Space Center) Buncheck, Jess M.S. (Southeastern Universities Research Association, Kennedy Space Center) Bell, Suzanne Ph.D. (NASA Johnson Space Center) Whiting, Sara Ph.D. (KBR/Johnson Space Center)
Grant/Contract No.:	Internal Project
Performance Goal No.:	
Performance Goal Text:	
Task Description:	The capability to grow nutritious, palatable food for crew consumption during spaceflight has the potential to provide health promoting, bioavailable nutrients, enhance the dietary experience, and reduce launch mass as we move toward longer-duration missions. However, studies of edible produce during spaceflight have been limited, leaving a significant knowledge gap in the methods required to grow safe, acceptable, nutritious crops for consumption in microgravity. The “Veggie” vegetable-production system on the International Space Station (ISS) offers an opportunity to develop a “pick-and-eat” fresh vegetable component to the ISS food system as a first step to bioregenerative supplemental food production. We propose growing salad plants in the Veggie unit during spaceflight, focusing on the impact of light quality and fertilizer formulation on crop morphology, edible biomass yield, microbial food safety, organoleptic acceptability, nutritional value, and behavioral health benefits of the fresh produce. Phase A of the project would involve flight tests using leafy greens. Phase B would focus on dwarf tomato. Our work will help define light colors, levels, and horticultural best practices to achieve high yields of safe, nutritious leafy greens and tomatoes to supplement a space diet of prepackaged food. Our final deliverable will be the development of growth protocols for these crops in a spaceflight vegetable production system. Specific aim 1: Evaluate the effects of four light treatments and two different fertilizer compositions on the yield, morphology, organoleptic acceptability, and nutritional attributes of leafy greens during flight-definition and flight testing. Specific aim 2: Perform cultivar selection and evaluate the effects of four different red: blue light treatments and two different fertilizer compositions on the yield, morphology, organoleptic acceptability, and nutritional attributes of dwarf tomato during ground and flight tests. Specific aim 3: Perform hazard analysis, develop plans for minimizing microbial hazards, and screen flight-grown produce for potential pathogens.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Research Project: Our work on “Pick-and-Eat Salad-Crop Productivity, Nutritional Value, and Acceptability to Supplement the ISS Food System” focuses on developing a fresh food production capability on the International Space Station (ISS). We are using the Veggie hardware to develop light and fertilizer combinations that generate nutritious and appealing leafy green vegetables and dwarf tomatoes that astronauts can safely consume. The results of this research will directly translate to Earth-based controlled environment production of these and similar crops in vertical farms and urban plant factories. The capability to grow nutritious, palatable food for crew consumption during spaceflight can potentially provide health-promoting, bioavailable nutrients, enhance the dietary experience, and reduce launch mass as we move toward longer-duration exploration missions. However, studies of edible produce during spaceflight have been limited, leaving a significant knowledge gap in the methods required to grow safe, acceptable, nutritious crops for consumption in microgravity. The Veggie vegetable-production system on the ISS offers an opportunity to develop a “pick-and-eat” fresh vegetable component to the ISS food system as a first step to bioregenerative supplemental food production. Our goal is to grow salad crops in the Veggie unit during spaceflight and assess the impact of light quality and fertilizer formulation on crop morphology, edible biomass yield, microbial food safety, organoleptic acceptability, nutritional value, and behavioral health benefits. Our work will help define light color ratios, fertilizer composition, and horticultural best practices to achieve high yields of safe, nutritious leafy greens and tomatoes to supplement a space diet of prepackaged food. Our final deliverable will be to develop growth protocols for these crops in a spaceflight vegetable-production system. This will reduce the risk and close the gap of inadequate nutrition by helping us advance bioregenerative food production to supplement the packaged diet for future space exploration.
	Pick-and-eat Salad-crop Productivity, Nutritional Value, and Acceptability to Supplement the ISS Food System (VEG-04A, VEG-04B, and VEG-05) is a set of hybrid experiments of plant research with human organoleptic and behavioral research. These experiments are sponsored by the Human Research Program (HRP) but are implemented in partnership with the Space Biology Program. The VEG-04 flight experiments were conducted in 2019, and the VEG-05 experiment has been delayed due to hardware development and implementation. Because of this delay, an additional component was added to this experiment, known as HRF VEG (which stands for Human Research Facility – Veggie). The HRF VEG experiment consists of collecting data of opportunity from other space biology investigations with plants that are being conducted on the ISS between the VEG-04 and VEG-05 tests. Data collected are specific to the human research foci of this project and include only behavioral health and performance data as part of the Veggie Questionnaire and Profile of Mood States data collected, and Organoleptic data on the crops. VEG-04A and B VEG-04A was conducted during Increment 57-58 and ran from June 4, 2019-July 9, 2019. VEG-04B was conducted during Increment 61-62, and ran from October 1, 2019-November 28, 2019, and both had ground controls run ~48 hours later. Science samples were returned from ISS and were processed for microbiological food safety and chemical analyses. All plant samples have undergone chemical and microbiological analyses. Microbiological data analysis was

Task Progress:	finished, and results were presented in November of 2020 at the American Society for Gravitational and Space Research Annual meeting. In summary, inconsistent differences were seen in bacterial counts between the red and blue light treatments and the 2 experiments 04A and 04B. Microbial counts were higher on flight leaves than ground control leaves and counts increased with the repeated harvest method used in the VEG-04B experiment. Seven critical control points to prevent microbiological contamination have been identified for Veggie grown leafy greens from ground processing through harvest. All cultured bacterial and fungal isolates were identified and archived. Some chemical analyses remain in work after being postponed due to COVID-19. This work was not able to be added to the mission essential list of onsite work until late spring 2021. The completion of the chemical analysis of the leaf tissue from VEG-04B was resumed after COVID restrictions were lifted at Kennedy Space Center for this project. This has been delayed again due to equipment failure. The equipment has been replaced and will be installed in the next few weeks enabling the extraction of the leaf tissue to analyze for phenolic compounds as well as oxygen radical absorbance capacity (ORAC) completing the elemental and nutritional chemistry data set for these experiments. The new equipment EDGE Automated Solvent Extraction System (CEM) can extract a wide range of samples 3 times faster than the previous extraction system. It has the capability to filter, cool, and wash extracted samples. Additionally, it is equipped with a Q-Dry Solvent Evaporator. The VEG-04 plant, microbiological, chemical, organoleptic, and behavioral health data to date were presented at the Human Research Program Investigator Workshop held virtually in Feb. 2021. HRF VEG Plans for HRF VEG, essentially the collection of human data of opportunity on plant growth tests including VEG-03 I, J, K, and L and PH-04, were approved by the Human Research Program Control Board on Sept. 17, 2020. The Institutional Review Board (IRB) and crew informed consent briefings were modified to include these additional experiments, all crew members for the possible missions received Informed Consent Briefings, and organoleptic and veggie questionnaires were modified to allow the additional crops (‘Outredgeous’ lettuce, ‘Dragoon’ lettuce, ‘Wasabi’ mustard, ‘Red Russian’ Kale, ‘Extra Dwarf’ Pak Choi, ‘Amara’ mustard, and ‘Española improved’ Hatch Chile peppers) and additional hardware (Advanced Plant Habitat) to be evaluated by participating subjects. Collection of plant data is not a part of the HRF VEG studies. VEG-03 I and J were grown Jan. 4 through Feb. 2, 2021. VEG-03 I consisted of a mixture of crops and VEG-03 J consisted of tests of a new seed film technology with ‘Outredgeous’ red romaine lettuce. Crew were able to eat only crops grown in VEG-03 I. Immediately following these growth tests, VEG-03 K and VEG-03 L were conducted from Feb. 8 through April 13th with ‘Amara’ mustard and ‘Extra Dwarf’ Pak Choi, respectively, and both crops could be eaten. Surveys were collected from participating crew aboard during these tests and analysis is in work. The PH-04 test growing ‘Española improved’ Hatch Chile peppers in the Advanced Plant Habitat was initiated July 12th. Plants will grow for 120 days and behavioral health and organoleptic data will be collected. VEG-05 is currently planned for no earlier than spring of 2022. Purdue University Research. Purdue University MS student Asmaa Morsi, who successfully completed and defended her master’s Thesis at the end of 2019 is completing work on two manuscripts related to fertilizer use in Veggie-grown crops.
Bibliography Type:	Description: (Last Updated: 10/26/2023)