Fiscal Year:	FY 2020	**Task Last Updated:**	FY 10/29/2020
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:**	09/30/2021
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	1
No. of Master's Candidates:	2	**No. of Bachelor's Degrees:**	2
No. of Bachelor's Candidates:	12	**Monitoring Center:**	NASA JSC
Contact Monitor:	Douglas, Grace	**Contact Phone:**	
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Flight Program:	ISS		
Flight Assignment:	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:	No Changes		

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) Roma, Peter Ph.D. (KBR/NASA Johnson Space Center) Buncheck, Jess M.S. (Southeastern Universities Research Association, Kennedy 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.
	Reporting Period: 08/31/2019-08/31/2020 Flight Experimentation 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 but are implemented in partnership with the Space Biology Program. VEG-04A was conducted during Increment 57-58, and ran from June 4, 2019-July 9, 2019. VEG-04A grew Mizuna mustard, a leafy green crop, for approximately 28 days under 2 different light quality treatments in space. VEG-04B was conducted during Increment 61-62, and ran from October 1, 2019-November 28, 2019, with a ground control run 48 hours later. VEG-04B also grew Mizuna mustard, but this time for approximately 2 months under the same 2 different light quality treatments in space, with multiple harvests of the leafy produce. For both VEG-04 A and VEG-04B, the impact on crop growth was analyzed in terms of the differences observed in plant yield, nutritional composition, and microbial levels. Ground studies were conducted in parallel to determine the effects of spaceflight on plant growth. Consenting crew members, after eating the vegetables, were asked to rate the flavor, texture, tenderness, etc. of the

Task Progress:	produce grown under the different light treatments. Crew members also participated in surveys to evaluate their moods and assess any psychological benefits from interacting with plants in the spaceflight environment. For VEG-04A, 6 pillows were initiated in each light treatment. Mizuna germination was noted in all 12 pillows. All objectives were conducted as expected, despite a plant establishment anomaly. Five pillows grew successfully to harvest in the red-rich light treatment, while 3 pillows grew successfully in the blue-rich light treatment. Plant mortality was attributed to too much water added early in the experiment. For VEG-04B, 6 pillows were initiated in each light treatment. Mizuna germination was noted in all 12 pillows. All objectives were conducted as expected, despite a plant establishment anomaly and a fungal anomaly. At initiation, the crew noticed loose plant growth media in the bag containing pillow 3. This pillow was successfully installed 1 day after initiation of the others after the ground team had determined the risk to the crew and ISS environment, the cause of the leaked media, and cleanup requirements. Plants in five pillows grew successfully in the blue-rich light treatment; however, the seedlings in plant 7 dried out before the first watering procedure and did not survive. Plants in six pillows grew successfully to the first harvest in the red-rich light treatment; however, pillow 2 was removed following this activity after fungal growth was detected on the base of the plant. Data from flight include photos, videos, and downlinked water volumes added. Samples from each harvest were collected for science (1 harvest in VEG-04A and 3 in VEG-04B). The remaining produce was subjected to organoleptic analysis or retained for consumption. Science samples were returned and have been processed for microbiological food safety and chemical analyses. Plant sample elements have been assessed, and fungi and bacteria have been identified via traditional microbiological techniques and MicroSeq. Plant pillows and swab samples have been analyzed for microbial constituents, with a focus on bacteria and fungi isolated for identification. Survey data have all been collected. Within each study, plant growth did not differ across light treatment or location (flight versus ground). In flight plants, Mizuna grown in the blue-rich treatment produced more biomass when grown longer, and on the ground, mizuna produced more biomass in both light treatments when grown longer, but growth of this crop declined over time with the repeated harvests. On average, bacterial and fungal counts were significantly lower on ground control samples than flight samples, and microbial counts increased with repeated harvests. Light treatment did not influence any elements in tissues tested; however, the growth duration did impact levels of several elements. Antioxidant and phenolic analyses remain incomplete due to COVID-19. Organoleptic scores were generally higher in flight, and ground tasters considered samples more bitter. Amount of interaction and responses to Veggie varied widely by individual. Half of all crew time spent interacting with Veggie (47%) was Setup and Watering. Consumption and Voluntary Viewing accounted for 13% of crew time. Enjoyable tasks had higher impact than non-enjoyable tasks and interacting with Veggie was generally viewed as positive. These tests on ISS are helping to mitigate the risk of an inadequate food supply for long-duration missions by adding fresh vegetables and key nutrients to the crew diet and indicating which plant care activities are providing behavioral health benefits for the crew. Purdue University Research - Optimizing Controlled-Release Fertilizer for Lettuce and Mizuna Grown on the International Space Station Astronaut diets on the ISS depend on resupplied packaged food. However, missions to Mars of 3-5 years will not accommodate re-supply. In addition, many human macro- and micro-nutrients degrade during long-term storage. Thus, growing nutritional plants aboard ISS is essential for providing astronauts with fresh, healthy produce. NASA is using Veggie to grow fresh salad crops aboard ISS to provide astronauts with healthy diets. In Veggie plants are grown with roots in a baked-ceramic substrate (arcillite) incorporating controlled-release fertilizer (Nutricote prills) and wicks delivering water by capillary action from a reservoir. The fertilizer prills release nutrients into arcillite slowly over time. Different controlled-release types have the same amount of fertilizer but release it over different time periods. The Purdue Mitchell lab in collaboration with NASA is testing growth of salad crops within Veggie analogs under ISS-like environments in a growth chamber. Specifically, we are evaluating effects of different controlled-release fertilizer treatments as well as different substrate particle sizes on “cut-and-come-again” harvest scenarios, comparing productivity and quality of Red Romaine lettuce as well as Mizuna mustard. ISS environments being mimicked include temperature, CO_2, relative humidity, and photoperiod. Arcillite medium contained one of two different fertilizer mixes: 7.5g 18-6-8 T 70 + 7.5g 18-6-8 T100, or 7.5g18-6-8 T70 +7.5g 18-6-8 T180 fertilizer/liter medium. LED Light treatment was the red-rich light treatment tested in VEG-04 A and B. Plants are grown under those conditions for 8 weeks, and harvested three times at 28, 42, and 56 days from planting. At each harvest, yield parameters as well as tissue mineral content have been measured for optimum fertilizer treatment selection. Lettuce and Mizuna plants grown in a mix of 100% fine substrate particles (Profile) and fertilizer treatment of 50% T100:50%T70 had the higher yield as well as nitrogen content compared to those grown in 50%T180:50%T70. Growing mizuna plants in 100% profile resulted in higher shoot fresh weight; although no significant differences occurred for shoot dry weight. In addition, there was no significant interaction between substrate and fertilizer, which is reported by other research as one of the advantages of using controlled-release fertilizer. M.S. Student Asmaa Morsi successfully presented and defended her thesis work in November 2019.
Bibliography Type:	Description: (Last Updated: 07/26/2024)
Articles in Peer-reviewed Journals	Burgner SE, Nemali K, Massa GD, Wheeler RM, Morrow RC, Mitchell CA. "Growth and photosynthetic responses of Chinese cabbage (Brassica rapa L. cv. Tokyo Bekana) to continuously elevated carbon dioxide in a simulated Space Station “Veggie” crop-production environment." Life Sci Space Res. 2020 Nov;27:83-8. Available online 24 July 2020. https://doi.org/10.1016/j.lssr.2020.07.007 , Nov-2020
Papers from Meeting Proceedings	Spencer LE, Hummerick ME, Stutte GW, Sirmons T, Graham GT, Massa G, Wheeler RM. "Dwarf Tomato and Pepper Cultivars for Space Crops." 49th International Conference on Environmental Systems, Boston, MA, July 7-11, 2019. 49th International Conference on Environmental Systems, Boston, MA, July 7-11, 2019. ICES paper ICES-2019-164. , Jul-2019