Fiscal Year:	FY 2024	**Task Last Updated:**	FY 08/21/2023
PI Name:	Walters, Kellie Ph.D.		
Project Title:	Modeling Leafy Greens Physiological and Biochemical Responses to Light Intensity and Successive Harvest		
Division Name:	Space Biology		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	None		
Human Research Program Risks:	None		
Space Biology Element:	(1) Plant Biology		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	(1) Bioregenerative Life Support		
PI Email:	waltersk@utk.edu	**Fax:**	FY
PI Organization Type:	UNIVERSITY	**Phone:**	563-880-6933
Organization Name:	University of Tennessee, Knoxville		
PI Address 1:	Department of Plant Sciences		
PI Address 2:	2505 EJ Chapman Dr., Plant Biotechnology Building Room 112		
PI Web Page:			
City:	Knoxville	**State:**	TN
Zip Code:	37996	**Congressional District:**	2
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2020 Space Biology NNH20ZDA001N-SB E.12. Flight/Ground Research
Start Date:	10/20/2021	**End Date:**	01/23/2024
No. of Post Docs:		**No. of PhD Degrees:**	
No. of PhD Candidates:		**No. of Master' Degrees:**	
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:		**Monitoring Center:**	NASA KSC
Contact Monitor:	Massa, Gioia	**Contact Phone:**	321-861-2938
Contact Email:	gioia.massa@nasa.gov		
Flight Program:			
Flight Assignment:	NOTE: End date changed to 01/23/2024 per NSSC information (Ed., 9/3/23) NOTE: End date changed to 01/23/2023 per NSSC information (Ed., 8/25/22)		
Key Personnel Changes/Previous PI:	Ethan Darby has been selected as the Master of Science Graduate Research Assistant working on this project.		
COI Name (Institution):			
Grant/Contract No.:	80NSSC22K0205		
Performance Goal No.:			
Performance Goal Text:			

Task Description:

Integrating space-grown food into the astronaut diet is integral to mitigating nutrient deficiencies on long-duration flights and has been deemed a priority in the NASA Decadal Survey and the Space Biology, Plant Biology Element. Potassium, calcium, and vitamin K concentrations in stored space food may not be adequate to meet the recommended daily human intake, and compounds including vitamins B1, and C degrade over time and can become inadequate for human nutrition. For example, vitamin C concentrations of space food stored in International Space Station (ISS) conditions degraded 32 to 83% over three years. Additionally, space radiation increases the risk of cataracts, creating a need to integrate more lutein and zeaxanthin, carotenoids that potentially mitigate eye issues, into the astronaut diet. Mizuna is one of six leafy greens species to be considered for incorporation into the diet on medium- to long-duration space missions based on productivity, volume, growth pattern, mineral nutrient accumulation, and phytochemical concentrations. However, models characterizing crop physiological and biochemical responses to crop production and environmental factors are needed to improve productivity and nutrient density while mitigating labor and energy resource use. Without improving productivity and nutrient density, the regular integration of fresh produce into the astronaut diet and the feasibility of long-duration space missions remains in question.
The long-term goal is to aid in the facilitation of long-term space missions by establishing environmental conditions and cultural factors required for optimal leafy greens growth, nutritional value, space- and energy-use efficiency, and labor by modeling crop physiological and biochemical responses. The overall objective of this proposal is to improve and quantify the consistency, phytonutrient quality, and productivity of cut-and-come-again mizuna by identifying suitable cultivars, determining the optimal light intensity and photoperiod, and quantifying changes over time in ISS-like environmental conditions (temperature of ~23°C, ~2,800 ppm CO2). Specific aim 1 is to identify at least two or three mizuna cultivars with great yield and nutrient potential making them highly suitable for production in space. We hypothesize that some cultivars will produce biomass faster than others while some cultivars will have higher nutrient concentrations. Specific aim 2 is to determine the optimal light intensity and photoperiod for maximum biomass production and phytonutrient density of mizuna, creating models to predict growth and biochemical responses in ISS-like conditions. We hypothesize that yield and phytonutrient concentrations will increase as light intensity increases to a cultivar-specific optimum by increasing photosynthesis, photoreceptor mediated biochemical reactions, and beneficial stress responses. Specific aim 3 is to quantify changes in plant physiology and phytonutrient concentrations over time to identify an optimal cut-and-come-again harvesting and production protocol for mizuna. We hypothesize that as plants age, the nutrient profile and biomass production will change as well. Therefore, new seedlings may have to replace more mature cut-and-come-again plants prior to reductions in yield to maintain nutritional quality for astronaut diets.

By the completion of this study, we expect to have identified at least one high-yielding nutrient-dense mizuna cultivar highly suitable for space production. We will have the data required to calculate resource-use efficiencies to balance energy use, production duration, yield, and nutrition. We also expect to have identified how long cut-and-come-again mizuna should be grown to maximize biomass and nutrient productivity, thus improving the feasibility of long-duration space missions.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

Selecting proper cultivars is not only essential to optimize plant production in space but on earth as well. The cultivar data generated from our study can inform terrestrial indoor plant producers. With this thorough dataset, producers can weigh factors based on their production goals; for example, fresh mass is generally the most heavily weighted parameter for indoor plant producers. However, other factors such as anthocyanin concentration may also be of greater interest on earth because anthocyanins confer a red or purple leaf pigmentation that can be appealing to consumers. One benefit to earth production that has not been thoroughly explored from an industry perspective is phytonutrient concentrations. Detailed phytonutrient analyses, such as the analyses conducted in our research, is not common in the indoor plant production industry. With this data available, producers can select more nutrient-dense cultivars for production and can potentially communicate the benefit of the cultivar(s) they select to consumers.

Task Progress:

Specific Aim 1:
We evaluated 20 cultivars of mustard greens, including 12 mizuna cultivars, under International Space Station/ISS-like conditions to determine which would provide the greatest yield and highest nutrient concentrations. Plants were grown for 31 days, harvested, and flash frozen. Morphological and fresh mass data were collected prior to freezing. This was completed three times over time. Half of the plants were then processed and analyzed to determine concentrations of specific carotenoids, total anthocyanins, and vitamins C, B1, and K1. The other half were processed and analyzed to determine concentrations of calcium, potassium, iron, and magnesium. The data were then transformed using a weighting system to determine which cultivar would provide the best phytonutrient, growth, and dimensional profile based on needs and priorities for long-duration space missions. Significant variations among cultivars' appearance – including color and morphology, biomass production, and phytonutrient concentrations – existed. The two cultivars selected for further production optimization studies were Brassica carinata ‘Green Amara’ and Brassica rapa ‘Hybrid Red Mizuna’. These two cultivars have different phytonutrient profiles and appearance. For example, ‘Green Amara’ has green leaves and a relatively high vitamin B1 concentration, while ‘Hybrid Red Mizuna’ has red leaves and a relatively high vitamin K1 concentration. Another observation was that mizuna and mibuna tended to have lower vitamin B1 concentrations than other mustard cultivars.

Specific Aim 2:

We grew Brassica carinata ‘Green Amara’ and Brassica rapa ‘Hybrid Red Mizuna’ under four light intensities: 200, 400, 600, or 800 µmol·m-2·s-1; and two photoperiods:16 and 24 hours. For ‘Green Amara’, as light intensity increased under a 16-h photoperiod, fresh mass increased linearly; while under a 24-h photoperiod, the greatest fresh mass was achieved at 600 µmol·m-2·s-1. Carotenoid concentrations decreased with increasing light intensity; photoperiod had no effect. As light increased, vitamin K1 concentration decreased under a 24-h photoperiod, but increased under a 16-h photoperiod. Vitamin B1 concentrations exhibited opposite quadratic responses to light intensity when grown under 16 or 24-h photoperiods. Given the contrasting trends across lighting treatments, we normalized and weighted the mean rankings. ‘Green Amara’ grown under 800 µmol·m-2·s-1 for a 16-h photoperiod had the highest weighted score. However, this data could be further utilized to select for more tailored phytonutrient profiles and/or energy efficiency. We have completed all phytonutrient quantification for ‘Hybrid Red Mizuna’ and are analyzing data.

Specific Aim 3:

	Prior to conducting the Specific Aim 3 experiments, we conducted preliminary feasibility studies to determine how the selected cultivars would respond to traditional "cut-and-come-again" harvesting methods (time based) compared to removing individual leaves (development based). We determined Brassica carinata 'Green Amara' and Brassica rapa 'Hybrid Red Mizuna' had different responses to harvesting methods, but both may be feasible from a labor perspective. Based on Specific Aim 2 results for both cultivars, we grew 'Green Amara' and 'Hybrid Red Mizuna' under 200 or 800 μmol·m-2·s-1 for a 16-h photoperiod harvesting via time or development based methods for 4 or 5 harvests. We have completed plant production and are currently completing phytonutrient quantification.
Bibliography Type:	Description: (Last Updated:)