Fiscal Year:	FY 2024	**Task Last Updated:**	FY 10/16/2023
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Project Title:	Growing Food on Mars: Determining the Impact of Radiation, Atmospheric Composition, and Rock Substrate on Plant Growth in a Space Rock Garden Experiment		
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Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
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Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	(1) Bioregenerative Life Support		
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Comments:			
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COI Name (Institution):	Rodrigues, Jorge Mazza Ph.D. (University of California, Davis) Melotto, Maeli Ph.D. (University of California, Davis) Zaharescu, Dragos Ph.D. (University of California, Davis)		
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Task Description:	1. SCIENCE GOALS AND OBJECTIVES. As human civilization expands outside of its terrestrial cradle to explore the Moon and Mars, the sources and delivery of nutrients for long-duration missions must be identified and refined. The importance of using local mineral resources for sustaining life, and the bioengineering of such environments remain at the vanguard of sustainable human space exploration. Our overarching goal is to test how ionizing radiation, atmospheric composition, and rock substrate constrain and influence plant growth in deep space exploration, specifically the maintenance of plants in Lunar and Martian environments. This Early Career Investigation (ECI) will produce new publishable findings that integrate how food plants interactively respond to spaceflight stressors (carbon dioxide / CO2 and radiation) and environmental constraints imparted by basalt rocks containing different morphological and elemental arrangements that serve as nutrient sources for plants and microbes in Mars-relevant environments. Once constructed, the Space Rock Garden Experiment (SRGE) will serve as the framework for performing additional plant studies experiments to be proposed through full-ground based proposals and future International Space Station (ISS) flight experiments. We will achieve three objectives: 1) Develop and construct the SRGE, an integrated experimental system capable of controlling the mineral substrate, water, atmospheric and ultraviolet (UV) radiative conditions, and the presence of plants and microbes; 2) Identify how the flux of short wavelength (UV-B) radiation and atmospheric composition influence the rock weathering environment (e.g., nutrient elements compartmentalization), therefore assessing how coupled atmospheric and stellar energy sources influence the formation and habitability of incipient soils; 3) Integrate tomato and N-fixing plant genotypes, arbuscular mycorrhiza, and associated microbiota into the SRGE to assess how rock properties affect the growth and development of plants as viable crops for deep space exploration under increased CO2 and UV-B radiation. 2. METHODOLOGY. We will design, construct, and test the SRGE to simulate plant growth and microbe-mineral interactions under atmospheric and radiation scenarios relevant to Martian landscape. We will assess plant and microbial stress indicators in combination with biogeochemical analyses of major and trace elements in mineral, water and biomass pools. Micro-XCT (X-Ray Computed Tomography) will be used to assess plant root architecture, pore space morphology, and the biogeochemical indicators required to support complex plant life. We performed a pilot study using basalt rock substrates sampled from Mars analog sites in Iceland and confirmed that: i) tomato and lentil plants successfully co-germinated and grew together in basalt rock substrates under ambient conditions; ii) DNA was can be extracted from fresh basalt rock substrates, indicating that the rock materials are capable of hosting microbial life; and iii) a microXCT approach successfully differentiated dense mineral particles, water-filled pores, air-filled pores, and roots from tomato plants grown in the basalt rock substrates.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Rock weathering replenishes nutrients in the environment, shapes geochemical carbon sequestration, and drives physical, chemical, and/or biological processes at a multitude of scales. Globally, lithology type and distribution, climate, and ecosystem activity are predictors of mineral weathering rates and long-term carbon cycling. Our research is examining the intricacies of how contrasting crystalline and glassy basaltic rock substrates weather and release mineral-bound elements that are essential to life using controlled environmental chambers through the Space Rock Garden Experiment (SRGE). We are also examining how morphological and elemental differences in basalt rock composition impacts food plant production under both Earth and Mars atmospheric conditions, which is expanding understanding of how rock substrate composition influences plant growth. Our work is advancing knowledge of sustainable food production using natural (rock-based) fertilization through basalt weathering. Carbon-capture through mineral weathering is another important secondary effect.
Task Progress:	A main objective for our one-year, Early Career Investigation (ECI) grant is to develop and construct the Space Rock Garden Experiment (SRGE), which is an integrated experimental system capable of controlling the mineral substrate, water, atmospheric composition, and UV radiative conditions, and the presence of plants and microbes. Excellent progress has been made on the design, development, and construction of the SRGE. Finalizing the construction and testing of the SRGE chambers are top priorities for the project so that we can simulate energetic surface conditions on Mars, both through the current research project and in the submission of upcoming proposals to NASA. Design and development of SRGE Environmental Chambers: The design and development phase of the project involved a multi-month, iterative process led by Science Principal Investigator (PI) Zaharescu. Science PI Zaharescu organized meetings with experts who offered insight on the development process for the SRGE environmental chambers. Science PI Zaharescu also led organizational meetings and discussions with our team to solicit input and to receive any feedback on the process (including the testing of materials, and selection of supplies, among other logistical and technical questions/activities required to advance the project. Science PI Zaharescu and PI Lybrand also worked on purchasing tools and equipment needed for the chamber construction, including the identification and purchase of acrylic sheets, adhesives, and other supplies. Both Science PI Zaharescu and PI-Lybrand worked on identifying and preparing a space for the SRGE Environmental Chambers in the laboratory. Science PI Zaharescu also worked extensively to set up the laboratory work space required to construct the SRGE environmental chambers. Mars analog rock substrate characterization, analysis, and selection for SRGE: Our team employed an electron microprobe analysis technique to compare and contrast Mars analog rock substrate materials collected from Mars analog sites to determine which substrates should be included as the primary substrates in the upcoming Space Rock Garden Experiments. Preliminary data sets are suggesting geochemical similarities between Mars rock measurements and Mars analog rock materials to be used in our experiments. The electron microprobe analysis approach also produced micrographs, which provided microscale imagery of the Mars analog rock substrates, including glassy and crystalline substrates, to be examined in the upcoming experiments. Construction of SRGE Environmental Chambers: The design and construction of the Mars simulation chambers was performed in iterative phases using an innovative design thinking method, and a versatility-esthetics centered approach, that included: 1) Ideation, 2) Mapping, 3) Design Block, 4) Implementation, and 5) Testing. Identifying Mars-relevant radiation and lighting conditions: Science PI Zaharescu worked to compile an extensive database comprising 15+ published papers and data sets from Mars rovers and satellites on the Martian radiation environment. Science PI Zaharescu also organized several meetings to discuss the findings of the literature review and the subsequent selection of the radiation lamps and conditions with university experts and NASA scientists. Science PI Zaharescu also conducted an exhaustive literature review and compiled 15+ papers on plant use wavelengths that would

	be relevant to Mars for use in selecting lightning system components. Selection of relevant atmospheric Mars gas composition: Science PI Zaharescu conducted a thorough review of literature on Martian atmospheric compositions and compiled 20+ papers as a result. We selected an atmospheric composition that has a high-degree of similarity with the Martian atmosphere at Gale Crater. The Martian atmospheric composition of the SRGE environmental chamber will be composed of CO2, N2, Ar, O2, and CO. Science PI Zaharescu worked closely with the purchasing department to place orders for custom gas mixture tanks that will be used in the upcoming experiments. Abiotic Weathering and Plant Growth Experiments: The completion of the construction and testing of the SRGE environmental chambers is set for October 2023. The Science PI will be leading the preparation and implementation of the abiotic weathering and subsequent plant growth experiments for November-December 2023.
Bibliography Type:	Description: (Last Updated: 10/24/2024)
Abstracts for Journals and Proceedings	Zaharescu DG, Rodrigues J, Melotto M, Lybrand RA, et al. "How did plants walk the land and how can we use their strategy to walk on Mars?" Earth and Planetary Sciences Department Workshop, University of California, Davis. Abstracts. Earth and Planetary Sciences Department, University of California, Davis. , Apr-2023
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Abstracts for Journals and Proceedings	Rodrigues J., et al. "The soil, plant, and human continuum." Computational Bioscience Research Center Meeting, King Abdullah University of Science and Technology, Saudi Arabia. Abstracts. Computational Bioscience Research Center Meeting, King Abdullah University of Science and Technology, Saudi Arabia. , May-2023
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Abstracts for Journals and Proceedings	Zaharescu DG, Qafoku O, Ayala-Ortiz C, Tfaily MM, Bowden ME, Chu RK, Morris ML, Collins C, Melotto M, Mazza-Rodrigues J, Lybrand, RA. "Exploring the complexity of biological weathering with EMSL-based biogeochemical and mineralogical capabilities." Environmental Molecular Science Laboratory (EMSL) EMSL User Meeting 2023: Visualizing Chemical Processes Across the Environment. Pacific Northwest National Laboratory; Richland, WA. Abstracts. Environmental Molecular Science Laboratory (EMSL) EMSL User Meeting 2023: Visualizing Chemical Processes Across the Environment. Pacific Northwest National Laboratory; Richland, WA. , Oct-2023
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