Lunar Lettuce Production during Artemis III mission to the Moon's South Pole

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Introduction

The Artemis Science Plan identified that the infrastructure and resources associated during a human/robotic exploration mission can be used to conduct fundamental lunar science needed to mitigate the risks of human exploration of surface systems (i.e. Mars and the Moon). In particular, studying the response of life to the combination of fractional gravity and deep space radiation of the Moon is needed to mitigate the HEOMD risks to the crew that result from inadequate diets. Essential nutrients and vitamins available to astronauts have been shown to degrade within the stored food system during long duration missions. Other risks to exploration missions were isolation and confinement, distance from the Earth, radiation and partial gravity.

The Lunar Exploration Roadmap (version 1.3, 2016) identified several high priority science investigations to be carried out during human/robotic sortie missions to Moon's South Pole:

- Investigation-FF-A-2A: Test countermeasure technologies.
- Investigation-FF-A-1E: Perform long-duration testing of an integrated surface life support system.
- Investigation-Sci-D-13A: Study the effects of the lunar radiation environment and variable gravity on plants.
- Investigation-Sci-D-13B: Study the use of regolith as a growth medium for plants.
- Investigation-FF-A-1D: Test bioregenerative technologies.
- Investigation-Sci-D-13A: Study the effects of the lunar radiation environment and variable gravity on plants.

Justification for Science Goals

Fresh crops make essential nutrients and vitamins available to astronauts that have been shown to degrade within the stored food system during long duration missions [1]. Demonstrating crop production on the Moon can result in a major risk of reduced performance and illness to the crew that result from inadequate diets. In addition, anecdotal evidence suggests that incorporating plant cultivation into astronaut daily routines (i.e. Mark Kelly grew zinnias on the Veggie on ISS) may improve morale, which may improve crew performance during distant, isolated and confined missions. Future crop growth systems must be reliable, sustainable, and employ autonomous plant health and food safety monitoring systems to ensure that the food produced is suitable for human consumption [2, 3]. The state-of-the art crop production systems are Veggie and APH (while Ohalo III is being developed for Gateway) [4, 5, 6]. Thus, the proposed research is foundational and necessary for both the development of future crop production systems for Mars and to meet the demands of more extensive lunar operations.

Proposed Science Goals

Although seeds were germinated on the Moon during China's recent Chang'e 4 lunar lander mission, plant growth under the combined influence of the ionizing radiation and the partial gravity (1/6g) environment of the Moon has not been demonstrated.

The impact of ionizing radiation on crop plants remains a critical gap in spaceflight radiation research because short-term acute exposures do not mimic chronic low dosage exposures. The effects of ionizing radiation include reduced germination and seed viability as well as the potential for abnormal growth due to DNA damage [5]. Thus, an in situ demonstration is needed to validate the feasibility of crop production systems for supplying essential nutrients to crew diets in future exploration missions conducted in surface habitats.

We propose to grow a leafy green crop for an entire life cycle (7-30 days) using an autonomous plant growth system deployed in either a crewed habitat, or in a cargo ship, on the surface of the Moon. This demonstration will be the first example of a crop grown to maturity on a planetary surface, and the first American example of plants grown under the combined effects of deep space ionizing radiation and partial gravity.

The proposed system requires minimal or no crew intervention (initial unstowing and final disposal of the root module) if deployed on a lunar habitat. Alternatively, the system could be deployed in a cargo vehicle as long as a suitable supply of air and temperature is present. A multispectral imaging system will record plant growth and monitor plant stress and health using vegetation indices from daily images collected during the entire mission. Environmental data collected during the mission will be used for conducting a ground control. The performance of the lunar food production system will be compared to an identical experiment performed on Earth.

Methods: The proposed demonstration will consist of deploying a pre-planted crop growth system to either a crewed lunar habitat or a cargo ship on the Moon. The growth system will consist of a light bank, a self-contained root module, and an autonomous plant health monitoring system. The system will be designed to demonstrate the growth of a leafy green crop from germination to maturity (28 days), but could operate for shorter durations to accommodate payload/mission limitations. The self-contained root module houses a controller to power the light bank, operates the watering system, and collects plant health data - images. Once the experiment reaches the lunar surface, it will require: 1) experiment activation, 2) growth and image acquisition, and 3) biomass disposal. Data collection and teleoperation would be accomplished via telemetry and ground commanding capabilities. Since crew time is not required to meet science goals, the demonstration could be conducted if the payload is deployed in a cargo ship to the lunar surface, as long as environmental control and a suitable atmosphere are available.

Dimensions. The footprint of the 20-30 cm tall plant growth system can range from 0.05-0.1 m2. The plant growth system will rely on the air revitalization subsystem of the lunar habitat for supplying CO_2 to the plants, as well as temperature and humidity control. **Light bank**. A light bank requiring between 35-70 W provides a 16hr day/8hr night photoperiod and serve for illumination required for the plant health imaging system. **Self-Contained Root Module**. The root module will consist of light weight watering system composed of a pre-planted seed cassette, a water reservoir, and a pump. The root module will house a controller responsible for telemetry, for recording environmental sensors (i.e. CO_2 concentration, light level, etc), for operating the watering system, for controlling the light bank, and for operating the imaging system.

Acknowledgments:

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References:

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