COMPARING HYDROPONICS AND REGOLITH GRWOTH AND EVOLUTION (CHRGE). R. Loureiro[1], L.E. Fackrell[2], and A.G. Palmer[3,4], [1]Department of Biological Sciences-Winston-Salem State University, [2]Biotechnology and Planetary Protection Group, Jet Propulsion Lab, California Institute of Technology (laura.e.fackrell@jpl.nasa.gov), [3]Department of Ocean Engineering and Marine Sciences, [4]Department of Biomedical and Chemical Engineering and Sciences, Aldrin Space Institute - Florida Institute of Technology

Introduction: The development of bioregenerative life support systems is crucial for the sustainability of human habitats beyond Earth in the context of advancing deep space exploration [1-3]. These systems aim to produce fresh, nutrient-rich crops to support the dietary needs of space crews, contribute to oxygen production, and offer psychological benefits. This study examines and contrasts the effectiveness of hydroponic and regolith-based agricultural (RBA) systems in creating autonomous extraterrestrial habitats. Our investigation provides a detailed comparison in terms of growth performance, biomass accumulation, and operational efficiencies.

Materials and Methods: Morphological evaluations were executed via a destructive sampling methodology at five-day intervals throughout a thirty-day cultivation period. Parameters such as plant height, crown diameter, Specific Leaf Mass (SLM), Root Mass Fraction (RMF), Shoot Dry Mass (SDM), Root Dry Mass (RDM), and leaf area were measured during the testing period. Furthermore, stomatal conductance was quantitatively assessed thrice daily at predetermined times (06:00, 10:00, 14:00, and 18:00 hours). Concurrently, environmental variables, including $CO2$ concentration, relative humidity, and ambient temperature, were monitored hourly using a HOBO data logger within a precisely controlled environment chamber. Additionally, comprehensive quantification of energy and water consumption for both experimental systems were conducted hourly, encompassing all system interactions and setup durations.

Statistical analysis determined mean values and standard deviations for all measured parameters. The Shapiro-Wilk test was applied to the dataset to validate the assumption of a normal distribution. Given that all data conformed to a normal distribution, ANOVA was employed to identify significant differences between the means of the groups. Subsequent to the ANOVA, a Tukey's(HSD) test was used as a post hoc analysis to discern specific group differences.

Results and Discussion: Results indicate that hydroponically grown lettuce plants exhibit superior growth metrics, including an average plant height of 22.43 cm, root length of 14.66 cm, and shoot length of 7.85 cm, significantly outperforming their regolith-grown counterparts with means of 12.21 cm, 7.02 cm, and 5.45 cm, respectively (ANOVA $p<0.001$). Furthermore, hydroponic plants demonstrate a greater biomass yield, with a mean total weight of 4.42 g and a leaf area of 35.07 cm^2, indicative of an enhanced photosynthetic capacity.

Figure 1: Images of hydroponic (left) and regolith growth (right) lettuce plants.

Despite their smaller stature, regolith plants present a higher edible biomass ratio of 85.47% when compared to hydroponically grown plants (ANOVA $p<0.031$), suggesting a potential for greater nutritional efficiency. After a 30-day grow-out, operational analysis reveals that RBA systems require less time investment, totaling 736.15 minutes, compared to 949.24 minutes for hydroponic systems, suggesting a more efficient use of resources

The combined energy consumption and water usage also show that RBA is a more efficient management method than hydroponics. Stomatal conductance measurements further differentiate the two cultivation methods. Hydroponics exhibited enhanced gas exchange and potential photosynthetic activity, while regolith systems showed lower, more stable conductance values, indicating a more stressful environment for plant growth.

Conclusions and Future Work: Our comprehensive study advocates for a hybridized cultivation approach, integrating the growth efficiency of hydroponics with the resource optimization seen in RBA systems [4]. This strategy proposes a balanced and adaptable life support solution for future space exploration endeavors. Additional data to inform this approach is also expected with bioinformatic analysis of the metagenome comparing the microbiome in the hydroponic and regolith growth settings. Additional benefits in RBA approaches may also arise as validated methods to ameliorate regolith materials for plant growth are developed. Such advances in RBA must also include consideration for the resources, efforts, and risk required for the ameliorative process and comparisons to equivalent risk and resource requirements for hydroponic systems.

By customizing a hybrid model to suit the needs of different crops and balance the strength, weaknesses and costs of each approach, we can optimize sustainability and productivity, ensuring the viability and success of human activities in space.

References: [1] Wheeler, R. (2010) *Grav. and Space Bio. Bul., 23(2)*, 25-36. [2] Nelson, M. et al. (2008) Adv. Space Res., 41, 675-683. [3] Fackrell, et al. (2021) *White Paper submitted to BPS Decadal 2023-2032*. [4] Eichler, A. (2021) *Icarus, 354,* 114022.