A multidisciplinary modeling approach of plant gas exchange in reduced gravity environments

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ASGSR Abstract

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In-situ food production is a necessary step for human exploration of the solar system and requires a deep understanding of plant growth in reduced gravity environments. In particular, the lack of buoyancy-driven convection changes the gas exchange at the leaf surface, which decreases photosynthesis and transpiration rates, and ultimately biomass production. To understand the intricate relations between physical, chemical, and biochemical processes, the following methodology combines the development of a mechanistic model of plant growth in reduced gravity environments, computational fluid dynamics (CFD) simulations, and experiments in different time frames.

The model presented here is a coupled mass and energy balance using the single round leaf assumption, including gravity as an entry parameter, and the leaf surface temperature as an output variable. Measures of the leaf surface temperature using infra-red cameras allow for a computation of the transpiration rate. This approach was followed to design a parabolic flight experiment, which performed 7 flights, and enabled data collection for model validation in different gravity and ventilation settings on a short time frame. Current measures of carbon assimilation and transpiration rate at the leaf and canopy level using an infra-red gas analyzer (Li-6800) in 1g lab conditions on several species will enable a validation on longer time frames and further calibration of the model. CFD studies both on the parabolic flight and on the lab experimental set-up allow the precise assessment of ventilation above the canopy and plants' leaves.

Ultimately, this work will provide recommendations for the design of future plant growth hardware, especially on the lowest adequate ventilation for optimal plant growth in reduced gravity environments, as well as assessing biomass and oxygen production rates on planetary surfaces and space stations. This work was funded by CNES, CNRS, Clermont Auvergne Metropole, and NASA Space Biology through NASA postdoctoral program / USRA.