FLOW AND DISTRIBUTION OF FLUID PHASES THROUGH POROUS PLANT GROWTH MEDIA IN MICROGRAVITY


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NASA’s Advanced Life Support program believes that particulate solid substrates are best suited to meet its short and long term needs for plant growth during space flight. Due to mass, volume and power constraints, root modules are characterized by small volumes of growth media and high root density. These conditions leave little margin for error in control of water, air and nutrition. Results from plant growth experiments utilizing particulate growth media during space flight have demonstrated the difficulties associated with providing reliable reproducible air and water (and thus nutrients) supply to plant roots. This is attributed to the general lack of understanding of fundamental transport processes occurring in the growth media. The quantitative characterization of physical processes associated with the flow of wetting and non-wetting phase(s) in particulate plant growth media in microgravity is essential for the successful design and control of plant production systems during space flight.

At present we are in the initial phase of a comprehensive program of research that will employ some new advanced experimental, numerical and analytical techniques for examining flow and distribution of fluids in plant growth media. For example, Nuclear Magnetic Resonance Imaging (MRI) will provide a visual record of wetting front dynamics and gas diffusion in porous media. New mathematical models that account for adsorption and liquid films, discontinuous phases, effect of vibration, solitary ganglion, pore network behavior, air entrapment, and water retention characteristics will be developed and evaluated. Upscaling procedures will be employed to describe microscale phenomenon on scales relevant to root modules. Hydraulic conductivity and water retention characteristics are being experimentally verified under simulated microgravity conditions using terrestrial zero-g simulators such as manipulation of media depth and pore size distribution, or neutral density fluid pairs. The final conceptual model of water and air transport will be verified in 1 g by forward and inverse simulation on the root module scale using flight compatible measurement techniques. A significant component of using flight compatible measurement techniques will be a critical analysis of water content and matric potential sensors presently used or proposed for space flight. The research will result in a model and experimental methods that are ready for final validation in microgravity. The most recent results of experiments will be presented and discussed.