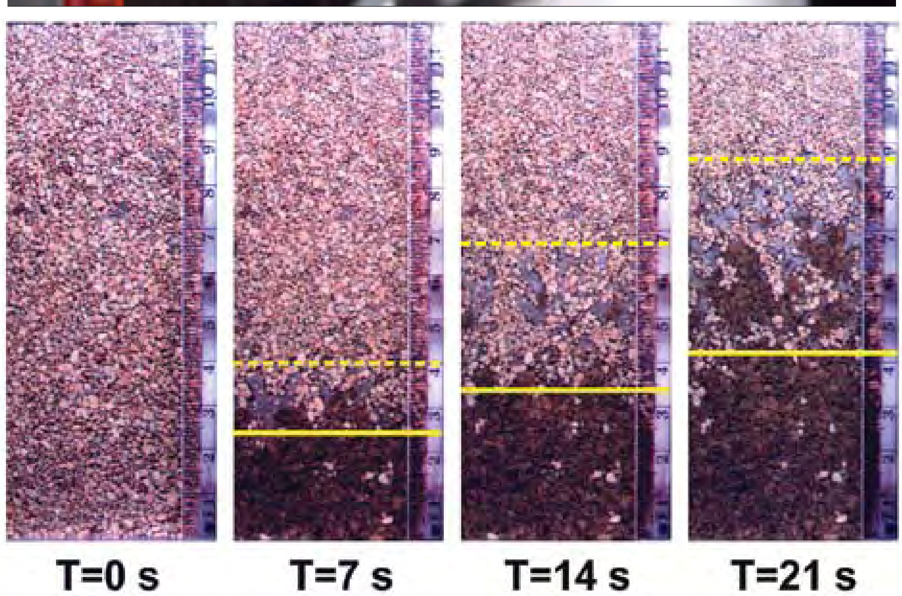
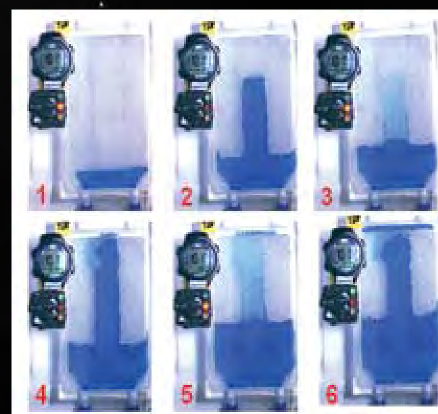
Uncovering the Challenges of Watering Plants in Space

Plants are an integral piece of future space exploration, providing food, oxygen, and psychological balance for astronauts. In trying to grow plants in space, researchers discovered that plant growth was stunted by reduced gas exchange rates to the roots. This happens on earth when plants are overwatered and roots become waterlogged. Under these conditions, roots can no longer exchange gases for respiration with the atmosphere as water blocks continuous air pathways. While potting soils on earth have been chosen to drain under earth's gravity, thereby avoiding water logging, under weightlessness conditions like those on the International Space Station, capillary forces retain water much like





TOP LEFT: Researchers Scott Jones (left) and Robert Heinse (right) monitor experiments in parabolic flight on NASA's C-9 aircraft. Conducting experiments in flight is no easy task; imagine trying to work during a roller coaster ride. BOTTOM LEFT: The series of images shows the wetting front advance in the absence of gravity leaving behind dry particles and entrapped air resulting in a destabilization of the wetting front without the draining effect of gravity. ABOVE: Phase entrapment in a micromodel containing two coarse particle regions (glass bead size of 2.4 mm) surrounded by finer-textured glass beads (0.9 mm). The series of images reflect flow behavior under cyclic gravitational conditions and the preferential flow in the finer pore space bypassing coarse inclusion and leading to air entrapment during imbibitions in the absence of gravity.

in a sponge. Therefore, maintaining plant health in the reduced-gravity environment requires new approaches to manage water and air in the root zone.

Watering plants in the absence of gravity is an enticing challenge that researchers at Utah State University in cooperation with the University of Arizona, the Universities Space Research Association, and the Ecole Polytechnique Federale de Lausanne in Switzerland are trying to address. The NASA-funded study applied principles of soil physics to understand the effects of reduced gravity on water in potting media. Results from the study are published in the November issue of the *Vadose Zone Journal*.

The pressing question is how does water configure itself in porous media without the draining effect of gravity? Parabolic flights aboard NASA's C-9 aircraft provided 20-second snapshots of reduced gravity. These brief snapshots enabled the measurement of the energy of water held in the porous media over a range of water contents. This key property, known as the soil-water retention function, provides a basis for the controlled watering of plants.

The study demonstrated similar water retention functions and hydraulic conductivities in reduced gravity when compared to earth-based results, which bodes well for applying earth-based porous media hydraulic models. However, more detailed measurements revealed an unexpected distribution of water. Robert Heinse and Scott Jones, who conducted the experiments, say this discovery suggests that highly localized nonuniform water contents may arise during the addition or removal of water, which may lead to potential problems with the oxygen supply to plants. According to the researchers, this phenomenon is a result of hysteresis inherent in the soil-water retention function, and further study is needed to determine the extent and longevity of this phenomena.

Research is ongoing at Utah State University in conjunction with the Space Dynamics Laboratory to investigate the distribution of water in microgravity on the International Space Station. Scientists are currently watching the progress of an experiment on the International Space Station conducted together with Russian scientists. Their efforts will facilitate the design of root modules for vigorous and reliable plant growth in space and for future manned travel to the Moon and Mars.

Heinse, R., S.B. Jones, S.L. Steinberg, M. Tuller, and D. Or. 2007. Measurements and modeling of variable gravity effects on water distribution and flow in unsaturated porous media. Vadose Zone J. 6:713–724. View the full article online at http://vzj.scijournals.org/content/vol6/issue4/