Soil moisture sensors used in space to develop crop production techniques

NASA has just landed its Perseverance rover on Mars but it will be some time before astronauts can visit the red planet. One challenge to overcome is how to keep astronauts nourished. Because vitamins and antioxidants in vegetables degrade over time, long-term missions will need fresh greens for the astronauts to eat. NASA is now funding research into growing crops in space.

Dr Oscar Monje, a research scientist at NASA's Kennedy Space Center in Florida, says, "Growing plants in a space station is challenging because both space and power are limited. All the plant chambers built in the past 40 years focused on enabling space biology studies that cantered on how to grow plants in space. But now we want to focus on space crop production."

Monje was a student of Dr Bruce Bugbee at Utah State University, who studies plants in space for bioregenerative life support systems. He started at Kennedy in 1998 researching how to grow wheat in space in the PESTO (Photosynthesis Experiment and System Testing Operations) Experiment. Dr Gary Stutte, the principal investigator, and Dr Monje grew wheat in the Biomass Production System (BPS), a four-chamber system that consumed 280 W of power.

Monje says, “Back then, all experiments were shuttle experiments (7-11 days). The PESTO Experiment flew for 73 days in space and was essentially several shuttle missions conducted back-to-back. We learned that as long as you provide plants with adequate root zone aeration, good soil moisture, and the right light and CO_2, they grow normally with no visible plant stress—just like on earth. The BPS was a precursor of the Advanced Plant Habitat (APH) facility on the International Space Station, an environmentally controlled growth chamber for both fundamental and applied plant research experiments lasting up to 135 days.

Ten years ago, NASA developed two large area (0.2 m^2) crop production systems to grow fresh salad crops for astronauts to eat: the ‘Veggie’ and the ‘APH’. Monje says, “Veggie is open to the cabin so there is no environmental control of CO_2 or temperature, and it is watered by the crew. The light level provided by LEDs is moderate and the environment is not monitored. With the APH, you can load experiment profiles from the ground that control the light level, the spectral quality, the CO_2 concentration, photoperiod of light and root zone moisture. The APH can be monitored in near-real time with minimal crew intervention for weeks at a time.”

The 5 cm tall APH root zone is divided into four independently controlled root modules, called quadrants. In each quadrant, media moisture is controlled based on matric potential using a pressure sensor. However, this does not capture vertical variations in volumetric moisture. Monje says, “Each quadrant is watered with a porous tube system that distributes water throughout the porous media that is mixed with slow-release fertilizer. In the 5 cm tall root zone at one g, most of the water is ponded at the bottom, and the top layer of media where the plants are germinating can become too dry. For these reasons, two small, rugged volumetric EC-5 moisture sensors, manufactured by METER Group, were added to each quadrant to monitor moisture redistribution phenomena in microgravity. These sensors are insensitive to salinity and temperature effects. When watering in space, moisture redistribution occurs because capillary forces in microgravity distribute water evenly across the substrate and affect aeration.

“If you don’t water plants enough, they don’t grow fast enough, but if you give them too much water, then you inhibit O_2 supply to roots and nutrient uptake. So, we’re

using volumetric water content sensors in the APH root module at different levels to control the moisture.”

Readying crop growth systems for a crewed mission to Mars will need more time. Meanwhile, the Moon is a new proving ground for these technologies and deploying experiments on the Moon brings it sown challenges in terms of temperature, radiation, and partial-gravity.

Labcell is the sole UK distributor for METER Group’s volumetric water content sensors and has demonstration instruments available. For more email us on mail@labcell.com or call +44 (0)1420 568150.