NASA STTR 2021 Phase I Solicitation

T6.07 Space Exploration Plant Growth

Lead Center: KSC

Participating Center(s): ARC, JSC

Scope Title:

Remote Sensing Technologies for Monitoring Plants

Scope Description:

Plant (crop) systems envisioned for future space travel could provide supplemental fresh food for the human crews during early missionsÂ and increased amounts of food along with oxygen and carbon dioxideÂ removal for future longer-term missions.Â This latter concept has been referred to as bioregenerative life support.Â To do this will require controlled environments for growing the crops, perhaps using techniques similar to recirculating hydroponics used on Earth.Â But this will require careful monitoring of the environment and the plants themselves to assess their health and performance.Â In addition, crew time will likely be limited in many space settings, so having the monitoring systems operate autonomously or with little human intervention would be beneficial.

This subtopic solicits advanced technologies for remotely sensing the status of plants in controlled environments of space. These environments are typically small in volume, often use narrow band lighting from light-emittingÂ diodes (LEDs), and are subject to reduced gravity.Â Example methods might include multispectral andÂ hyperspectral sensing of crops, use of bio-indicators in the crops themselves, or other innovative, noninvasive means.Â Technologies could focus on approaches for (1) monitoring the morphology and growth of plantsÂ and possibly standing biomassÂ and/or (2) monitoring stress to the plants, including water stress, nutrient stress, and plant pathogens.Â Sensing of volatile compounds produced by the plants is not solicited for this subtopic.Â *Â*

Expected TRL or TRL Range at completion of the Project:Â 3 to 5Â
Primary Technology Taxonomy:Â
Level 1: TX 08 Sensors and InstrumentsÂ
Level 2: TX 08.3 In-Situ Instruments/Sensor**Â**
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware

Desired Deliverables Description:

Phase I Deliverablesâ€”Reports demonstrating proof of concept, including test data from proof-of-concept studies, and concepts and approaches for Phase II. Phase I tasks should answer critical questions focused on reducing development risk prior to entering Phase II.

`. Identification of microbes of interest from literature accounts or current experimentation from existing libraries, including Veggie or the International Space Station (ISS).
a. Obtain full genomic profiling to scan for unfavorable genomic components and triage candidates for beneficial effects.

Phase II Deliverablesâ€”Delivery of isolated microorganisms and/or microbial communities for testing on candidate crops. Preliminary assessment on the safety for use with food crops should be included. Scientific publications and presentations at relevant professional societies.

`. Apply to candidate crop seedlings and conduct growth evaluations.
a. Assess growth and metabolite content of treated crops.
b. Perform toxicity and biofilm tests for candidate microbes both in isolation and in combination. Toxicity screen will be against relevant human cell lines.

State of the Art and Critical Gaps:

NASAâ€™s Advanced Plant Habitat (APH) growth chamber on the International Space Station (ISS) provides a controlled environment with about 0.2 m^{2Â} growing area.Â Within the APH, environmental control includes light from LEDs, temperature, humidity, and carbon dioxideÂ concentration, along with water delivery to a solid medium used to support root systems.Â The APH is used primarily for plant research on the ISS, and the environmental parameters are logged regularly. Plants in the APH chamber can be monitored with visible imagery and infrared sensing for canopy temperatures.Â The APH is closed atmospherically to allow condensate recovery and water recycling and to also track plant carbon dioxideÂ uptake and evapotranspiration.Â Larger plant chambers used for crop production on future missions would build on these capabilities, but may or may not be atmospherically closed to the crew cabin.

Relevance / Science Traceability:

This technology could be proven on the ISS and would be useful to long-duration human exploration missions, including Gateway, lunar surface, and Mars, including surface and transit.Â This subtopic is directed at needs identified by the Life Support and Habitation Systems Capability Leadership Team (CLT) in areas of in situ production of fresh foods.

References:

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Scope Title:

Biopriming of Plant Microbiome to Promote Crop Health and Growth

Scope Description:

This subtopic solicits advanced technologies for identifying, selecting, developing, or designing microbes that can promote plant growth in controlled environment crop production systems for space.Â In the terrestrial environment, the microbiome of the roots (rhizosphere) and the above ground plant (phyllosphere) act as a genetic extension of the plant. The rhizosphere consortia metabolizes precursor compounds that can be further metabolized by the plants and in turn promote growth. This consortia can also produce secondary metabolites that exhibit antimicrobial activity and further protect the plant. Currently, space-bound seeds are surface sterilized, and growth substrates are sterilized, which does away with most microbially conferred advantagesâ€”think of a human without its own healthy gut microbes. Therefore, NASA is interested in tailoring a rhizosphere for space crops and â€œbioprimingâ€ plant seeds with a beneficial, probiotic microbial assemblage that is amenable to containment and presents no human health risk. Approaches should consider one or a fewÂ organisms that have demonstrated beneficial effects on crops rather than whole communities.Â These organisms could be applied to seeds or be transferred endophytically (inside the seed or plant material).Â Crops for these systems would be grown hydroponically or in solid media watered with nutrient solution, or using water along with controlled-release fertilizer. As examples, microbes that confer resistance to stresses such as root zone hypoxia, root zone drought stress, and plant pathogens could be considered.Â Target crops should focus on leafy greens, such as lettuce, leafy Brassica species, leafy Chenopod species, or small fruiting crops such as pepper and tomato. The ability to put organisms into stasis and then reactivate them in a relevant, operational mode should be considered.

Expected TRL or TRL Range at completion of the Project:Â 1 to 3Â
Primary Technology Taxonomy:Â
Level 1: TX 06 Human Health, Life Support, and Habitation SystemsÂ
Level 2: TX 06.3 Human Health and PerformanceÂ
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis

Desired Deliverables Description:

Phase I Deliverablesâ€”Reports demonstrating proof of concept, including test data from proof-of-concept studies, and concepts and approaches for Phase II. Phase I tasks should answer critical questions focused on reducing development risk prior to entering Phase II.

a. Identification of microbes of interest from literature accounts or current experimentation from existing libraries, including Veggie or the International Space Station (ISS).

b. Obtain full genomic profiling to scan for unfavorable genomic components and triage candidates for beneficial effects.

Phase II Deliverablesâ€”Delivery of isolated microorganisms and/or microbial communities for testing on candidate crops.Â Preliminary assessment on the safety for use with food crops should be included.Â Scientific publications and presentations at relevant professional societies.

a. Apply to candidate crop seedlings and conduct growth evaluations.

b. Assess growth and metabolite content of treated crops.

c. Perform toxicity and biofilm tests for candidate microbes both in isolation and in combination. Toxicity screen will be against relevant human cell lines.

State of the Art and Critical Gaps:

NASAâ€™s Advanced Plant Habitat (APH) and Veggie plant growth chambers on the ISS provide controlled environments with about 0.2 m^{2}Â growing area.Â Plants are grown in a solid medium (arcillite or calcined clay) that is sterilized prior to launch, and plants are typically propagated using surface sterilized seeds.Â But neither system is sterile in its operationsÂ and are open to the cabin environment (Veggie) or occasionally opened and accessed by the crew for horticultural operations (APH).Â For one Veggie study, a Fusarium fungus was noted growing on zinnia plants, likely due to a malfunction in the air circulation resulting in very high humidity.Â Similar environmental anomalies (environmental control failures, too little or too much water in the root zone, nutrient stress) can occur in any controlled environment, including those envisioned for future space crop production systems.Â Having a microbiome that can confer resistance to such perturbations and generally promote healthier growth can reduce the risk of crop failures for these systems. Biocontainment measures are not typically required for probiotic consortia in field settings, but may be an issue in confined environments of space. Introducing a tailored microbiome into a controlled environment such as Veggie aboard the ISS will undoubtedly rule out classes of microbes due to their propensity to become opportunistic pathogens. Therefore, there is a large knowledge gap when it comes to the types of strains that will be beneficial for crop production not only in space, but in closed environments.Â Storage and handling of these tailored microbiomes for long-duration space exploration also presents a unique challenge.

Relevance / Science Traceability:

This technology could be proven on the ISS and would be useful to long-duration human exploration missions, including Gateway, lunar surface, and Mars, including surface and transit.Â This subtopic is directed at needs identified by the Life Support and Habitation Systems Capability Leadership Team (CLT) in areas of in situ production of fresh foods. The research is also applicable to the rapidly expanding controlled environment agriculture (CEA) industry on Earth.

References:

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