***How space farming can contribute to the terrestrial agriculture?***

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Agriculture has been practiced by humans for centuries and when one considers space exploration, it’s logical to assume agriculture will follow. Crops could be used to produce food, oxygen, and remove carbon dioxide for human life support. Because of the harsh environments in space, this agriculture would need to be in controlled environments, similar to what is used in greenhouses, plant factories, or vertical farms on Earth.

Space missions are always constrained by mass, power, and volume. Mass to grow crops in space includes things like water, fertilizer, trays, troughs, pumps, lighting hardware, spare parts, and so forth. Power needs are driven largely by electric lighting systems, air circulation, and thermal management, which is equivalent to HVAC systems on Earth. Volume constraints will force efficient spacing of plants and their support hardware. In low-Earth orbit and transit missions to Mars, we must also deal with weightlessness, and this creates a separate set of engineering challenges. But for surface settings like the Moon or Mars, there will be fractional gravity that can help with water flow.

Plants continuously need water and nutrients, so concepts like recirculating hydroponics fit well for space. Of course, hydroponics been used for years on Earth but NASA extended hydroponic testing to agronomic crops like wheat, rice, soybean, potato, peanut, and sweetpotato. By using hydroponics to eliminate water and nutrient stress, along with giving the plants high light intensities, NASA researchers surpassed world record yields reported from field settings for wheat and potatoes, showing there is still untapped potential for many crops. NASA’s approach for growing potatoes in nutrient film hydroponics is now being used in the “seed” potato industry, where it is important to grow disease-free seed potatoes.

Electric lighting and its associated cooling typically drive the power requirements for controlled environment grown crops. In 1990, NASA researchers at the University of Wisconsin explored and patented the concept of using light emitting diodes (LEDs) for growing plants. LEDs had many advantages for space and their electrical efficiencies have improved remarkably over the past 10-15 years. Nowadays, LEDs are used around the world for plant lighting systems in vertical farms, plant factories, and even smaller plant growth chambers, like the Astroculture chamber where they were first tested on the Space Shuttle.

Volume constraints of space forced NASA to come up with ideas to grow as many plants in a fixed volume as possible. This led to the design of the Biomass Production Chamber (BPC) in the mid 1980s NASA’s Kennedy Space Center. The BPC supported multiple shelves of hydroponic trays and electric light banks that could be stacked efficiently in a fixed volume. Unbeknownst to our group at the time, this was probably the first working example of a vertical farm, and operated from 1987 to 2000. The atmosphere for the chamber was tightly closed, as would be needed for space, and this allowed capturing condensed humidity to recycle the water back to the plants. This practice of capturing condensed humidity is also expanding terrestrially to get maximum use of the water. The atmospheric closure also allowed direct measurements of crop photosynthetic rates and hence overall growth.

To reduce fertilizer needs, NASA used stirred tank bioreactors, composting, and other approaches to recover nutrients from the inedible biomass (e.g., leaves and stems) to grow more plants. In one study, successive generations of potatoes were grown in hydroponics (NFT) using recycled nutrients for over 400 days. To recover even more nutrients, especially nitrogen, NASA tested (and continues to test) bioreactors for processing urine. Even after you process things like inedible leaves and stems, you still have left over cellulosic biomass. NASA and other space groups viewed as a resource for feeding secondary organisms like Tilapia fish, fungi (mushrooms), and insects, which in turn can increase the overall production of food for humans on long duration space missions.

These concepts for reducing energy costs, recycling water and nutrients, and use of volume efficient growing approaches all fit well with the current interest in sustainable living on Earth. Earth might be considered a big spaceship with large resources and buffers, but with increasing population around the planet, we are now seeing that these resources are finite and must be conserved and recycled, just as in space craft and space settlements on other planets. As we learn more about sustainable living in space, we will learn more about sustainable living on Earth, and vice versa.

Further Reading

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