HydroFuge Growth Chamber

Flight Days: April 7th, 8th

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Goal: To create a unique, functional plant growth chamber using centrifugal technology to produce an ideal environment for vegetation under microgravity conditions.

Objectives

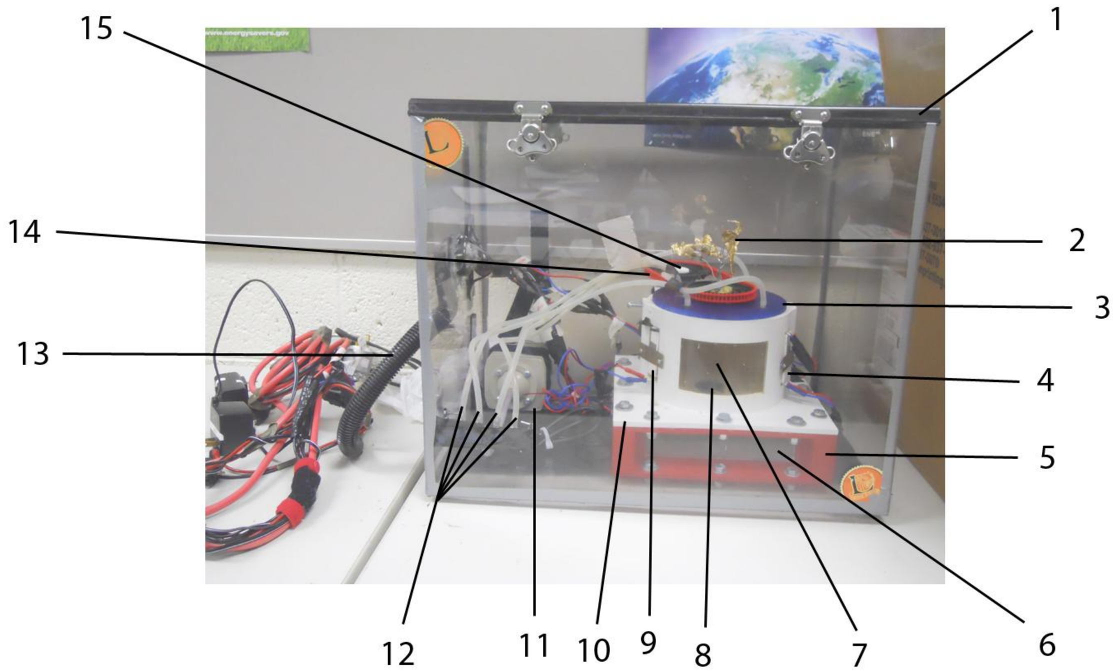
- A common problem in space is that the water retention on the roots and lack of gravity prevents the water from dripping off, causing the plants to drown or develop disease such as Root Rot. The main project objective was to develop a solution to this issue. Testing Tiny Tim Tomatoes, the chamber used a centrifuge to flick the water off of the roots, while simultaneously simulating gravity through the forces of inertia.
- The Zero-G flight objectives were to find the optimum speed for the centrifuge spinning the entire plant and to observe the system functionality (including water tank, micropump, motor, aerator and distributor, and control panel).
- Ultimately, we plan to provide alternative, fresh food sources for astronauts in space as well as evaluate the psychological benefits of flora in a sterile environment. We hope to actualize this concept through a Personal Plant Growth Chamber (PPC) for astronauts.

Methods and Materials

- Our system, HydroFuge, is based on the concept of aeroponics, a plant system that suspends a plant in air and sprays the roots with a nutrient/water solution. The chamber is comprised of numerous parts. The plant is rotated by a bearing spun by a motor and adjustable chain functions as a centrifuge. The roots hang inside the water-tight chamber, where a mister sprays the roots. Once there is water on the roots, the centrifuge spins the plant and flicks the water from the roots to the sides of the plant chamber. An aerator pumps air through the air distributor, into the chamber, forcing the water down the sides of chamber and sloped surface of the chamber through a check-valve. The water then goes into a sealed water chamber to be recycled by the micropump sending water to the mister.
- The system is contained inside a 2x3x3 foot Lexan box placed inside a NASA Reduced Gravity Office Glove Box to provide the required double containment. The primary system parts (centrifuge container with root chamber and water chamber) were printed in

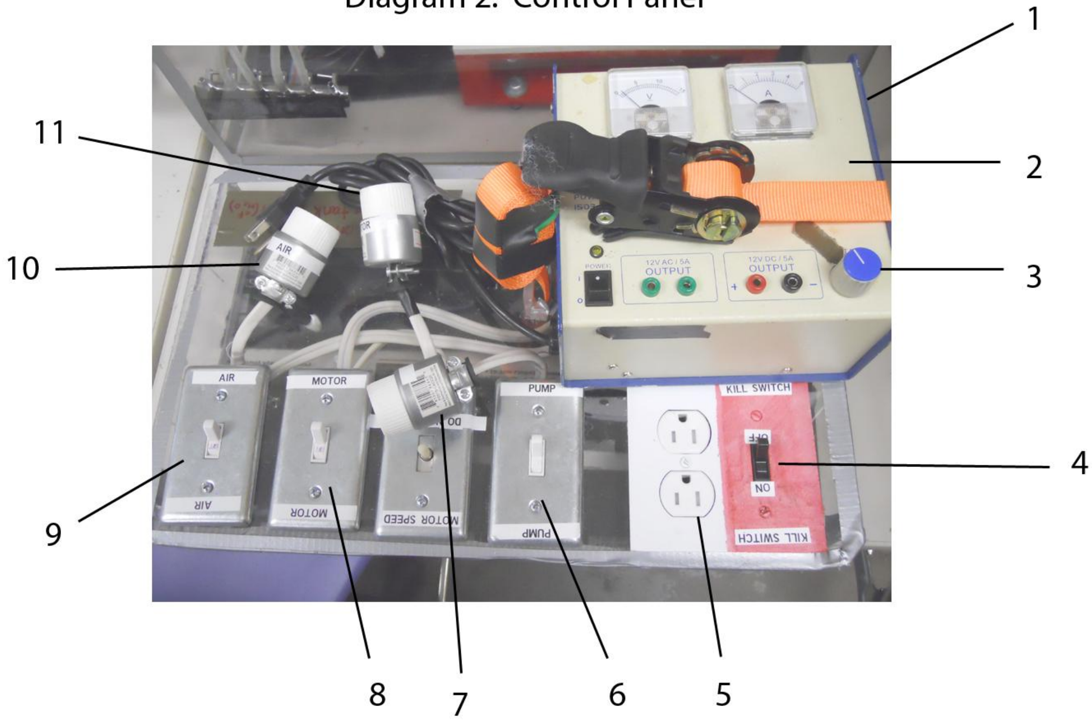
a Dimension 3D printer out of ABS plastic. The two parts were then sealed with silicone caulk and bolted together using 12, 5/16” zinc-plated, hex head bolts. The plant was placed inside a sealed, steel bearing. The steel bearing was spun by an ABS chain controlled by a motor. The aerator, placed inside the Lexan box outside of the actual system was an ActiveAqua air pump. Vinyl plastic tubes were attached to the aerator and led to holes in the top chamber into the root chamber to distribute air in order to push the flicked water back into the water chamber. Windows were installed in the root chamber and water chamber to allow for observations during the flight. These were made out of sheets of polyurethane that were then silicone caulk-sealed. LED lights (1.5”x.5”) were also installed on both the root and water chambers to make the specimen more visible during the experiment. A mister with a nozzle was installed in the bottom of the root chamber to mist the roots. A 2-inch ABS plastic check-valve was fitted in the bottom center of the root chamber to send through the valve into the chamber. In the water chamber, a submersible-micropump was secured to the bottom using Velcro. The 14mmx14mmx28mm pump ran on 12 V DC power and pumped 250 mL a minute. The entire system was managed from the control panel, attached to the floor of the plane using Velcro. The structure of the control panel was created out of Lexan, with labeled switches made out of metal light-switch wall panels for the lights, micropump, aerator, and kill switch, and a dimmer switch for the motor to control the centrifuge’s speed.

Diagram 1. HydroFuge Experiment



1) Lexan box
2) Plant in bearing
3) Air distributing chamber cap
4) LED light
5) Water tank
6) Submersible pump
7) Mister
8) Check-valve
9) LED light
10) Plant root chamber
11) Aerator
12) Air tubes
13) Wire harness
14) Adjustable chain
15) Rotating gears

Diagram 2. Control Panel



1) Panel power supply plug (behind)
2) Motor power supply
3) Motor speed adjustment
4) Kill switch
5) LED lights outlet
6) Pump power switch
7) Pump outlet
8) Motor power switch
9) Aerator power switch
10) Aerator outlet
11) Motor outlet

Results

System/Part	*Function of System*	*Appearance*	*Efficiency*	*Errors*	*Needed Changes*
Plants	Plants are spun in centrifuge and water tension on the roots is observed	Top half of plant visible through Lexan box and roots visible through root chamber window. Roots looked tangled and clumped.	Flight Day 1, plant was inefficient because of size and root length (became tangled, broke, and ruined the micropump). Flight Day 2 proved more efficient with a smaller plant	Roots too long; plant height limited by space-restrictions	Solution for plant roots such as a pump filtration system; more versatility for varying plant sizes
Water Removal (Aerator & Distributor)	The aerator and distributor forces the water from the sides of the chamber to the bottom through the check-valve to recycle the water	Air distributing tubes floated around the Lexan box	Water removal worked but was not efficient because there was not enough pressure to remove all of the water	Better secure the air distributing tubes so they do not interfere with the plant	Air pump with a higher pressure; elimination of/better securing of distribution tubes in microgravity
Water/Watering system (micropump & mister)	Water is kept in the water chamber where it is pumped through the micropump to a mister to water the plant roots, and then recycled back into the chamber	Water was dyed green with food coloring for visibility and the system remained water sealed for the duration of the experiment. The water formed what appeared to be a large bubble under microgravity.	Water mister and micropump did their job but did not efficiently water the plant	Due to microgravity and complications, the pump and mister produced globs of water much of the time	Pump filtration system is necessary; pump with a higher pressure should be used in future

Centrifuge	Swiftly rotates the entire plant to remove water from the roots in microgravity	Spun smoothly at each speed variance	Very efficient, needed little force to flick all of the water off roots	Because of complications with the pump and time spent fixing it, flyers were unable to find the exact optimum speed. However, it was discovered that the speed is much less than we originally thought, and in the first day flight, the plant was damaged by the speed of the spinning	Lower speeds will be used to flick water off of the plant. In terms of functionality, the centrifuge worked as hypothesized
Control Panel	Contains all of the switches for manual control of each part of the system as well as the emergency kill switch	Located on the outside of the glove box, attached to the floor with Velcro	Very efficient, was easy to use	Under the 2-G force, the Lexan of the control panel was not built in a way that was sturdy enough to withstand both days of flight. As such, it cracked	Use a stronger material with a more durable design for future trials

Discussion

Challenges

There were numerous unanticipated challenges that arose during the flight. The most pressing issue was the lack of a filtration system for the micropump. On the first flight day while testing a plant at a higher speed, the roots were too long and became caught in the check-valve, severing the roots and polluting the water with root particles. This matter clogged the micropump and resulted in the malfunction of the misting system, and thus, making it difficult to perform the experiment. On the same flight, the air distributor tubes detached from their secured places on the exterior of the plant chamber, and then became tangled with the tall, spinning, tomato sprout.

The result was a decapitated tomato plant. Furthermore, neither the aerator nor the micropump were strong enough to perform their tasks efficiently. The aerator distributed the air but the pressure was not high enough to force all of the water in the root chamber through the check-valve. The micropump, even after it was replaced for the second flight, did not have enough pressure to mist the plant proficiently. On some trials, the water from the mister would glob due to lack of pressure or an obstruction of water flow, as opposed to a forceful dispersion of the solution as seen on trials under gravity.

Successes

Despite the numerous challenges the team experienced, overall the experiment was a great success and provided numerous concepts for future innovation. Conceptually and in terms of overall functionality, the system worked as we had hoped. Using centrifugal force was determined to be an efficient solution to the original problem of removing excess water from the plant roots. Other successes include the LED lights were excellent in making the observation and video documentation of the experiment very clear, as well as the control panel's simplicity and usability. The team also considers the challenges successes, because with the knowledge that was gained, we can innovate a better system that can perhaps be used in space in the future. After talking with numerous astronauts such as James Voss and Dorothy Metcalf-Lindenburger, it was determined that astronauts in space would love to be able to take care of plants and possibly have a fresh food source. As such, from the information gathered from these flights, the team is considering taking the project in the direction of a Personal Plant Growth Chamber (PPC) for astronauts on future ISS flights.

Conclusion

The experience we had on the Zero Gravity Plane was certainly enlightening as to what is realistic concerning our experiment and what is not. We learned that plant size is integral to the success of the experiment, as a plant that is too large interferes with the operation of all of the components of the system. It was especially problematic when the roots got caught in the check-valve at the bottom of the reservoir because little pieces were severed and got sucked up into the micropump. The micropump was another problem we encountered. Although it was neat that such a small pump had so much power, it wasn't enough power for what we needed it to do, especially because we had enough space in our Lexan box to have a bigger and stronger pump. We also needed a filter to ensure that no particles got sucked into the pump. We also learned that we needed a stronger source of air to push the water off the walls of the chamber, as the aerator was ineffective in microgravity.

The outreach items we chose to use primarily were a slinky, a foam dart gun, and small foam gliders. The gliders were interesting to observe with the lack of resistance, especially because they were not very effective on the ground with full gravity. The foam dart gun had a similar effect as the gliders. The slinky was also interesting due to the way it compressed and reacted when moved without the presence of gravity.

Acknowledgments

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We would like to express our gratitude to the Reduced Gravity Office and the HUNCH program for this amazing opportunity. We sincerely appreciate the support in producing, conducting, and adapting our experiment, as we work to make a Personal Plant Chamber.