Designing and Assessing a Vertical Hydroponic Garden

Growing Plants in Space

Background Information

There's no question about it — plants are vital to our very existence. They provide us with food, oxygen, and shelter. But have you ever stopped to think about how these benefits would translate beyond our planet?

Plants provide:

Food

Currently NASA compares its food system for astronauts to a picnic because space travelers must pack everything they consume. Their meals include few if any fresh fruits and vegetables due to limited room and rapid spoilage. But as we use the International Space Station, and someday have an outpost on the moon and colonies on Mars, we'll need a renewable food source that will be more economical than "packing groceries." Besides, fresh produce provides nutrients, flavor, texture, and variety to meals that break the monotony of packaged foods.

Air

Plants use carbon dioxide (CO2, produced by astronauts) and produce oxygen (O2, consumed by astronauts) through the process of photosynthesis. They also remove chemical pollutants from the air. Plants would improve the air quality inside spacecraft.

Water Purification

It costs about $22,000 per kilogram to ship objects into space! This makes water a very expensive commodity, so creating a way to reuse water would be very beneficial. Plants can play a role because they produce pure water in the process of transpiration. Scientists are developing techniques to irrigate plants with wastewater— such as that from washing — and then recapture the purified water given off during transpiration.

Waste Recycling

Scientists are also investigating ways to recycle human waste and inedible plant matter to provide nutrients for plants. This is an important element for creating a self-contained ecosystem.

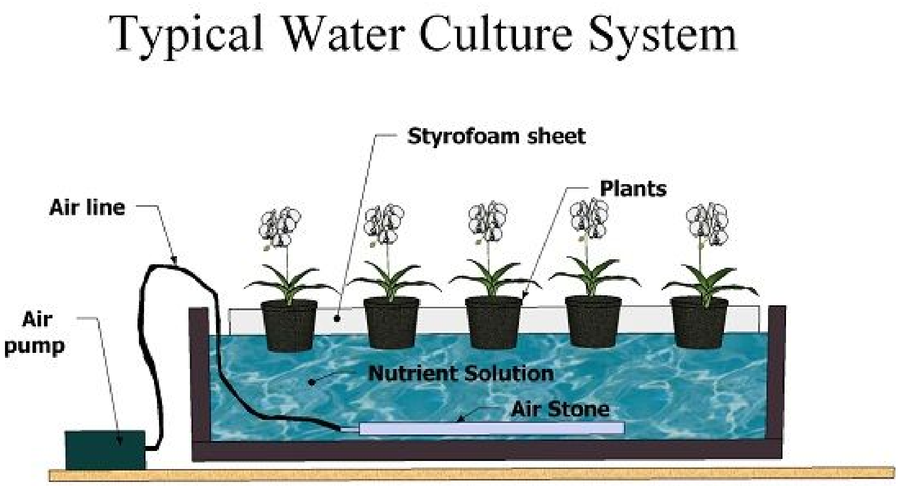
Table A: Think About It

Consider some of the difficulties astronauts face when trying to accommodate plants with the things they need to grow. You may use your lab partners or your favorite search engine to aid in your responses. Water has been completed as an example.

Plant Need	Importance to Plants	Difficulty in Space
Water	It is a reactant for photosynthesis. It carries nutrients from growing media into the plant. Transpiration (water loss through stomata) allows for circulation.	There is no water cycle in space. It is very expensive to send heavy materials into space.
Air		
Light		
Medium and Nutrients (N, P, K, Ca, Mg, Fe)		

Your mission:

Design and build a DWC system that can accommodate two or more plant species.



Basic Materials:

- Nutrient reservoir (size of your choosing)
- Lid or acrylic sheet to support net cups
- Lightweight Growing Medium (hydroton and rockwool)
- Air pump, airline tubing, check valves, and air stones
- You may add to this list as your design calls for

Your Building Plan: Deep Water Culture FAQ

DWC System Design Considerations

** The key here is to embrace the spirit of STEAM and focus on upcycling and repurposing materials. Research for your design is encouraged as you will find there is a wide spectrum of possibilities for creating this type of system. You are also encouraged to sketch and label your design and then evaluate it in Table B on the following page before building it.

Table B: Evaluate it

Consider the plant needs from Table A. Using your knowledge of plant anatomy, explain what part of the plant is responsible for acquiring the needed resources from the environment in Column A. Next, discuss what components of the hydroponic setup will allow for the acquisition of these materials in an extraterrestrial growing location in Column B.

Plant Need	Part of Plant Anatomy Responsible	Hydroponic/Classroom Resource
Water		
Air		
Light		
Nutrients		
Medium	This will be some variety of traditional soil.	

Record Data:

Use the table below to record system data to compare your design to traditional soil. Make copies of page 5 as needed to complete your research.

Date:	Hydroponic System	Soil
Temperature		
pH		
# of Leaves		
Plant Height		
Volume of water used to date		
Corrective Actions Taken		

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Data Analysis:

Use the data you collected to compare the success of your design to that of traditional growing, the designs of others, and the larger classroom system.

1. Create line graphs that allow you to visualize the data patterns for temperature, pH, plant height, and leaf numbers. Each graph should have the date of recording on the x-axis as well as a key that identifies the data for your design and soil. Be sure to include appropriate titles and axis labels with units.

2. Based on your results from your line graphs, which growing method appeared to be the most stable in terms of temperature and pH? Why do you feel this was so?

3. Based on your results from your line graphs, which growing method was most successful in terms of supporting a plant?

4. Which of the growing methods were the most efficient in terms of water usage? Use quantitative data to justify your response.

5. Compare your data analysis to that of your classmates. Share your results on FlipGrid and compare them to what others are reporting.

6. What flaws do you feel were a part of your design? If you were to redesign your growing system, what accommodations would you make to account for these errors?

Going Further:

Throughout the course of your experiment, you kept records of water usage and the amount of energy used by your system. In this section, you will evaluate the efficiency and cost of vertical hydroponics.

Calculate the cost of your hydroponic system.

You will need to know the kilowatt hours that your system has used. You may have get this number from your instructor or read it from the kill-a-watt system. Before we see how much electricity costs, we have to understand how it's measured. When you buy gas they charge you by the gallon. When you buy electricity they charge you by the kilowatt-hour (kWh). When you use 1000 watts for 1 hour, that's a kilowatt-hour To find the approximate costs of electricity you need to know 3 pieces of information :

1. The amount of kilowatt hours that have been used
2. The time over which your measurement occurred
3. The cost of electricity (ie. in Massachusetts it is $.15 per kilowatt-hour, on average)

What uses electricity on your system?

You need to figure out the TOTAL electricity use for your system. To do this you need to measure EVERYTHING that uses electricity. So what uses electricity on your system?

1. The pump for the air
2. The lights for system
3. Anything that moves, lights, beeps, buzzes that is associate with your system

To determine the cost of electricity

1. Plug in the Kill-a-Watt to your system or whatever it is that you wish to measure in terms of electricity use
2. Push the Red button to read kwh. If you push the button again you will the see the time (how long the meter has been measuring electricity use)
3. Now you are recording data!!!!

To get the cost of electricity do the following steps

1. Multiply the number of kilowatts and cost of a kilowatt hour
2. Divide the result by the recording time (so if you had the kill-a-watt plugged in for 20 minutes) your formula will look like

(Number of kWh used * $.1471) / 20 minutes

If your system used .1 kWh the costs per minute will be

(0.1kw-hr * .1471 cents/kWh) / 20 minutes = **.00074 cents/minute**

That doesn't seem like much does it? But you have to figure it out per hour and day and per crop. To determine the money spent per hour you will need to multiply by 60 (60 minutes in an hour). Your final formula is

((Number of kWh used * Cost of kWh) / time (minutes))* 60

For a system that uses .1 kWh the total cost per hour is

.00074 * 60 = **.044 cents/hour**

To run that system for 24 hours (all day) the total cost would be

Total cost for one day = .044 cents / hours * 24 hours = **$1.06**

For 365 days a year the total cost would be

Total cost for the year = $1.06 * 365 = **$386.90**

How much does my system really cost per crop?

Now that we know how much our system costs per hour we can figure out how much it costs per crop? So what do you need to know to figure out how much it costs to grow your crop? Well, you need:

1. What kind of plants are you growing?
2. How many plants are you growing?
3. How long will it take them to grow to harvest?

Once you have answers to the above questions it is possible to determine how much electricity it costs per plant. Assume you have a system that has 24 plants and you are growing leaf lettuce. Typically leaf lettuce will be able to harvest approximately 6 weeks after transplanting in your system. From before, we figured out that it cost $1.06/day to operate the lights. So for 6 weeks that means you have 42 days that the light has to be on. So the total cost of operation is

Total costs for 24 lettuce plants = 42 days * $1.06 / day = **$44.52**

The formula for cost per plant is

The total electricity cost for the systems / the number of plants

In this case the total cost per plant is

$44.52 / 24 = **$1.86**