HYDROPONICS DESIGN RESEARCH

Introduction to Hydroponic systems Design

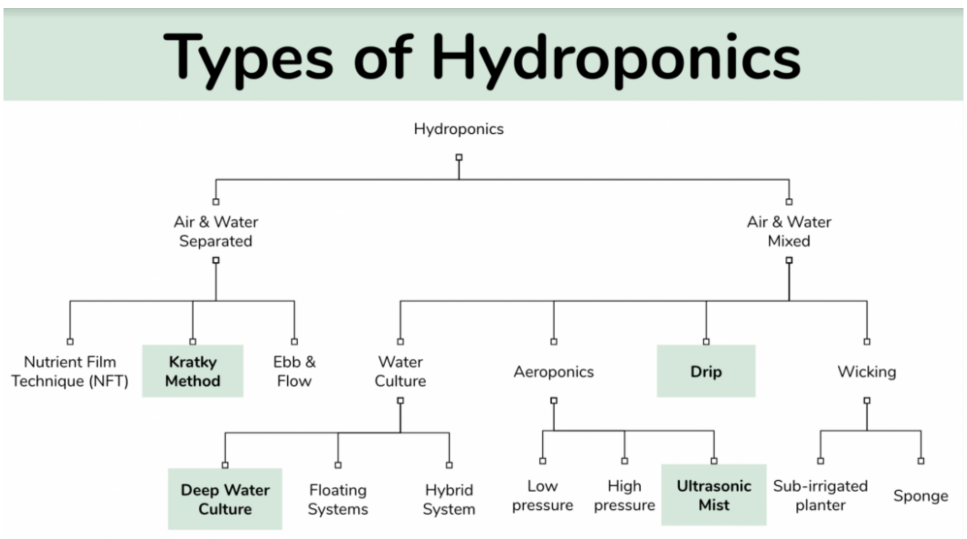
There are several design considerations and trade-offs to consider when designing a hydroponic system: ***PLEASE WRITE IN ANY QUESTIONS THAT WOULD BE GOOD TO CONSIDER PERTAINING TO THE FOLLOWING TOPICS***

- Yield (maximize output and minimize time between harvests)
  - **What microgreen grows the easiest and the fastest and gives the greatest yield? See types of microgreens section**
  - **What technique will allow for the greatest yield of plant mass?**
  - **How are we measuring growth yield?**
- Use of space
  - **Lab room size restrictions, How can we maximize the space we have available?**
  - **Plant density to maximize plants growth?**
- Materials
  - **What are the cheapest materials to use for building (substitutions for PVC)?**
  - **There are materials that have risks associated with them that make them unsuitable for hydroponics. See section Risks.**
- Parts
  - **Type of pipe (square or round) affects the contact the roots have with the water.**
- Automation and Climate Control
  - **Most effective Raspberry Pi version?**
  - **How many things can we automate with our budget?**
    - **What is most important to automate?**
  - **Do we need cameras to monitor?**
    - **How many?**
- Power consumption
  - **How much power will this system consume?**
  - **How much power will the individual components consume?**
  - **What is the maximum pump size that we need?**
- Energy
  - **Is there energy restriction of different components?**
- Water consumption
  - **How much water will we use on a per time or cycle basic?**
  - **How large does our reservoir need to be?**
  - **Will the water be hard or soft water?**
  - **If the water is hard water will it need to treated?**
    - **What's in the water?**
    - **Is it bad for the plants?**
    - **How will it be removed?**
- Nutrient requirements
  - **What Nutrients will we use?**
  - **What Nutrients do we need?**
- Usability (simplify installation, use and maintenance)
  - **Is it easy to disassemble?**
  - **Is it easy to clean?**
- Risk mitigation (see corresponding chapter below)

- **What are the associated risk with different systems**
- **How can these risk be mitigated?**

YIELD FACTORS: Ideally, we want to grow the most amount of plant mass, using the least amount of energy, the least amount of water, least amount of space, etc. Crop yield can be maximized through the following factors: How will we implement the most optimal techniques in order to increase yield while keeping the system efficient and sustainable?
PLEASE WRITE IN ANY QUESTIONS THAT WOULD BE GOOD TO CONSIDER PERTAINING TO THE FOLLOWING TOPICS

- Growing technique
  - **Which growing technique works the best for microgreen cultivation**



  - **How does hydroponics compare to** soil-based cultivation? **(CONTROL GROUP)**
- Light (intensity and time cycles)
  - **Light spectrum requirements, light fixtures, etc..**
  - **Will the type of light needed change depending on the type of plant that is grown**
- Air temperature
  - **What is the optimal Temperature for the particular microgreen we are growing?**
- Temperature in nutrient solution
  - **what is the optimal Temperature of solution for the particular microgreen we are growing?**
- Nutrient mix
  - **what is the optimal MACRO AND MICRO nutrient solution composition for the particular microgreen we are growing?**
- pH (acidity in nutrient solution)
  - **What is the optimal pH for the particular microgreen we are growing?**
  - **How can we test different pH's at the same time?**

- EC (Electrical conductivity in nutrient solution
    - **What is the optimal EC for the particular microgreen we are growing?**
- Water flow (not applicable for all growing techniques)
    - **What effect would decreasing/increasing water flow to the plants would have on the growth?**
- Droplet size of nutrient solution (applicable for aeroponics and fogponics)
    - I don't think we need to worry about this.
- Humidity
    - What range of humidity should the system operate at?
- Aeration of nutrient solution
    - What is the optimal amount of dissolved oxygen that is needed in our nutrient solution?
- Airflow in grow environment
- CO2
    - How often will the fan have to be run to provide the plants with enough CO2 to meet their needs?
    - Will this length of time have a significant impact on the humidity of the tent to the point where the plants won't be dehydrated

USE OF SPACE: Ideally, you want to grow as many plants as possible per unit of volume. Different systems, i.e. combinations of Hydroponics methods and System Designs, allows for different number of plants per cubic meter. The possibility of vertical stacking with hydroponics adds a dimension of flexibility and more output per area. ***PLEASE WRITE IN ANY QUESTIONS THAT WOULD BE GOOD TO CONSIDER PERTAINING TO THE FOLLOWING TOPICS***

- **Number of plants per cubic meter for various example systems???**
- **How large scale do systems have to be to be the most efficient?**
- **What is the most efficient system for the space available in the lab?**
- **How many tests will we need to run???**
    - **How many trials/conditions can we run at once?**

MATERIALS & PARTS: Ideally, you want to minimize the number of parts, however, trade-offs can be made to maximize yield. We need to keep this system economical. What are the tradeoffs of having different subsystems, how do they affect yield? ***PLEASE WRITE IN ANY QUESTIONS THAT WOULD BE GOOD TO CONSIDER PERTAINING TO THE FOLLOWING TOPICS***

Safe plastics:

- Hemp bioplastic
- HDPE (high-density polyethylene)

- PP (polypropylene)
- PVC (Polyvinyl chloride)

Mediums:

- Will one medium or substrate provide any additional benefits over another? Or does one medium have benefits when used in a system over one that may normally be considered better?

Ceramics

Glass

POWER CONSUMPTION AND ENERGY: Ideally, you want to minimize the energy consumption required to run the system. What are the energy or power consumption tradeoffs involved with incorporating certain components to our system. ***PLEASE WRITE IN ANY QUESTIONS THAT WOULD BE GOOD TO CONSIDER PERTAINING TO THE FOLLOWING TOPICS***

How do we minimize losses through the pipe so we don't need to have our pump work as hard?

If the pump we are using is moving water at a high enough rate, will an aerator be necessary? Without this, power consumption go down?

If not, can the aerator be put on a timer and sensor so oxygen is added as needed?

AUTOMATION AND CLIMATE CONTROL: A hydroponic control system can measure and manage the yield factors via the tools listed below: Which ones would be best to vary for the purpose of selecting aims. ***PLEASE WRITE IN ANY QUESTIONS THAT WOULD BE GOOD TO CONSIDER PERTAINING TO THE FOLLOWING TOPICS***

- Growing method
- Light; grow lights with the optimal frequency and distance from plants (LED lights and timer)
- Air temperature: thermometer, heaters
- Temperature in nutrient solution: thermometer, heaters
- Nutrient mix: automatic doser
- pH (acidity in nutrient solution): pH-sensor, automatic nutrient doser.
- EC (Electrical conductivity in nutrient solution): conductivity sensor, automatic nutrient doser
- Water flow: pump
- Humidity: humidifier
- Air flow: fans
- Oxygen levels in water: air stone
- Carbon dioxide levels in grow room

Water consumption

Nutrient requirements

Usability

Installation

The number of parts and their design is a factor.

Maintenance

Maintenance may include

- cleaning of pipes (10% bleach)
- replacing parts
- Cleaning reservoir periodically

Use

Use involves

- putting seeds into substrate (typically a rock wool cube) for germination (the stage where plants break out of their seed shells and become seedlings.)
- transferring seedlings into net pots with substrate and putting them into hydroponics system
- dosing (managing nutrient levels in water)
- room control (managing temperature, humidity and other factors shown under automation)
- harvesting
- refilling water reservoir

Ideally, the system shall be designed to be used with ease and good ergonomics.

Risks and Risk Mitigation

- When using a large reservoir, water is more likely to become stagnant and can become a breeding ground for anaerobic bacteria which will compete for nutrients
    - make sure that water is constantly moving to ensure there is dissolved oxygen in the water, or use an aerator
- Nutrient solution will not always remain dissolved in water, proper flow of water can also help prevent this
    - Need to research solubility limits
- What microgreens have the smallest number of risks that go along with them?
    - Which have high germination rates, and do certain ones grow better under an aeroponic vs hydroponic system
- What are some of the disadvantages that come with different hydroponic systems?
    - Ebb and flow systems are prone to breaking down for beginners, and power failures are more often than in other systems
    - These systems are also prone to nutrient deprivation, as well as nutrient lockout due to fluctuating pH levels

https://plantsheaven.com/ebb-and-flow-system-pros-and-cons/#Disadvantages_of_an_Ebb_and_Flow_System

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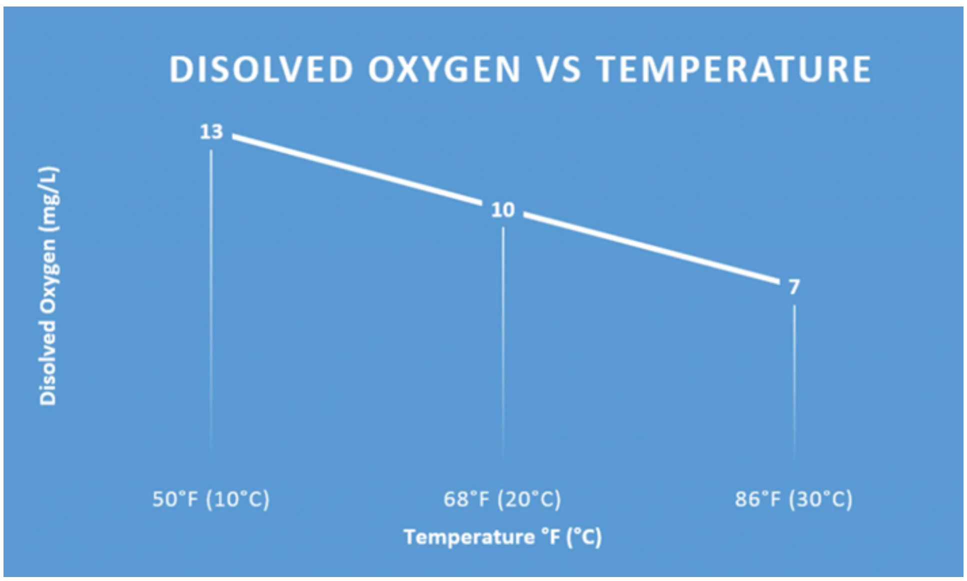
HOW WILL WE OPTIMIZE FACTORS OF THE SYSTEM TO INCREASE YEILD?

Varying temperature/DO:

- Affects dissolved oxygen (DO) in system
- The greater the temperature the less DO
- 

- https://hydrobuilder.com/learn/why-hydroponic-water-temperature-matters/
- Optimal temperature is 65*-68*F
- DO helps with nutrients uptake and growth, reduces tip burn
- 10 ppm for leafy plants
- Decreased root length with increased DO since don't need to branch as far for oxygen
- https://hortamericas.com/blog/news/dissolved-oxygen-improves-plant-growth-reduces-crop-time/#:~:text=Dissolved%20oxygen%20improves%20plant%20growth%2C%20reduces%20crop%20time,real%20challenge%20during%20warmer%20times%20of%20the%20year.

Types of Microgreens

- Arugula microgreens
  - Time to harvest 5-14 days
  - ~1000 seeds $2.49 (401 seeds/$)
- Broccoli microgreens
  - Time to harvest: 5-14 days

- ~4000 seeds $7.14 (560 seeds/$)
- Napa Cabbage microgreens (Chinese cabbage)
  - 8-12 days
  - High germination rates
  - ~6800 seeds $5.44 (1250 seeds/$)
- Kale microgreens
  - 5-14 days
  - ~250 seeds $2.49 (100 seeds/$)
- Radish microgreens
  - Germination: 2-3 days
  - Time to harvest: 6-10 days
  - ~400 seeds $2.99 (133.78 seeds/$)

Possible Variables that can be changed

Flow rate of nutrient-water solution: Using a three-way splitter connected to the pump, we can posibly use different sized pieces on the splitter to control the average flow rate different rows of a NFT or another kind of drip system receive

- This can be a possible alternative for increasing/decreasing the concentration of nutrients, which may not be possible with only one reservoir

Automation Steps

- Any version of Raspberry Pi should work (GitHub)
- Download and Install MyCodo
- Must use Linux
- Start with configuring inputs and outputs
- Calibrate sensors
- Functions
  - Grow light schedule
  - pH regulation
  - Electrical conductivity regulation
  - Vapor pressure deficit regulation
  - Cameras and Timers
    - Camera timelapse??
- Dashboard configuration
- Notification control
- Test without plants to debug

Pump information

https://www.pumpfundamentals.com/Pump%20and%20piping%20sizing.pdf

Link to write up for YouTube demonstration:

https://kylegabriel.com/projects/2020/06/automated-hydroponic-system-build.html

Hydroponic system design considerations

https://wiki.opensourceecology.org/wiki/Hydroponic_system_design_considerations

Link has a graph explaining efficiency of aeroponics vs hydroponics systems, and EC and pH for crops

https://www.researchgate.net/profile/Kaushal-Kumar-18/publication/330080392_Hydroponics_as_an_advanced_technique_for_vegetable_production_An_overview/links/5c7e14e4a6fdcc4715af8a93/Hydroponics-as-an-advanced-technique-for-vegetable-production-An-overview.pdf

Link for coding steps and information:

https://github.com/kizniche/Mycodo

Systems Material List:

Base Hydroponic System:

Planting:

Enviromental monitoring and Regulation System:

Power Control Box:

Water Condition Sensing:

Water Dosing:

Water Flow & Level Sensing:

Air Condition Sensing:

Electrical Power Sensing:

Challenges:

1. Peristaltic pumps put us over budget
    a. Can we use simple cheap peristaltic pumps and be less precise with the measurements?
    b. Ask ECE professor if this change can be made and how it will simplify the code.
2. The pH sensor and EC sensor is expensive
    a. Can we use different pH sensors and EC sensor without having the code be significantly changed?
        i. PH sensors that are available are mostly analog rather than digital and require additional coding and parts to operate
        ii. To solve this problem, an ADC can be used to convert the data collected from analog to digital but additional code my be needed
3. Flow meter is out of stock
    a. Ask Atlas Scientific distributor when will be back in stock, move on without a flow meter for now.
4.

Materials and Dimensions of the Hydroponic System:

- Need to determine the size of the system we are working with
    - This will determine the growth light size we need to purchase, and the materials needed for the grow tent

- How will changing the dimensions of the system affect the amount of water needed, and the reservoir size needed?
- Will downspouts for gutters be used, or PVC piping?
- How many rows of PVC or gutters will we have, and how many sections will each have? How many different variables can be tested with each growing season?
- Need to know how much PVC piping is needed, as well as other tubing and parts, which depends on the size of the system

- Need to determine the aims that will be tested besides the control groups in soil
  - Flow rate, seed density, plant type, DO based on water temperature
  - Flow rate, we will need two different sized tubes to provide different flow rates, will have to either use a splitter or a second pump (may require additional purchases depending on the materials we have already)
  - Depending on number of systems that can be built (light intensity, nutrient concentration, pH range)
- Materials and sensors have already been determined (final materials count is shown in excel sheet), parts need to be ordered in a timely manner to assure system can be built

Kyle's Dimensions:

- 2 ft x 4 ft
- He fits 5 downspouts, with a checkerboard pattern of holes to maximize room for the plants to grow
- Holes are cut 6 inches apart from one another and the downspouts are 30 inches each
- Total of 17 holes cut

Current Plan:

Build one base system and buy individual sensors with spare money and try to build another system from scratch

- This spare system can be used for additional labs in the future, like a process simulation control lab.

With one system being built the following aims will be tested:

- Control groups (soil, controlled environment; soil, non-controlled environment)
  - Non-controlled control microgreens will be grown outside the tent.
- Hydroponic system: Flow rate, seed density, plant type, DO concentration, type/intensity of light, CO_2.
  - Flow rate controlled with various sized grommet. Different sized microtubes will be needed to supply different amounts of nutrient solution.
  - Seed density can be controlled by how many seeds we put per area of growing material.
  - Plant type can be controlled by planting different microgreen seeds.
  - DO concentration can be controlled by varying the temperature of the reservoir water.

- Type/intensity of light can be controlled by varying the color of the light and how intense it is.
- CO_2 can be controlled by having a reaction between yeast and sugar released into the system.

- Experimental data will be weight of microgreens and wet growing material.
  - The plants will be weighed every day except weekends.
- Up to a possible 4 growing seasons ending by April 17th
  - Can have 4 if we do short growing season the week prior to spring break.

The dimensions of the system will be ______ and we will be able to test ______ variables per growing season with a total of ______ growing sections throughout the system.

Timeline:

Feb 2nd : Order Atlas Scientific Hydroponics kit and Gravity Analog Sensor kits

Feb 2nd – 7th : Research/design system for finalization

Feb 9th : Meet with Dr. B + order remaining

Feb 7th – 14th : Setup of sensors + construction of hydroponics base

Feb 20th : Start germination of control group + grow season 1

Feb 20th – Mar 6th : Grow season 1 + setup of DIY Arduino sensors

Mar 6th : Start germination of control group + grow season 2

Mar 6th – 11th : grow season 2 with shorter period/no grow season/play with Arduino

Mar 20th – Start germination of control group + grow season 3 (possibly 2)

Mar 20th – April 3rd : Grow season 3/2 + analysis of previous grow season data

April 3rd : Start germination of control group + grow season 4 (possibly 3)

April 3rd – 17th : Grow season 4/3 + analysis of previous grow season data

April 17th – May 1st : Data analysis/report work/presentation preparation

Next week:

- What aims
- Finalize
- Quantify
-