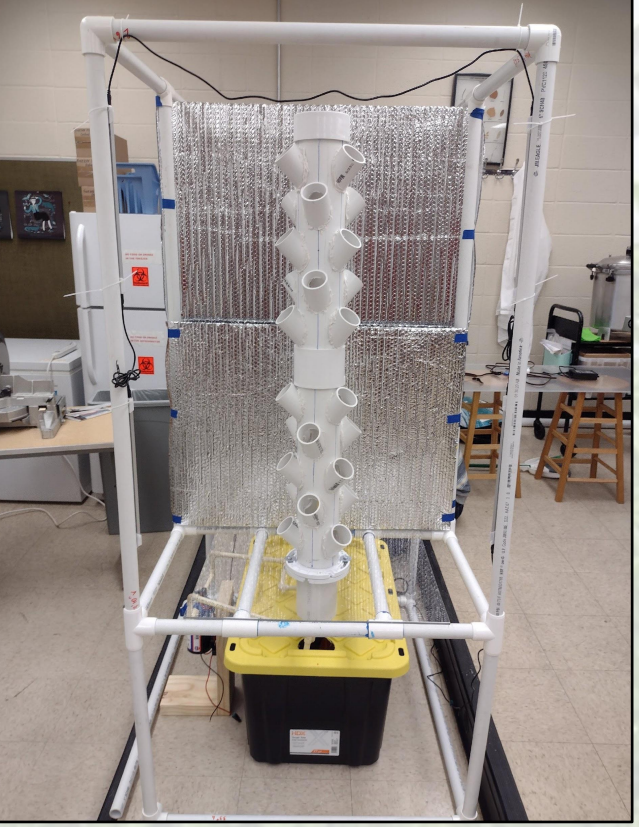
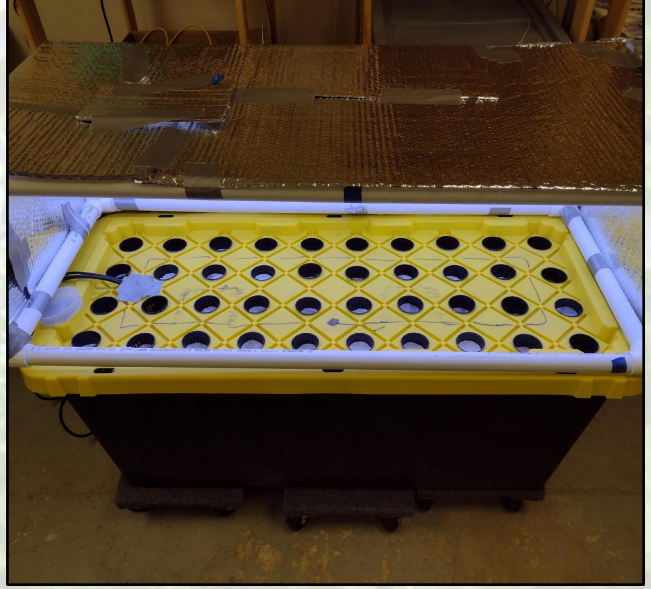




Hydroponics: An Overview

Jonathan Cleary

Definitions

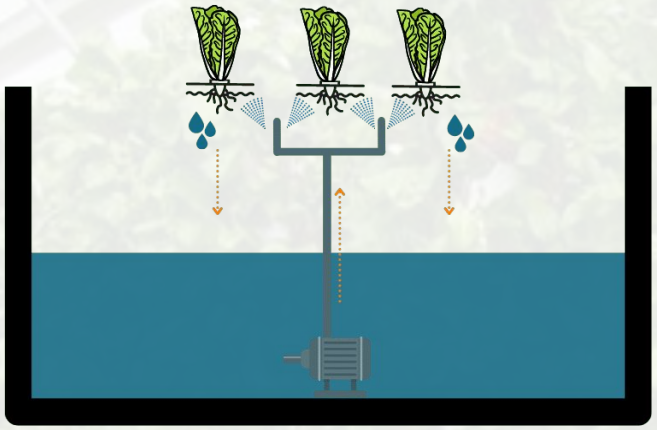
Water/Hydro Culture – Growing Plants without soil

Hydroponics – A subsystem of water or hydro culture; the growing of plants in nutrient solutions with or without an inert medium (such as soil) to provide mechanical support

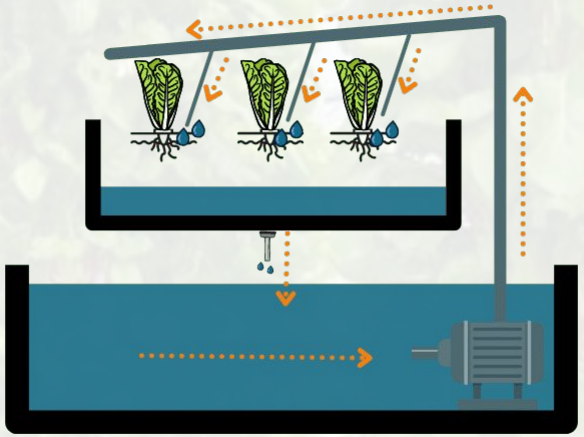
Aeroponics – A subsystem of hydroponics wherein one uses sprayers to mist nutrient solution to plants' seeds or roots

Aquaponics – Another subsystem of hydroponics; growing plants in the water that has been used to cultivate aquatic organisms

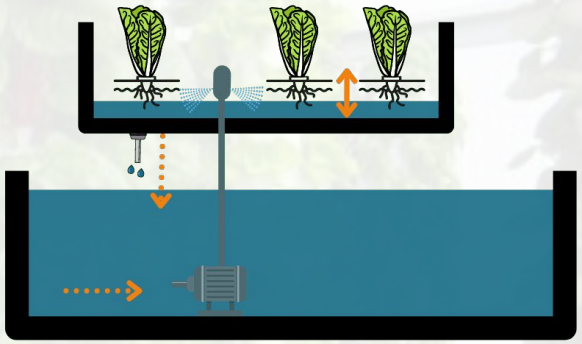
Major Hydroponic Systems – The Big Seven



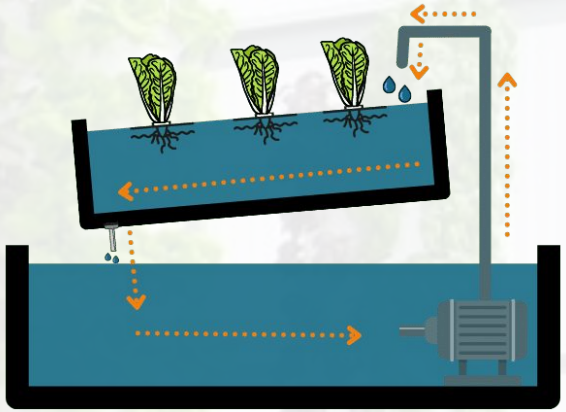
Aeroponic



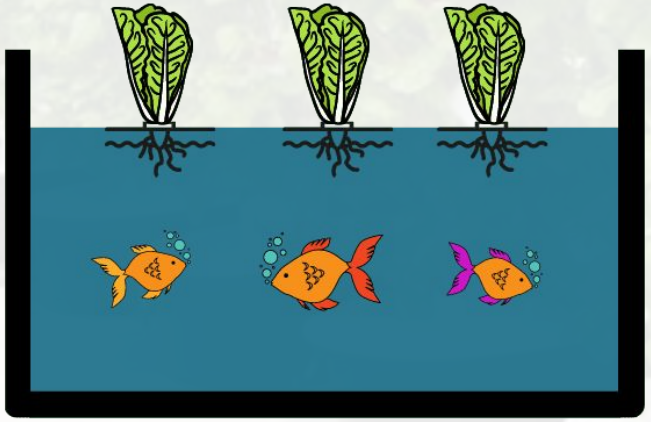
Drip



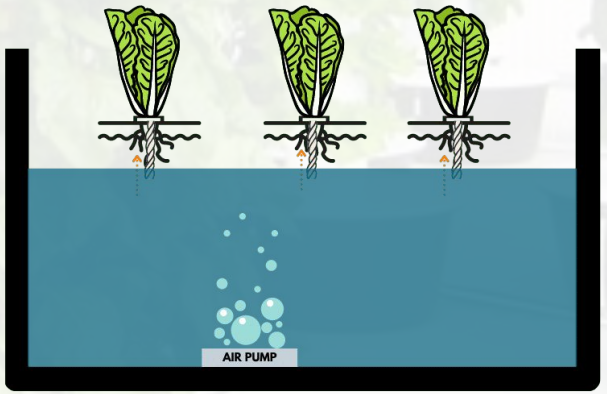
Ebb and Flow



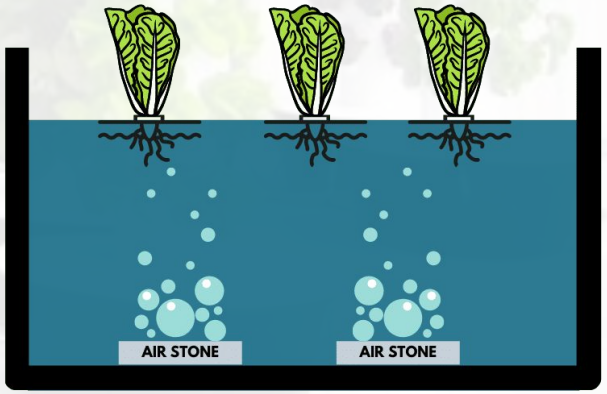
Nutrient Film Technique



Aquaponic



Wick



Deep Water Culture

Commonalities/Differences Among Hydroponic Systems

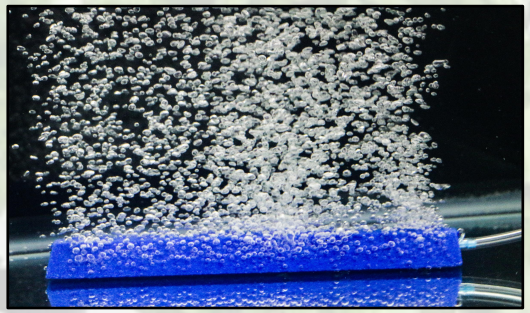
- **Nutrient solution**, not soil, feed plants (THE MAIN THING)
- Growth medium and net pots hold the seeds, roots in lieu of soil
- Reservoirs (of various sizes) holds the nutrient solution
- Lighting (as needed for all plants), usually artificial
- Nutrient solution can be split into multiple parts, ratios
- Aeroponics uses sprayers to get nutrient solution
- Most systems uses pumps except Wick, Deep Water Culture types

Clay pellet growth medium

Reservoir tote (DIY)

Submersible Pump

EC/pH Meter



Air stone

Sprayer head

3-part nutrient solution

Benefits/Drawbacks of Hydroponic Systems

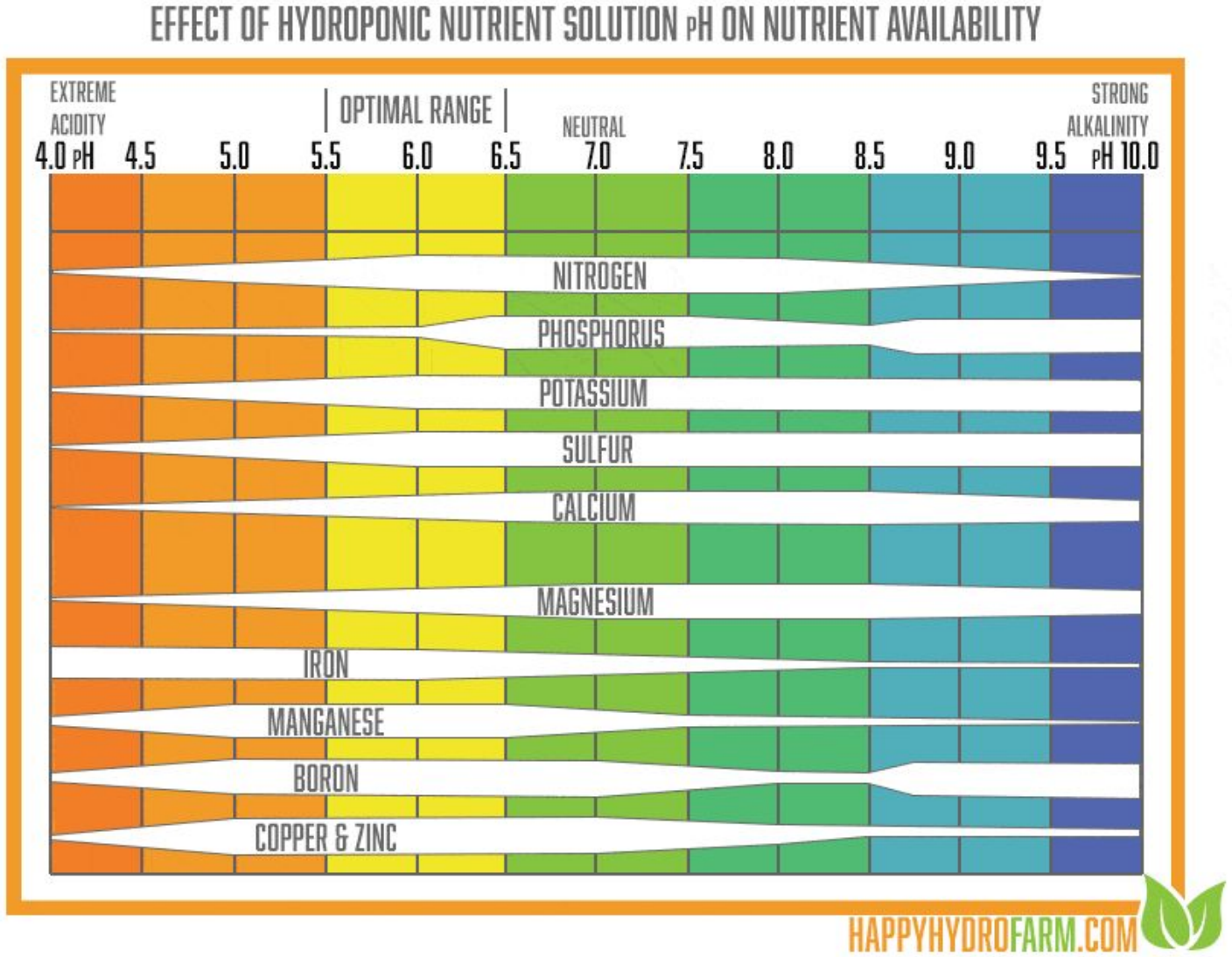
Pros

- Recycles water, nutrients
  - Uses 10% of water, nutrients compared to traditional agriculture
  - Little if any nutrient solution lost to evaporation
- Space-efficient
  - Vertical farming allows for more plants grown per area
- Can grow most vegetables, some fruit
- Food is at least as healthy as store bought
- No soil-based diseases
- Indoor growing means control of climate
- Scalable
  - From one cubic foot to entire warehouses

Cons

- Startup costs can be prohibitive
  - Bare-bones DIY systems cost at least $75 to $100
- The more complex the system, the more maintenance
- Energy for lights, pump, air stone, climate control is limiting factor
- Cannot fully grow trees, some vegetables
  - Systems not capable of handling weight, size of trees, large shrubbery (yet)

Plant Preferences in Hydroponic Systems

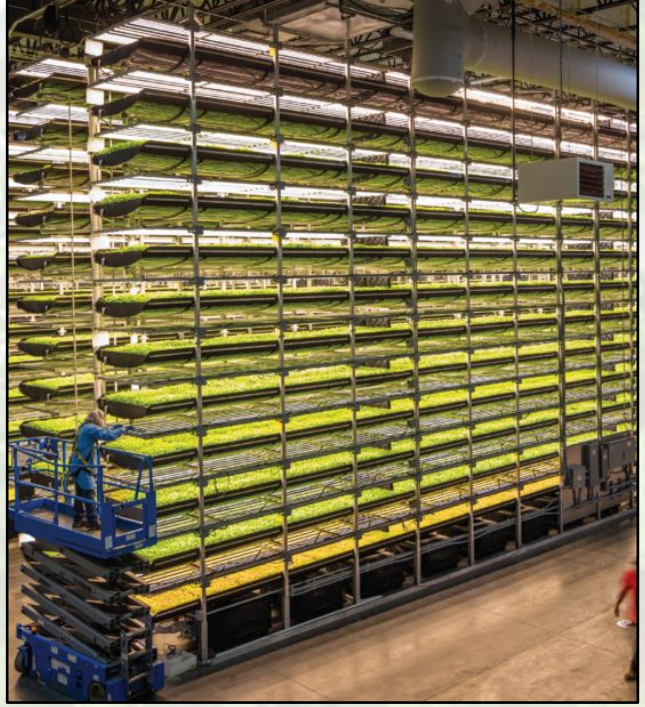


Optimal pH & EC HYDROPONIC VEGETABLES

VEGETABLE	pH	EC	VEGETABLE	pH	EC
ARTICHOKE	6.5-7.5	0.8-1.8	MARROW	6.0	1.8-2.4
ASPARAGUS	6.0-6.8	1.4-1.8	OKRA	6.5	2.0-2.4
BASIL	5.5-6.5	1.0-1.6	ONIONS	6.0-6.7	1.4-1.8
BEAN (COMMON)	6.0	2.0-4.0	PAK CHOI	7.0	1.5-2.0
BEETROOT	6.0-6.5	0.8-5.0	PARSNIP	6.0	1.4-1.8
BOK CHOI	6.0-7.0	1.5-2.5	PEA	6.0-7.0	0.8-1.8
BROAD BEAN	6.0-6.5	1.8-2.2	PEA (SUGAR)	6.0-7.0	0.8-1.8
BROCCOLI	6.0-6.5	2.8-3.5	PEPINO	6.0-6.5	2.0-5.0
BRUSSELL SPROUT	6.5-7.5	2.5-3.0	PEPPERS	5.8-6.3	2.0-3.0
CABBAGE	6.5-7.0	2.5-3.0	PEPPERS (BELL)	6.0-6.5	2.0-3.0
CAPISCUM	6.0-6.5	1.8-2.2	PEPPERS (HOT)	5.0-6.5	3.0-3.5
CARROTS	6.3	1.6-2.0	POTATO	5.0-6.0	2.0-2.5
CAULIFLOWER	6.0-7.0	0.5-2.0	PUMPKIN	5.5-7.5	1.8-2.4
CELERY	6.5	1.8-2.4	RADISH	6.0-7.0	1.6-2.2
CUCUMBER	5.8-6.0	1.7-2.5	SPINACH	6.0-7.0	1.8-2.3
EGGPLANT	5.5-6.5	2.5-3.5	SILVERBEET	6.0-7.0	1.8-2.3
ENDIVE	5.5	2.0-2.4	SWEET CORN	6.0	1.6-2.4
FODDER	6.0	1.8-2.0	SWEET POTATO	5.5-6.0	2.0-2.5
GARLIC	6.0	1.4-1.8	TARO	5.0-5.5	2.5-3.0
KALE	5.5-6.5	1.25-1.5	TOMATO	5.5-6.0	2.0-5.0
LEEK	6.5-7.0	1.4-1.8	TURNIP	6.0-6.5	1.8-2.4
LETTUCE	5.5-6.5	0.8-1.2	ZUCCHINI	6.0	1.8-2.4

These values are general guidelines for hydroponic gardening, and may be slightly different based on your climate and growing conditions.

HAPPYHYDROFARM.COM

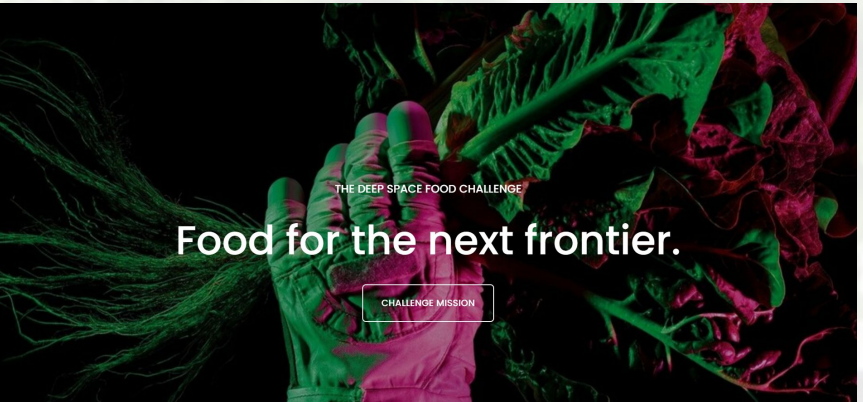


Implications

- **Food can be grown for entire communities or just for single households**
  - Scalability, vertical farming can provide immense or very small amounts of produce
- **Systems good for water-scarce areas due to efficiency, recycling of resources**
  - Some of the largest systems in the world are being built in the Middle East
- **Problems such as food deserts can be tackled using this technology**
  - Can be implemented in places where traditional agriculture comes up short
- **Systems, companies may compete with big agriculture, might run into limitations**
  - Indoor systems can only get so big due to limits of space, energy needed

How this Ties into Data Week

- Collected data for senior capstone aeroponic system project
  - Monitored EC, pH, water temperature, air temperature, humidity
  - Started from an extracurricular project put forth by NASA
- Used Python to create charts from the data
- Measured mass of microgreens growth
- Used Kruskal-Wallis test to determine significance between mass of “harvests” of microgreens

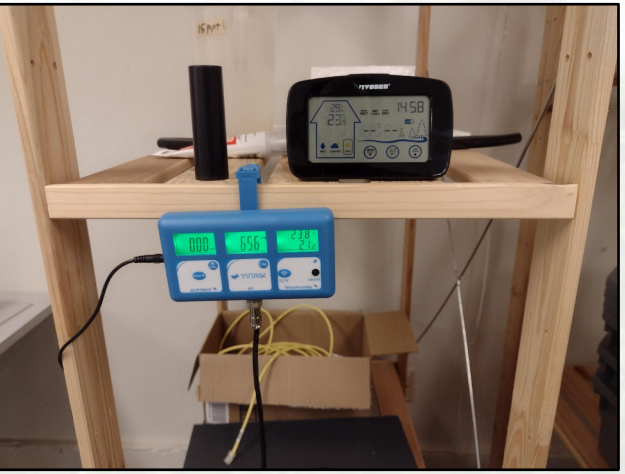



```python
###GOT PLANTS AND/OR WATER - GROUPED BAR CHART###
#original code from Codefinity, modified for use in this project

#importing necessary modules
import matplotlib.pyplot as plt
import pandas as pd
import numpy as py

#setting up necessary parameters(?)
got_plants_and_water = pd.read_excel(r"C:\Users\terra\OneDrive\Documents\UB_Documents\Classes\2024_Spr
                                     sheet_name = "Got_Water_or_Plants",
                                     usecols = ["Pot", "Days with Water", "Days with Growth"])
plants_and_water_df = pd.DataFrame(got_plants_and_water)

#making arrays
Pots = py.array(plants_and_water_df["Pot"])
water_pots = py.array(plants_and_water_df["Days with Water"])
growth_pots = py.array(plants_and_water_df["Days with Growth"])
positions = py.arange(len(Pots))
water_or_growth = py.array([water_pots, growth_pots])

#plotting bars using for loop
width = .4
for i in range(len(water_or_growth)):
    plt.bar(positions + width * i, water_or_growth[i], width)


#customization of axes, labels, add legend, size title, etc.
plt.xlabel("Pot Number", color = "navy")
plt.ylabel("Number of Days", color = "navy")
plt.title("Number of Days Pots had Water and/or Plant Growth",
          fontsize = 15,
          color = "navy")
plt.xlabel("Pot")
plt.yticks(py.arange(0, len(water_pots), step = 4))
plt.xticks(py.arange(start= 0, stop=40, step = 1))
plt.legend( ["Days with Water", "Days with Growth"])
plt.show()
```

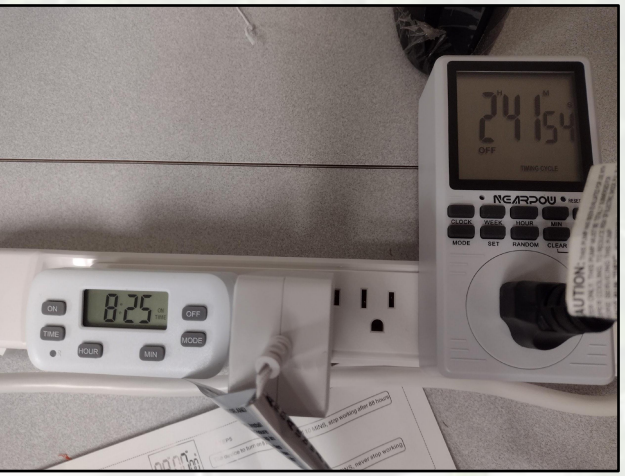
Date	EC	pH	Humidity	Water Leve	Water Tem	Air Temp	Pots with Gro	Notes
1/29/2024	0.00	6.33	23%	150	23.4	20.2	0	first planting!
2/4/2024	0.00	6.44	33%	147	23.8	23.8	10	10/40 pots growing :(
2/7/2024	0.00	6.40	27%	144	23.4	23.3	12	4-5 pots nicely growing, back row nothing
2/9/2024	0.00	6.42	25%	141	24.1	24.2	13	12 or so pots w/ any growth, 7-8 nicely
2/12/2024	0.00	6.42	33%	138	24.1	24.2	17	17 had any green, 7 were substantial. Harvest day!
2/15/2024	0.00	6.41	53%	135	23.8	23.8	11	only tiny growths rn
2/17/2024	0.00	6.83	17%	132	23.5	23.6	15	will need more water when WL reaches 120 or so
2/19/2024	0.00	6.81	17%	130	23.1	23.4	16	added some pH down to try and bring pH closer to 6.4, EC jumped to .05. ran pump to mix in pH down
2/21/2024	0.29	6.33	18%	130	23.3	23.4	24	need to double check where WL is measured from
2/24/2024	0.27	6.52	29%	143	23.7	23.8	24	Saturday. Shouldve been Friday
2/26/2024	0.27	6.63	18%	142	23.0	23.2	25	harvest day 2
2/29/2024	0.28	6.59	22%	140	23.6	23.6	22	largest growths may have been 1cm long; very little green
3/2/2024	0.29	6.56	32%	137	23.1	23.5	23	18 of the 23 pots had growth about 2cm
3/4/2024	0.30	6.57	36%	135	23.8	24.2	23	
3/7/2024	0.30	6.56	37%	133	24.3	24.9	23	signifcant growth in perhaps 20 of the 23 pots (maybe 3 or 4cm)
3/11/2024	0.31	6.55	19%	130	23.5	23.9	24	harvest day 3; recalculated needed portion of nutrient solution for 0.8 EC (53ml of both part A and B, 106ml
3/13/2024	0.87	6.90	32%	127	23.2	23.6	18	got video taken, will do so again in 2 mondays
3/15/2024	0.83	7.22	37%	123	23.4	24.1	24	added 2.5gal after measuring water level
3/18/2024	0.85	6.56	23%	131	23.2	23.6	24	microgreens look like they're on steroids
3/20/2024	0.86	6.77	24%	139	22.8	23.2	25	ditto last notes
3/22/2024	0.84	6.67	20%	127	22.6	23.1	25	looks like pot 35 had water before but not this time because plant looks dead
3/25/2024	0.87	6.93	24%	126	22.6	23.0	26	harvest day
3/27/2024	1.09	5.42	34%	123	23.3	23.7	20	evidently put lots of acid in reservoir because it had dropped notably but not dangerously
4/1/2024	1.04	5.60	37%	120	23.4	23.9	24	switched some felt pads because of potential mold growth
4/3/2024	1.03	6.01	38%	115	22.6	23.3	24	added the rest of the 4gal container to reservoir
4/5/2024	1.02	6.51	33%	125	22.3	22.8	24	need to switch out the cups, had 3 with mold
4/9/2024	1.07	6.66	37%	115	22.3	23.1	26	lots of moldy looking, bad growths
4/11/2024	1.02	6.33	45%	124	23.4	24.0	15	no mold today. Very little growth too
4/13/2024	1.04	6.45	25%	121	22.8	23.4	20	not as many with growth as expected
4/16/2024	1.04	6.50	38%	105	22.5	23.2	21	not sure why most of them are toppled over, need more water
4/18/2024	1.00	6.62	49%	101	22.9	23.7	22	same as last time
4/20/2024	0.99	6.74	43%	95	23.3	24.1	23	plants definitely hate the higher EC
4/23/2024	1.08	6.89	40%	132	23.1	23.6	23	
4/25/2024	1.17	7.04	36%	129	22.7	23.4		

Harvest	Gross Growth Mass	Net Growth	Growth per Pot	Gross Dry Mass	Net Dry Mas	Dry Mass per Pot
harvest 1-3 averages:	3.38980	1.97408	0.08838	1.24029	0.19981	0.00808
harvest 4-6 averages:	3.34395	2.33374	0.09261	1.22231	0.19211	0.00770
harvest 7-9 averages:	2.11251	1.07744	0.04088	1.20970	0.17463	0.00664

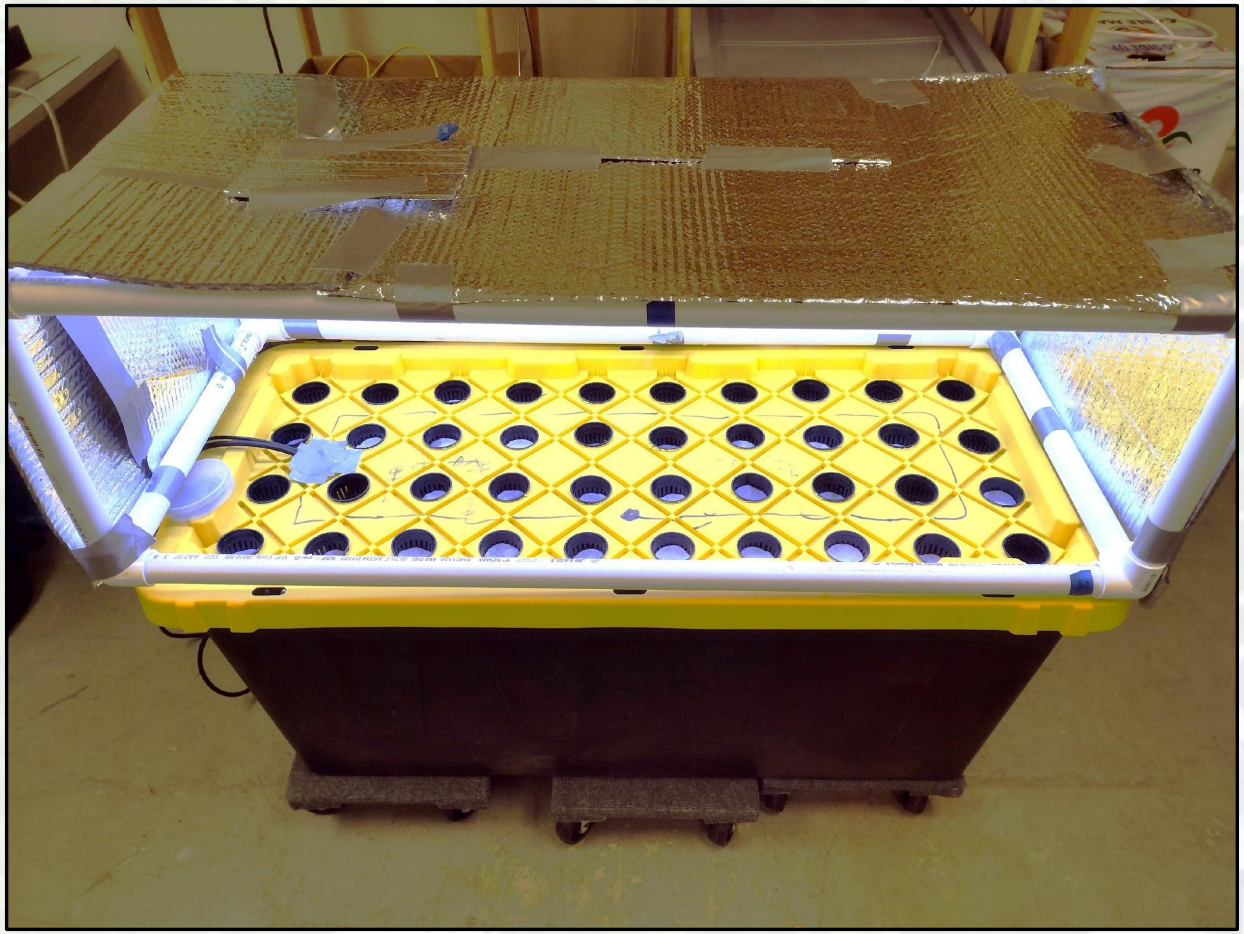
My Aeroponic System



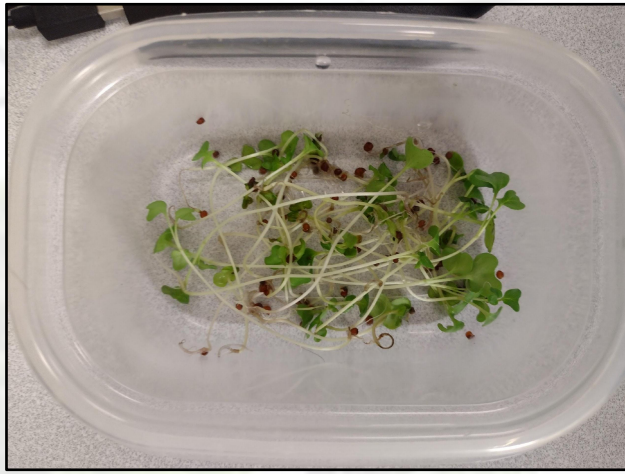
Monitors



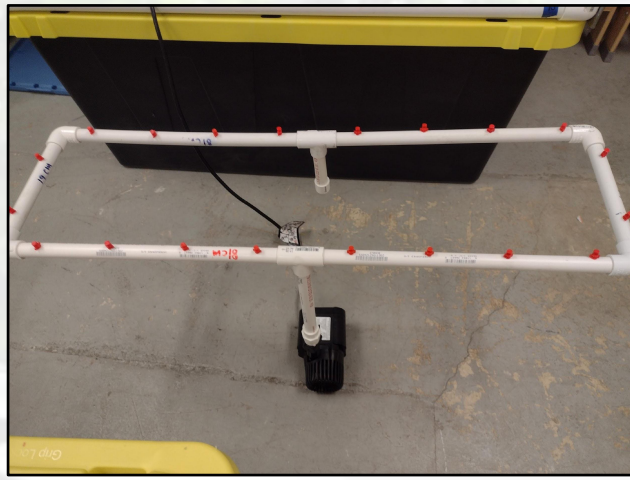
Pump and Light Timers



The main attraction: the reservoir tote, with net pots hanging into the tote, pipe frame with reflective insulation and lighting on top



A microgreens “harvest”



Internal piping apparatus to deliver nutrient solution to net pots, plants

References

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Deep Space Food Challenge Picture - https://www.deepspacefoodchallenge.org/challenge DSFC Pic

3-Part Nutrient Solution Picture – https://indoorgardening.com/

Submersible Pump Picture - https://www.walmart.com/ip/Hydrofarm-AAPW550-550-GPH-Active-Aqua-Submersible-Pump-550-GPH-Recommended-for-55-gallon-reservoirs-By-Visit-the-Hydrofarm-Store/839410884

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THANK YOU!
QUESTIONS?