HYDROPONIC GARDEN MANUAL

For Gandul

GUIDE TO BUILDING AND MAINTAINING HYDROPONICS FOR THE GANDUL COMMUNITY

ENGLISH

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I. INTRODUCTION AND ACKNOWLEDGEMENTS

This manual discusses the background and importance of gardening and hydroponics, as well as providing guidance and suggestions for maintenance and future productions. This hydroponic garden manual was created in order for residents of Gandul, including adults and children that visit the Gandul Community Center frequently, to collaborate with, understand the importance of, and maintain hydroponic gardens. To start, the background section covers fundamental concepts on hydroponics and their importance that could be useful to those that are unfamiliar with it. In addition to background, the next section is dedicated to a more in depth exploration of plant physiology. There also is a section regarding the different kinds of hydroponic systems that can be used. Then we explore the specifics when it comes to hydroponic maintenance. This includes, but is not limited to, pH levels, materials, minerals, water, and even the production of different kinds of plants.

Following the hydroponic background, there is a deep dive into the hydroponic model along the alley beside the Gandul Community Center. This hydroponic model serves as one of the first of hopefully many hydroponic gardens to be made in this alley and throughout the Gandul Community. This section provides production and maintenance details that will aid those that will maintain the garden or similar models in years to come. Finally, a focus on other hydroponic designs is included in order to broaden the scope of hydroponics and possibly encourage inspiration or collaboration on existing and future hydroponic gardens.

The student team thanks Jose Ramierez for his whole-hearted support, advice, experience, and positivity which helped shape this hydroponic manual. Mark Wilson and Rocio Nájeraurriola from La Corporacion Fondita de Jesus were also instrumental by sharing their knowledge of hydroponics with the team. This manual is the impressive result of teamwork and support from these Gandul residents, all of whom the authors are grateful for.

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II. Manual Objectives and Vocabulary

Manual Objectives

- ☐ Understand that hydroponic gardening produces the same results as traditional, soil gardening. Products from hydroponics have equal or greater quality compared to soil-grown produce
- ☐ Encouraging further hydroponic usage and applications; expanding domestic and commercial hydroponics
- ☐ Learn how to handle nutrients and adjust measurements to create the right environment for growth
- ☐ Under supervision, complete all stages of hydroponic tasks: from sowing to harvesting to later build confidence to complete these tasks independently
- ☐ Identify and detect nutritional deficiencies, pests, and diseases
- ☐ Learn how to maintain the hydroponic garden located at El Gandul Community Center

Vocabulary

Aerate *(verb)*: to introduce air into an area or material

Chloroplast *(noun)*: an organelle in plant cells where photosynthesis takes place

Chlorophyll *(noun)*: a green pigment in chloroplasts that is responsible for light absorption in photosynthesis

Electrical Conductivity (EC) *(noun)*: the measure of a material's ability to conduct an electrical current

Germination *(noun)*: the development of a plant from seed to a seedling or sprout

Glucose *(noun)*: a sugar that serves as a source of energy

Opaque *(adjective)*: non-transparent; doesn't allow light to pass through

pH or potential of hydrogen *(noun)*: a scale used to measure the acidity or alkalinity (basicity) of liquid solutions

Photosynthesis: a chemical process that occurs in plants when light energy is converted into chemical energy in the form of glucose

III. BASICS OF HYDROPONIC GARDENS

A) Definitions, Applications, and Basic Concepts

What is Hydroponics?

Derived from the Greek words “hydro” (water) and “ponics” (to work), hydroponics is a soilless gardening technique that utilizes a flowing nutrient-water system to grow a variety of plants. Proper nutrient distribution, pH control, and water flow allow for the cultivation of numerous kinds of produce, such as spinach, cilantro and tomatoes.

With this, hydroponics is an ideal gardening technique in places that lack fertile soil, landspace, and access to an abundance of water since the nutrient-water solution cycles within the system. In these systems, it is important to prioritize light exposure, access to electricity for a water pump, and ideal wind and temperature conditions.

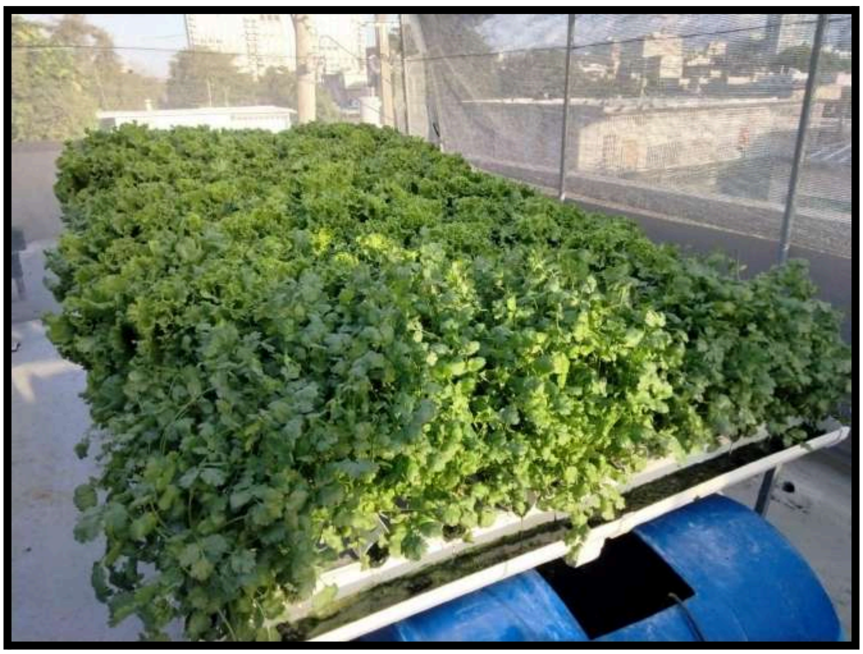

Figure 1: Hydroponic table at La Fondita de Jesús

Why are Hydroponics Important?

Hydroponics is an extremely useful gardening method that is gaining recent popularity. This agricultural method is a great alternative for traditional farming techniques and has several advantages. As previously mentioned, hydroponics does not require fertile soil, or soil at all, in order to grow healthy plants. Instead, hydroponics utilize water-based nutrient systems. Additionally, with the use of a water pump that continuously recycles water through the system, ultimately less water is required compared to traditional gardens in which new water must be added to the plant.

Since water and nutrient distribution is regularly tracked and maintained, gardeners have greater control to optimize plant growth through adjustments in these measurements. Moreover, without the need for pre-portioned mineral fertilizer, gardeners can create customized ratios of various minerals and nutrients according to the plants' needs. Harvest times are also reduced since nutrient and water distribution is constant and closely regulated.

Applications

There are several forms of harvested produce that are particularly suitable for Puerto Rican climate. Most commonly, cilantro and butter lettuce are well-suited and profitable options. Some other popular harvested produce include strawberries, spinach, and types of micro-herbs. Considering Puerto Rico's tropical and warmer climate, most produce can be grown year round with proper care and attention to both temperature, light exposure, and moisture levels. Typically produce grows best in the November through April time period since it is cooler and drier during this time. Regardless of season, however, most of these plants can be successfully grown with attention to growth factors.[10]

Strawberries tend to take longer as they have a flowering stage as well as time allotted to grow the fruit. So, expect 5 to 8 weeks for flowering, and then an additional 3 weeks for the fruit to mature.

Microherbs can be harvested anywhere from 1-3 weeks. This is because micro herbs are a form of produce that are harvested in early seedling stages, therefore requiring a shorter harvest timeline. (*See Table 1 for more details*)

B) Plant Physiology

Parts of Plants

Plants are divided into the following basic parts:

- *Roots*
  - Anchors plant and absorb nutrients/water from surroundings. In hydroponics, roots appear shorter since it's easier for plants to access their essential nutrients, compared to soil farming.

- *Stem*
  - Its purpose is to transport water and nutrients to and from the roots to leaves, branches, and flowers.

- *Leaves*
  - Gather sunlight, store water, location where gas exchange (between carbon dioxide and oxygen) and photosynthesis occurs.

All plants are generally made up of 80-95% water, ranging only from a number of factors such as species of plant, temperature, and more. The remaining constituents of plants are made of dry matter, where 90% of the dry weight consists of the essential nutrients: carbon, oxygen, and hydrogen. Water accounts for oxygen and hydrogen that plants require while carbon dioxide in the atmosphere provides the carbon and oxygen.[14]

The remaining 10% of nutrients and minerals must be derived from the soil. In the case of hydroponics, these nutrients are supplied through the soil through fertilizer and supplemental nutrients. There are currently 16 elements considered "essential" for plant life. The main nutrients include nitrogen, phosphorus, and potassium (NPK) as well as calcium, magnesium, sulfur, and others.[14]

Photosynthesis

Photosynthesis is the process where plants utilize energy from the sun to synthesize food. To do so, plants absorb water and carbon dioxide, and transform these elements into oxygen and glucose. The oxygen is released back into the air, and glucose is stored for energy.

Water helps carry nutrients through the soil to nourish the plant. Plants absorb the water from their roots and the water travels up the stem to the leaves. The roots need adequate space to absorb surrounding nutrients. If the soil lacks the nutrients needed, then fertilizer and supplemental nutrients can be added to sustain the plant.

In the cells of the leaves lies the organelle known as the chloroplast. Here, glucose is made and nourishes the plant. Chloroplasts contain a green pigment known as chlorophyll, which absorbs sunlight and transfers it to energy storing molecules. The stored energy is then used for the conversion of water and carbon dioxide to oxygen and glucose.[11]

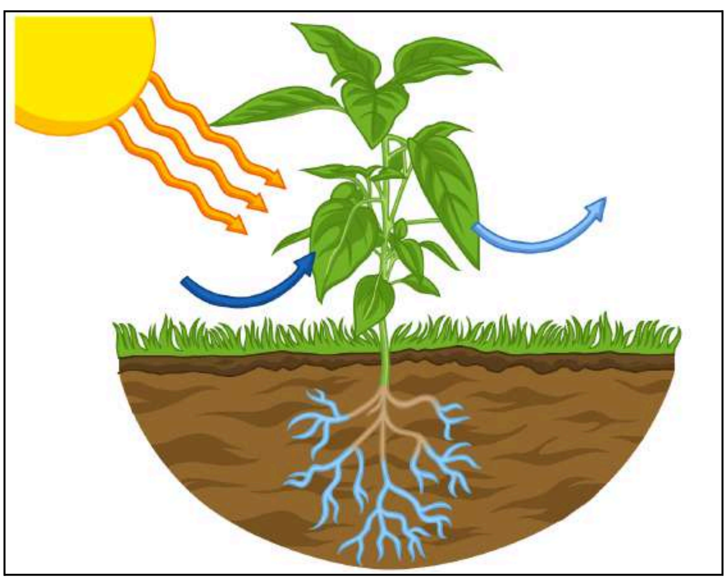

Figure 2: Photo representation of photosynthesis[11]

C) Types of Hydroponic Systems

Nutrient Film Technique (NFT)

The nutrient film technique is *the system utilized by the hydroponics described for Gandul in this manual*, and one of the most commonly used systems. Plants are secured in tubes which are slightly inclined, allowing water to flow downward into a tank with a pump that forces water up to the tubes again.

A stream of water flows over the roots of the plants, with nutrients added to the water if needed (NoSoilSolutions, 2023). This system works well for lettuce, cilantro, and other herbs or small plants.

Deep Flow technique (DFT) is a variant of NFT in which the roots of plants are submerged in a flowing nutrient solution (Pure Greens, 2023). DFT does not require an incline, but typically an air pump is needed to aerate the water.[3]

Deep Water Culture (DWC)

In deep water culture, plants are held in pots or nets above a tank of nutrient-filled water so their roots are submerged. An air pump is necessary to aerate the water and provide oxygen to the roots.

Once submerged in a bubbling, nutrient-infused water basin, nearly any type of fruit or vegetable can thrive. Large root systems can be supported with larger basins.[12]

Ebb and Flow System (Flood and Drain)

The ebb and flow system periodically floods a bed of plants with water using a timer. A drain at one end of the bed or tray prevents overflow and returns water to a tank to be recirculated. After a chosen amount of time the timer turns off the pump to empty the bed and aerate the roots.

This system works well for most plants and root vegetables. However plants with large roots are not recommended as they would need deeper, wider trays that take up more space.[12]

Drip System

Nutrient-infused water is pumped through tubing directly to the base of plants in the drip system. Water can be dripped onto the plant bed at a slow rate to conserve water, or quickly as excess is returned to a tank below.

Most herbs and small plants can be grown in this system once the precise amount of water is dripped onto the roots.[12]

Wick System

A wick system is the most passive form of hydroponics, as it uses no electricity or pumps. Instead, the plants are placed in a soilless, absorbent medium with rope or yarn wicks reaching from the plants to the nutrient solution below.

Without pumps, not as much water typically reaches the plants through this system. Herbs are optimal for the wick system since they require small amounts of water.[12]

Kratky Method

The Kratky method is another passive form of hydroponics in which plants grow in a net or pot above nutrient-infused water with only the tips of their roots submerged. Oxygen reaches the root through an air gap between the base of the plant and water.

This system works well for most garden plants as long as the nutrient solution is replenished to the container as needed.[12]

Aeroponics

Aeroponics can be more difficult to set up than other systems because nutrient-infused water is sprayed onto the roots of suspended plants. A water pump forces water through misters which spray the roots of nearby plants. Excess water dripping from the roots can be collected in a tank with the water pump.

This method can be used to grow most small garden plants, but is not ideal for plants with large root systems or large water needs.[12]

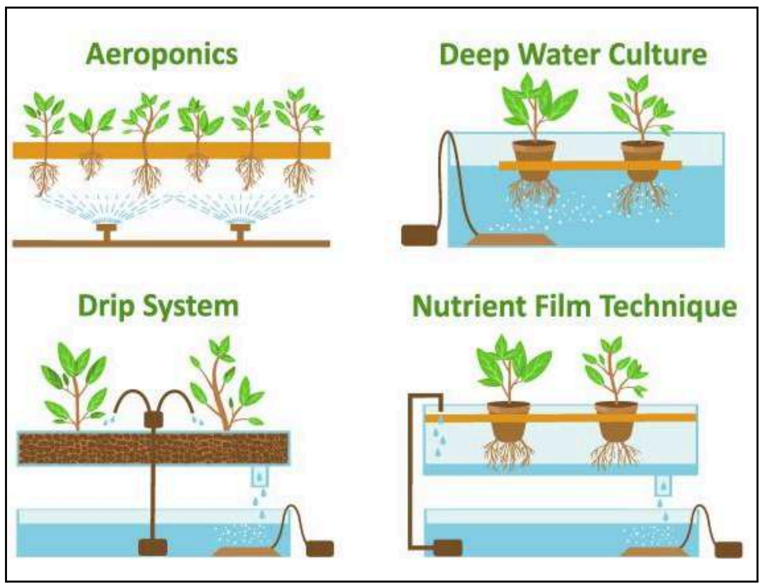

Figure 3: Display of different types of hydroponics explained above.[1]

D) Stages of Hydroponics

Seeding

Seeding is the initial step where seeds are placed into a suitable growing medium within a hydroponic setup. To begin, choose high-quality seeds that thrive in hydroponic environments and prepare the growing medium, such as rockwool or coconut coir Oasis Horticubes. Puncture equal-sized holes into the medium using an unsharpened pencil or object of similar diameter. Pour the seeds over the holes and fill each hole with enough seeds to reach the brim of the hole (around 10 seeds). Soak the growing medium in pH-adjusted water to ensure uniform moisture. Place the moist medium into seed trays, and sow the seeds at a depth about twice their size. Be sure to sow a few more seeds than necessary in case of germination failure. The objective during the seeding phase is to set up the seeds in a stable, well-prepared environment that facilitates the upcoming germination process.

After sowing, label each tray if multiple varieties of plants are being grown. This helps in monitoring and managing the growth conditions tailored to each plant type. The seeds do not require light at this stage, but maintaining the correct moisture level is crucial to prepare them for successful germination.

Figure 4: Ultrafoam Seed Starter, also known as Hydroponic Grow Sponges, where seeds are placed in the holes for germination.

Germination

Following seeding is **germination**, a critical phase where seeds begin to sprout and develop into young seedlings. This process starts when the seed absorbs water, swells, and breaks its shell. The ideal conditions for germination include maintaining temperatures between 68°F to 72°F and ensuring high humidity, which can be aided by using a humidity dome. Provide the seeds with 14-16 hours of light per day to encourage sprouting. Typically, it takes 7-14 days for cilantro seeds to germinate and 1-6 days for lettuce seeds to germinate.

Monitor the growing medium regularly to ensure it remains moist and maintain the pH within a range of 5.5 to 6.0. Once the seeds germinate, indicated by the emergence of the roots, start applying a nutrient solution at a quarter strength, gradually increasing as the seedlings mature. This careful management of environmental conditions during germination ensures that the seedlings have a robust start, setting the stage for a successful hydroponic garden.

The table below can be used to test the viability of seed germination. Tracking seed viability ensures that seeds are healthy enough for the next phase of hydroponic growth: transplanting.

Generally, germination takes 1 week with just water, 2 weeks with water and nutrients followed by a transportation to the hydroponic system typically for the next 3 weeks. It is important to note that these timelines are subject to change according to physical conditions and types of produce.[10]

Seed Germination Viability Log

Name: ______________________

Date: _______________________

<u>Seed Viability Test</u>

Date of Treatment/Seeding:

Seed #	Observations					
	2 days	4 days	9 days	11 days	16 days	18 days

Observed germination expressed as %:

$$\frac{(\text{\# healthy germinated seeds})}{\text{\# total seeds}} \times 100 = \#\ \%$$

Conclusions:

Transplanting

Transplanting in hydroponics is the process of moving seedlings from their initial germination medium to a permanent hydroponic system, crucial for their continued growth. Begin by ensuring that the seedlings are robust, displaying multiple true leaves and a well-developed root system.

Gently break off each square of oasis/foam with a plant inside. Try to bend the foam, not pull apart. Then place each foam square inside a hole in the hydroponic garden, being careful of the plant stem and angle of entry.

Figure 5: Mid-process of transplanting lettuce sprouts from the germination table to the hydroponic table. Carefully tear oasis cubes by separating in a top-down manner.

After transplanting, monitor the seedlings closely for signs of stress such as wilting or yellowing, and adjust light, nutrients, and environmental conditions as needed. Keep an eye on the nutrient concentration to avoid burning young plants with too strong a solution. Proper care during this stage sets a solid foundation for healthy plant growth in the hydroponic system.

Harvesting

Harvesting is the rewarding final phase of the hydroponic gardening lifecycle, crucial for maximizing yield and quality of the produce. Begin by monitoring your plants for signs of maturity, such as full color, size, and firmness, to determine the optimal time to harvest. Ensure that all equipment, like scissors or shears, is clean and sterilized, and always wear gloves to maintain hygiene and protect the produce.

Use sharp tools to cut plant roots cleanly; for leafy greens, you might snip individual leaves or entire heads, while fruiting plants require careful handling to cut fruits close to their stems without damaging them. Immediately after harvesting, place the produce in clean, dry containers or bags, and store them in a cool place or refrigerator to maintain freshness and extend shelf life. For long-term storage, consider methods like drying, freezing, or canning, depending on the type of produce.[10]

- ➔ The following timelines project the expected time of growth on both the germination table as well as the hydroponic frame.

Projected Plant Growth

Type of Produce	Germination TIme	Harvest Time (includes germination)	Best season
Cilantro	7-14 days	6-8 weeks	Oct-Feb
Lettuce	7-10 days	6-8 weeks	Nov-Apr
Strawberries	7-14 days	8-12 weeks	Nov-Apr
Spinach	7-14 days	5-7 weeks	Nov-Apr
Micro Herbs	3-10 days	1-3 weeks	Nov-Apr

Table 1: *Projected germination time, harvest time, and optimal seasons for specific types of produce*

E) Maintenance

pH Levels

The pH is one of the main points of emphasis when it comes to hydroponics, because pH levels influence every aspect of plant growth. pH provides an efficient read on how your plants will absorb nutrients; whether too acidic or too alkaline, your plants will not be able to absorb nutrients properly.

Considering this, pH levels must be tested each day to ensure proper growth. ***The proper pH should read ideally at 6.5*, but a range from 6.0-7.5 is a good level to maintain.** A pH test kit can be used to measure solution pH. This kit includes a pH testing solution that changes the color of the tested liquid based on its pH. The pH color scale is labeled on the bottle. Typically, when a green color is produced from the testing solution, the tested liquid is at the ideal 6.5 pH level.

pH down and pH up solutions are available to adjust pH levels accordingly, and the pH test solution allows for the exact pH level to be tested for. ***2 ounces of either pH up or down should adjust the level by one step accordingly.***

When testing the water for its pH, be sure to obtain a sample of the tank's water from the source (as it is pouring out of the black tubes into the tank). If the water is currently not running, then take the sample from the middle of the tank water to get an accurate read.

Figure 6: pH kit purchased at Hydro Warehouse. Contains pH Up, pH Down, and a pH tester.

Pest and Disease Control

To fight off pests, disease, and fungus, the easiest solution stems from the type of seeds purchased. Seeds will be labeled and coated in a bright dye when they have pesticide or fungicide treatments applied to them. It is most efficient to use these since they are pre-treated and can be seeded immediately without extra treatment required.

In terms of pest control, we ideally want to use sustainable and environmentally friendly options. In the Gandul area, some of the biggest pests are stray cats and chickens. We have taped aluminum foil to the bottom of the plastic tarp to scare off said pests. Additionally, the foil is known to repel other pests like aphids and thrips that are harder to detect.

Algae is a final pest that can be easily avoided by using opaque tubes and tanks. Additionally, if algae appears in tubing or the system at all, the model can be deconstructed to run a brush through the tubes and clear any excess roots or algae.

Minerals and Supplemental Nutrients

There are several nutrients and fertilizers necessary for hydroponic systems. The following measurements are necessary for a 55 gallon drum, and can be adjusted accordingly. *All the measurements should be mixed together in a water-tight container with one gallon of water before being added to the drum.*

Nutritional Solution Mixture

- 1 oz NPK
- 1 oz Calcium Nitrate
- 2 oz Magnesium
- 1 oz iron
- 0.5 oz Raizal
- 1 oz pH Down
- 1 oz Garden Phos

On the 3rd week of germination, the nutrient solution should be added to the germinating seeds. When transplanted to the A-frame, the same nutrient measurements should be used in the tank. These measurements will be added to the tank as necessary up until the final week on the frame. In the final week, the added nutrients are no longer necessary, and the system should be flushed out with water only.

Most importantly, be sure to utilize an NPK fertilizer (nitrogen, phosphorus, potassium) with the ratio of 11-11-40. Nitrogen is meant to help the plants grow leaves and turn green. Phosphorus particularly supports buds, flowers, and fruits on the plants. Potassium aids with overall growth.

Calcium nitrate should also be used in the mineral mixture. Calcium sulfate is also an option, but less soluble in water, making calcium nitrate the better option. Calcium nitrate is known to stimulate root growth and health. With stimulated root growth, the plant is more likely to uptake nutrients.

- ➔ Magnesium is vital as it aids the plants in sunlight absorption. In turn, photosynthesis is boosted by the increased sunlight absorption.
- ➔ Iron is important for chlorophyll synthesis, or the green color of plants. Therefore, if the plants turn yellow, this indicates low iron levels.
- ➔ Raizal is a good addition as it is a fertilizer aid that improves root growth in young plants.
- ➔ pH Down is necessary to drop the typically basic Puerto Rico water to a pH of 6-6.5. pH should be tested before adding pH up or down to the 55 gallon drum.
- ➔ Garden Phos is also important, as it is a phosphorus-based fungicide for plants and gardens. With this added nutrient, the plants are less susceptible to fungus infections.

☀️*Sunlight*

For proper growth, plants need at least 6 hours of sunlight a day. However, direct sunlight can be harmful to hydroponic plants and cause them to dry out and wilt. Therefore, some form of transparent roofing is necessary in order to allow for some light that isn't too harsh.

💧*Water Quality*

With the correct nutrient measurements, the water quality should be at the proper level for hydroponic growth.

Typical tap water in Puerto Rico is measured at around a pH of 6-7. With this level of pH, water quality is generally safe to use for hydroponics with minimal adjustments. The proper nutrients and minerals still should be added to the water, since it lacks the nutrients that plants require.

Electrical conductivity (EC) is also an important test to run for evaluating water quality. Conductivity meters can be purchased from hydroponic stores and online.

Test the EC levels starting at week 3 of germination, or whenever nutrients are added to the water supply. At the first week of nutrient addition, EC should read at 200-300 ppm. The first week in the hydroponic frame should have EC levels of 800-900 ppm. The second week should read at 1200-1400 ppm. The final week should fall back to the initial week, at around 200-300 ppm.

While pH and EC levels of tap water are generally safe, it still is important to regularly test pH and EC to ensure optimal plant growth.

Basic Supplies and Materials

Aside from the hydroponic frame, there are a handful of other necessary materials.

First seeds are important with the best seeds being pre-treated fungicide seeds. If non-treated seeds are purchased, purchase pest or disease control items (sprays or solutions) to add to the water tank.

Next, horticultural foam is necessary for seeds to germinate and grow in. This is generally referred to as Ultrafoam Seed Starters or Hydroponic Grow Sponges. Seeds are distributed into the foam, and then left to germinate and grow roots through the foam for the entirety of its growth.

Tracking Plant Progress

The following table can be used to record hydroponic progress to ensure target growth and measures are reached. This table is an example of one week's progress.

Daily Plant Data Collection Chart

Month:			Crop:		
	Transplant Day	Temperature (°F)	CE	pH	Date (Year)
1st Week	1				
	2				
	3				
	4				
	5				
	6				
	7				

IV. GANDUL COMMUNITY CENTER HYDROPONIC GARDEN

A) Garden Construction

Garden Set-Up

The hydroponic garden in Gandul was created as an A-frame model right outside of the community center. The A-frame design allows for 5 plant pipes on each side (10 total), with 9 holes on each pipe, a total of 90 plant holes on the frame.

The 55 gallon drum holds a 793 gal/hour adjustable water pump in roughly 30 gallons of water. Water is fed from the pump in the tank up black PVC tubing. A T-connector then feeds water through ½ inch spaghetti tubes to each plant pipe.

Figure 7: A rough mock-up of the hydroponic using skewer sticks and hot glue. The model was scaled to measurements of the outdoor alleyway in order to portray an accurate mock-up of the final product.

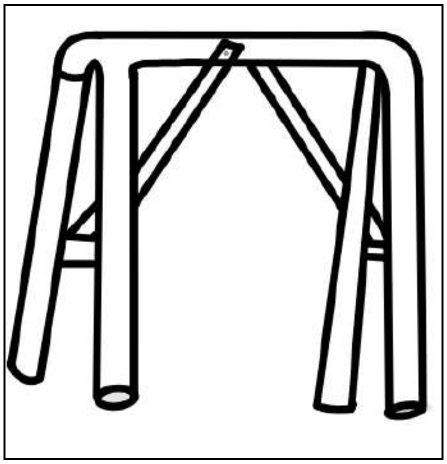

Figure 8: A digital depiction of the design of the final PVC frame. The figure is not to scale.

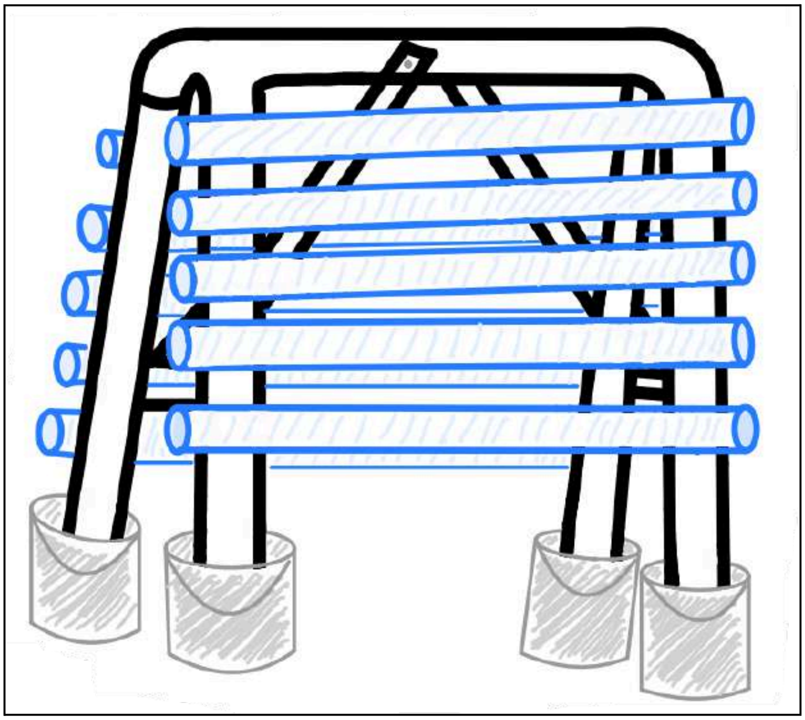

Figure 9: A digital depiction of the design of the final hydroponic system; not including water circulation pieces (tank, tubing, zip ties, water pump, and roofing). The figure is not to scale.

Location

Our hydroponic model is located in the outdoor alley area of the Gandul Community Center in Gandul, San Juan.

The alleyway is a rectangular space about 9 feet wide by 40 feet long, with troughs and some outdoor materials stored against the concrete walls. A stairway leads to the roof of the Community Center in the back of the alley.

Figure 10: The alleyway next to the Gandul Community center before construction (left) and after hydroponic construction (right).

Budget and Materials List

This table itemizes the required materials to build the hydroponic garden, and maintain it with nutrients and plants. Estimated costs are provided, however some items may vary depending on where they are purchased from hence why specific shops were also recommended.

In general, a *single quotation mark ‘* after a number indicates *measurements in feet*, while a *double quotation mark “* after a number indicates *measurements in inches*. More details about the table and characters used can be found below the table.

Table 1: Estimated Costs for Water System Materials

Hydroponic Garden Materials	Quantity	Estimated Costs (Tax included)	Store Where Item was Purchased
½" black rubber tubing	40 feet	$22.00	Hydro WareHouse PR
¼" black rubber tubing	30 feet	$9.00	Hydro WareHouse PR
ECOPlus 793 GPH Water Pump	1	$91.00	Hydro WareHouse PR
½” "T" connecter (plastic)	1	$0.50	Hydro WareHouse PR
Grow1 Mechanical Timer	1	$16.00	Hydro WareHouse PR
Food Grade Plastic blue 55 gallon drum	1	$45.00	Maderas 3C

Table 2: Estimated Costs for Nutrients and Seeds

Hydroponic Garden Materials	Quantity	Estimated Costs (Tax included)	Store Where Item was Purchased
11-11-40 Master Plant-Prod fertilizer	1 lb	$5.00	Hydro WareHouse PR
Magnesium powder	1 lb	$5.00	Hydro WareHouse PR
GH pH control kit	1	$22.00	Hydro WareHouse PR
Cilantro Seeds	1 lb	$22.00	Hydro WareHouse PR
Black plastic tray (20" x 10" x 2")	1	$4.00	Hydro WareHouse PR
Ultra foam Seed Starter	1	$6.00	Hydro WareHouse PR
Calcium Nitrate	55 lbs	$44.00	Pan American Grain Corujo

Table 3: Estimated Costs for PVC and Frame material

Hydroponic Garden Materials	Quantity	Estimated Costs (Tax included)	Store Where Item was Purchased
1-½" PVC Elbow	2	$13.50	Ferretería Comercial Caraballo
1 ½" PVC Duct 45 Degree Wye	2	$10.00	Ferretería Comercial Caraballo
1 ½" T-PVC connector	1	$3.00	Ferretería Comercial Caraballo
10' by 2" PVC pipe	6	$45.00	Home Depot
10' by 1 ½" PVC pipe	3	$22.00	Home Depot
10' by ½" PVC pipe	2	$14.00	Home Depot
J-hook for 2" pipe hanger	20	$30.00	Home Depot
2" PVC pipe caps	20	$31.00	Caribbean Lumber Cupey

Table 4: Estimated Costs for Tools

Hydroponic Garden Materials	Quantity	Estimated Costs (Tax included)	Store Where Item was Purchased
5/16" nut	4	$0.60	Ferretería Comercial Caraballo
5/16" Hex screw	4	$7.00	Ferretería Comercial Caraballo
⅜" Washers	8	$1.50	Ferretería Comercial Caraballo
¼" by 3" metal screw	4	$3.00	Ferretería Comercial Caraballo
¼" metal nut	4	$0.50	Ferretería Comercial Caraballo
¼" metal washer	4	$0.50	Ferretería Comercial Caraballo
Weld On 725 Wet 'R Dry PVC glue (32 oz)	1	$4.00	Ferretería Comercial Caraballo
12-inch Handsaw	1	$8.00	------------------------ --------
2" hole saw	1	$8.00	------------------------ --------
Hand dremel/Mini Rotary tool with cone attachment	1	$20.00	----------------------- ---------
Drill bit tool kit containing 5/16", ¼" and ½"	1	$11.00	----------------------- ------------

Table 5: Estimated Costs for Miscellaneous Items

Hydroponic Garden Materials	Quantity	Estimated Costs (Tax included)	Store Where Item was Purchased
black zip-ties	1 package (50 ties)	$5.00	Ferretería El Cometa
HUSKY plastic tarp (10ft x 20ft)	2	$16.00	Walmart
10' x 10' Instant Slant Leg Outdoor Canopy	1	$50.00	-------------------------------
½" Tube caps (alternative: marbles)	2	$3.00	-------------------------------
5 Gal Paint Buckets	4	$7.00	-------------------------------
Rocks/sand	100 lbs	$37.00	-------------------------------
Wooden or PVC 2' by 1' plank	1	$7.00	-------------------------------

Estimated Total Cost for Hydroponic system, nutrients, and seeds:	$649.10

Notes:

*Dashes (------) in the column "Store Where Item was Purchased" indicate that the material was already available at the Gandul Community Center for use in this project.

*A hand dremel is ideal, but still optional for smoothing rough edges and getting rid of rough pieces of PVC after drilling. Sandpaper is also an optional alternative for making the holes in the troughs smooth.

*****Some items identified above may already be freely available in homes or organizations for use. Each item was listed and an estimated cost provided to show a thorough, complete list of the hydroponic system requirements.

*****Quantities for all items are either exact or slightly over estimated in order to ensure enough material would be purchased for construction.

Building the Frame

Materials Needed:

- 30 ft of 1 ½" PVC pipe
- 1 ½"PVC T-connector
- 130 inches of ½" PVC pipe
- Weld On Wet 'R Dry PVC Glue
- 1 ½" PVC Duct 45 Degree Wye (2x)
- 1 ½" PVC elbow (2x)
- 2" wide J-Hook (20x) (and custom screws in the hooks)
- 5/16" metal screws (4x)
- 5/16" nut (4x)
- 3/8" Washers (4x)
- 1/4 by 3" metal screw (4x)
- 1/4" nut (4x)
- 1/4" washer (4x)
- Tools: Handsaw, hand drill, 5/16" drill bit, ½" drill bit, hand dremel
- 5 gallon Paint bucket (4x)
- Rocks/sand

Cutting:

- *See ***Health and Safety*** on **page 47** to protect yourself from PVC shavings and other concerns of hydroponic materials!
- Use the handsaw to cut the 1 ½" wide PVC into four 6 foot long pieces, and two 2.5 foot pieces
- Cut the ½" wide PVC into two 3.5 foot long pieces, and two 23 inch long pieces.

Gluing:

- Wipe PVC glue along the inside of the 1 ½" PVC elbow on one end, then immediately insert one of the 2.5 foot PVC pieces into the elbow. (Repeat this step using the second 1 ½" elbow and 2.5 foot long PVC pipe to make two identical ends).

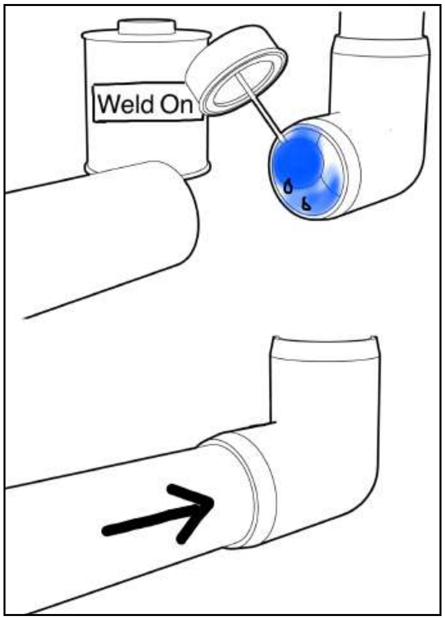

Figure 11: Gluing a PVC elbow with the 2.5 foot PVC pipe.

- Wipe PVC glue along the inside of the other end of the PVC elbow and insert the 1 ½" PVC Duct 45 Degree Wye. (Repeat this for the second elbow).
- Wipe PVC glue along the inside of a free end of the 1 ½" PVC Duct 45 Degree Wye, and immediately insert one of the 6 foot pieces of PVC. (Repeat this step for the third opening of the 1 ½" PVC Duct 45 Degree Wye. The result should be a large upside down "V" structure).

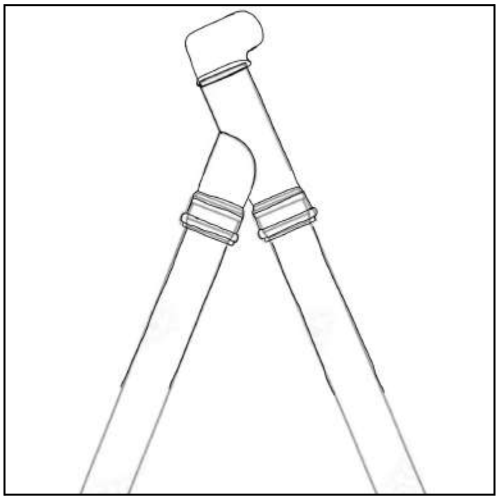

Figure 12: Sketch of the two legs of the hydroponic frame connected by the 1 ½" PVC Duct 45 Degree Wye. The PVC elbow is also drawn for clarity but the rest of the frame is not drawn. Image is not to scale.

- Repeat the previous step using the second 1 ½" PVC Duct 45 Degree Wye, and the rest of the 6 foot long 1 ½" PVC.
- Attach the two ends of the frame using the 1 ½" PVC T-connector. Attach the 2.5 foot long PVC pipes to make the frame a total of 5 feet long.

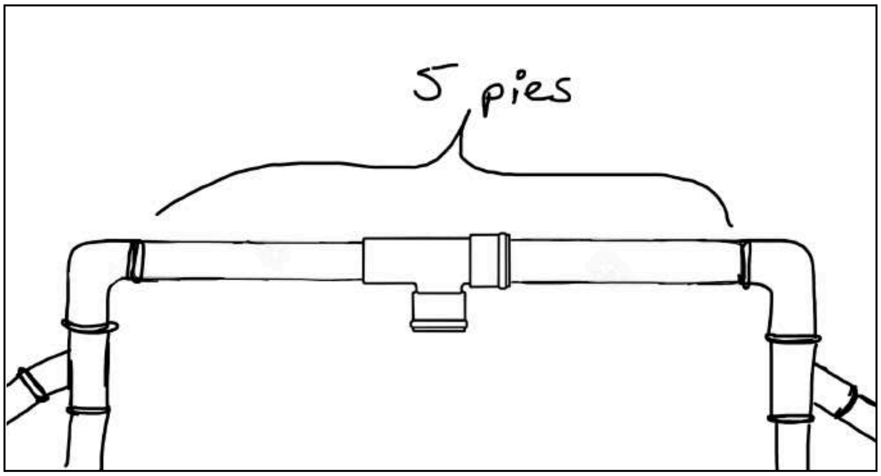

Figure 13: Sketch of the two 2.5 foot PVC tubes connected by the 1 ½"T-connector to form the top of the hydroponic frame. Image is not to scale.

Pressing/Melting:

- Flatten both ends of the 3.5 foot long pieces of 1 ½" PVC by placing the PVC on a hot burner (or other heat source) and gently hitting the PVC with a hammer
- Flatten 2 inches of the 3.5 foot long 1 ½" PVC on both ends, make sure to flatten on end horizontally and the other vertically (see Figure 14).
    - Flattening the ends of the PVC will make drilling this pipe into the rest of the frame easier
- Allow PVC to cool completely before use

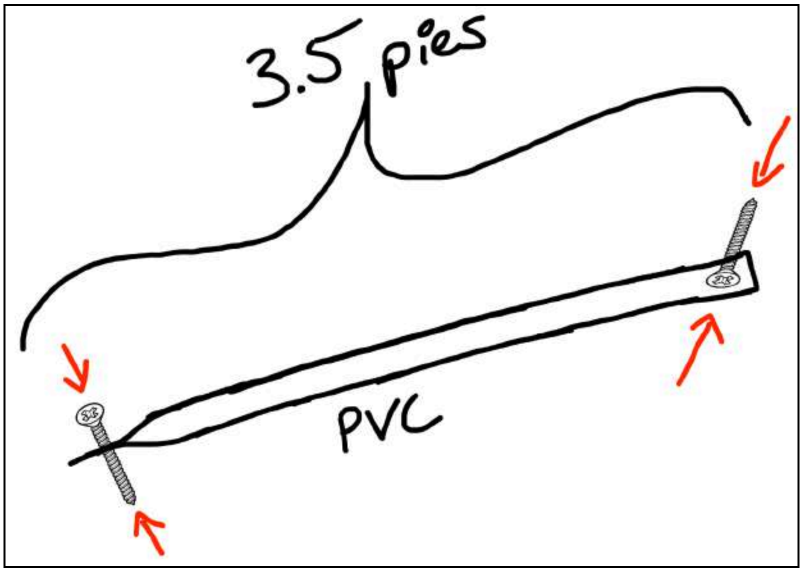

Figure 14: Sketch of the 3.5 foot long 1 ½" PVC which is flattened on both ends, but in perpendicular directions. Screws show where the pipe will attach to the frame. Image is not to scale.

Drilling:

- Use a 5/16" drill bit to create holes for the 5/16" metal screws, and attach the 23 inch long ½" PVC between the legs of the frame on both sides (see Figure 15). Attach fitted nuts and washers on the backs of screws.
  - The PVC should attach to two legs of the frame, and is situated roughly 3 feet off the ground.
  - We called this PVC pipe the "A-bar" because it creates the line that makes the hydroponic frame resemble an uppercase "A."
  - A hand dremel was used to smooth any rough edges and pieces of PVC after holes were drilled.
  - Repeat this process on both sides of the hydroponic frame.

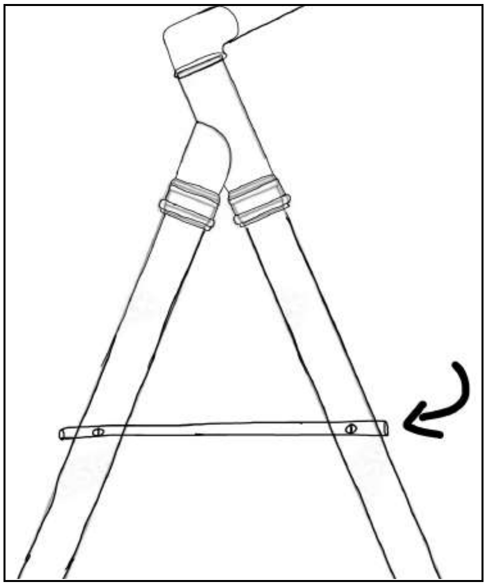

Figure 15: Sketch of the 23 inch PVC “A-bar” which stabilizes two legs of the frame. Image is not to scale.

- Use a ½” drill bit to create holes for the ¼” by 3” metal screws, and attach the 3.5 foot long ½” PVC to the frame. Attach fitted nuts and washers on the backs of screws.
    - One flattened end will be screwed onto the side of the frame approximately 3 inches in front of the 1 ½” PVC T-connector
    - The other flattened end will be screwed onto the top of the A-bar (see Figure 16).

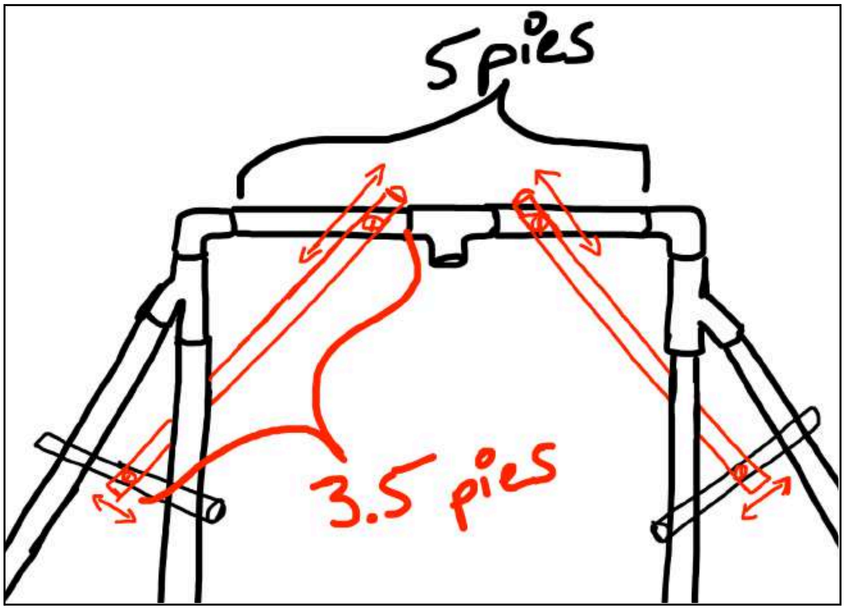

Figure 16: Sketch of the 3.5 foot long 1 ½" PVC pipes drilled into the A-bars and frame. One flattened end rests on an A-bar and the other is drilled parallel into the top of the frame. Image is not drawn to scale.

- The ½" bars provide more strength and stability to the hydroponic to endure plant weight and wind.
- Use a handsaw to cut off half of the 2" wide J-Hook neck, then use a hand drill to screw the J-Hooks into specific measured locations on the legs of the hydroponic frame. (Appropriate screws were provided in the package with the J-Hook).
    - The top hook (1st row) should be screwed into the leg of the frame directly below the 1 ½" PVC Duct 45 Degree Wye piece (see Figure 17). This is for both legs closest to the tank (outflow).
    - The following four hooks should be drilled into the leg of the frame closest to the water tank (outflow), at these specified heights measured downwards from the top of the PVC leg (inside the Wye piece):
        - 2nd row: 13 inches down
        - 3rd row: 24 inches down
        - 4th row: 36 inches down
        - 5th row (bottom): 47 inches down

- The following five hooks should be drilled into the leg of the frame closest to the water input ¼" tubes (inflow), at these specified heights measured downwards from the top of the PVC leg (inside the Wye piece):
  - Top row: 1.5 inches above leg (screwed into Wye connector)
  - 2nd row: 11 inches down (the leg of the frame)
  - 3rd row: 21 inches down
  - 4th row: 33 inches down
  - 5th row (bottom): 44. 5 inches down

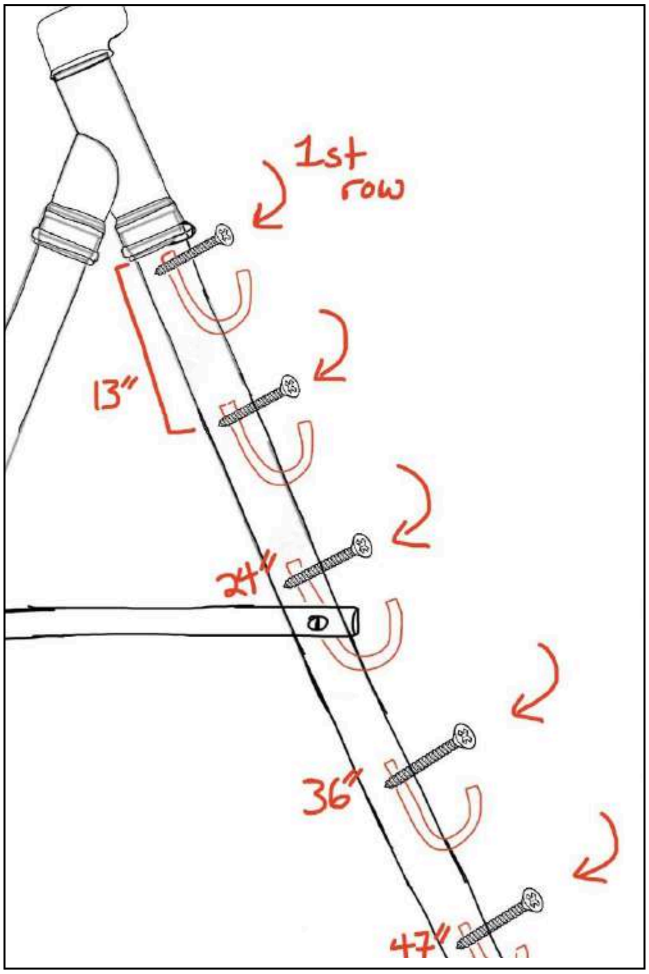

Figure 17: Sketch of J-Hook positions on one leg. Distance is measured from the top of the leg downwards. Hooks are roughly 1 foot apart. Image is not to scale.

- Hooks need to be drilled at these heights on both sides of the hydroponic frame (5 hooks per leg, 10 hooks on one side of frame, 20 hooks used total).

Stabilize:

- Place each 6 foot long PVC leg of the frame into its own empty paint bucket, then fill buckets with sand or rock to immobilize the hydroponic.

Building the Troughs

Materials Needed:

- Tools: Handsaw, hand drill, hand dremel, 2” hole saw, ½” drill bit, ¼” drill bit
- 60 feet of 2” PVC pipe
- 2” PVC Caps (20x)
- Weld On Wet ‘R Dry PVC Glue

Cutting:

- Use the handsaw to cut the 2” wide PVC into six, 6 foot long tubes, and use the remaining PVC scrap to create four, 6 foot 1 inch (73 inch total) long tubes of PVC.
    - Each 10’ pipe of PVC should have a regular end and a bulky end, the bulky end is for joining pieces of 2” PVC together (see Figure 18).

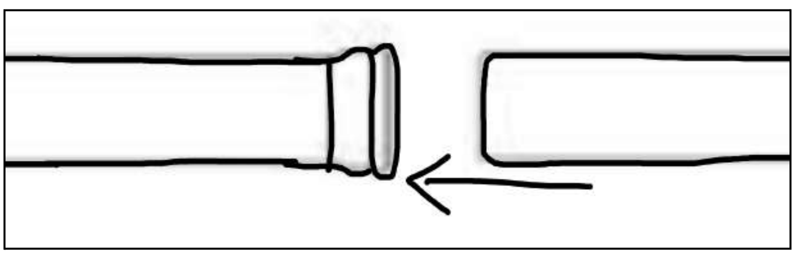

Figure 18: Sketch of a PVC pipe bulky end connecting with a regular/smooth end from a different pipe. Image is not to scale.[9]

Gluing:

- Wipe PVC glue along the inside of the bulky end of a PVC tube and immediately insert another piece of PVC.

    - (Our team joined 4 foot and 2 foot pieces of 2" PVC in order to create the necessary 6 foot long tubes to hold enough plants on the hydroponic).

Drilling:

- Use a ½" drill bit and a 2" hole saw attached to a hand drill to create 2" wide holes in each trough of PVC (total of 10 troughs, 9 holes per trough = 90 holes on hydroponic)
    - Make sure the drill does not go through both sides of the PVC!!! The hole is on one side of each tube, and all of the holes should be lined up in a row.
    - 9 holes can be made in total, with 5" of space between each
    - The first and last holes should be 7" apart from the edge of the troughs
        - (Although for the bottom tubes which are 6' 1" there can be more space from the edge. For example 8").

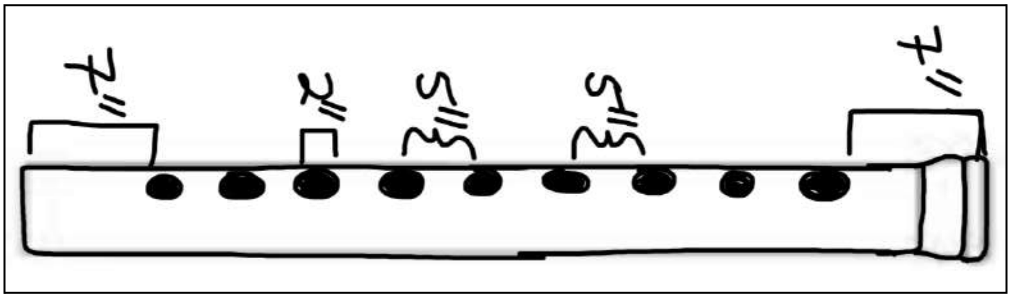

Figure 19: Sketch of one 2" PVC trough with 9 holes spaced apart appropriately. Image is not to scale.[9]

- Use a ½" drill bit attached to a hand drill to create a ½" hole in a corner for 10 of the PVC caps (see Figure 20).

Figure 20: Sketch of a hole made in a 2" PVC cap using the ½" drill bit. Caps with ¼" holes look similar. Image is not to scale.[4,8]

- Use a ¼" drill bit attached to a hand drill to create a ¼" hole in a corner for the other 10 PVC caps.
    - A piece of ¼" spaghetti tubing was used as a reference to make the hole the correct size, and be airtight with the spaghetti inserted.
    - A hand dremel was used to smooth rough edges and pieces of PVC after holes were drilled.

Stabilize:

- Place each trough into the curve of two J-Hooks. Troughs are secured when pushed down fully and a distinct "click" is heard from the tubing. Be careful not to crack the PVC.
- Push the 2" PVC caps onto each open end of the troughs with the hole closest to the ground.
    - The caps with a ½" hole should be on the side closest to the tank (outflow).
    - The caps with the ¼" hole should be on the side farthest from the tank (inflow).

Building the Water System

Materials Needed:

- Tools: Scissors, hand dremel
- 35 feet of ½" black rubber tubing
- 26 feet of ¼" black spaghetti tubing
- ½" plastic T-connector
- Zip-ties
- ½" cap or marbles (2x)

Cutting:

- Use large scissors to cut the ½" black rubber tubing into:
    - 122 inch piece (1x)
    - 50 inch pieces (2x)
    - 40 inch pieces (2x)
    - 25 inch pieces (2x)

  - 13 inch pieces (2x)
  - 9 inch pieces (2x)
  - 8.5 inch pieces (2x)
- Use large scissors to cut the ¼” black rubber tubing (a.k.a spaghetti tubing) into:
  - 50 inch pieces (2x)
  - 42 inch pieces (2x)
  - 30 inch pieces (2x)
  - 25 inch pieces (2x)
  - 9 inch pieces (2x)

Drilling:

- Select one of the 8.5 inch long ½” tubes, and use a hand dremel with cone attachment to create 5 holes of ¼” on one side of the tube (see Figure 21).
  - Make sure not to drill completely through the rubber tubing!!
  - Use a piece of ¼” spaghetti tubing as a reference to make the hole the correct size, and be airtight with the spaghetti inserted.
- Leave roughly 1 inch of space between each ¼” hole.
  - The first hole was made 1.5 inches away from the end of the tubing.
  - The last hole was made 2.5 inches away from the end of the tubing.
- Repeat this process for the other 8.5 inch long ½” tube.

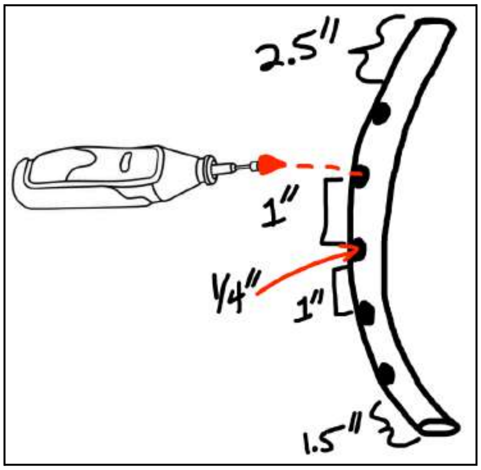

Figure 21: Sketch of the hand dremel being used to make ¼” holes in one side of the 8.5 inch long ½” tubing. Image is not to scale.

Connect:

- Use tip-ties to attach the 122 inch long ½" tubing to the frame, traveling up from the tank/pump, across the 5 foot long 1 ½" PVC (see Figure 22).

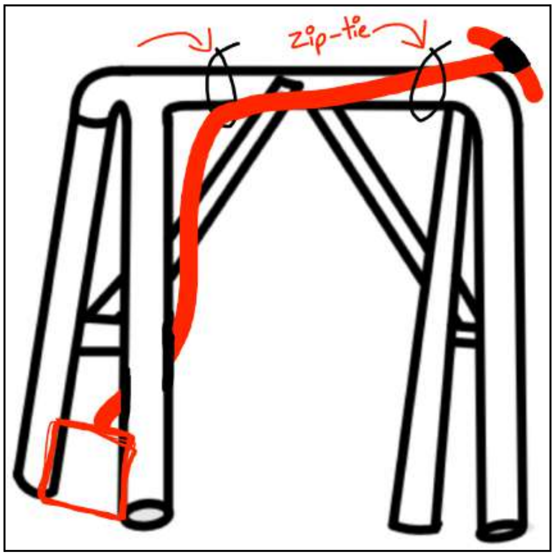

Figure 22: Sketch of water-delivering ½" tube crossing the hydroponic frame. Image is not to scale.

- Push the ½" plastic T-connector into the ½" rubber tube at the top of the frame, and attach each 8.5 inch long ½" tube to the sides of the "T" with the holes facing down.
  - The hole that is 2.5 inches away from the end of the 8.5 inch long tube should be closest to the T-connector.
  - The hole that is 1.5 inches away from the end of the 8.5 inch long tube should be farthest from the T-connector (see Figure 23).

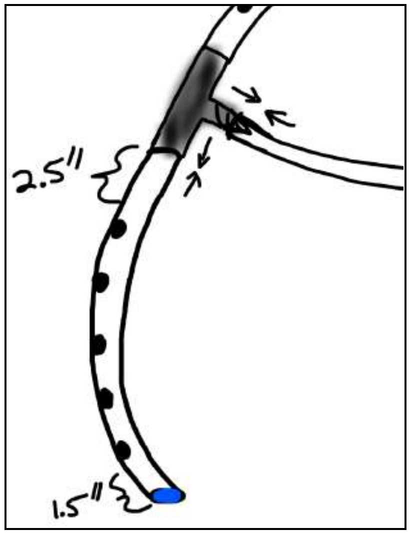

Figure 23: Sketch of ½" rubber tubing which distributes water to each PVC trough. Image is not to scale.

- Attach the appropriate lengths of ¼" spaghetti tubing to each hole in the ½" tubes. Put the opposite end of each ¼" spaghetti tube into the appropriate hole of the PVC trough caps (see Figure 24).

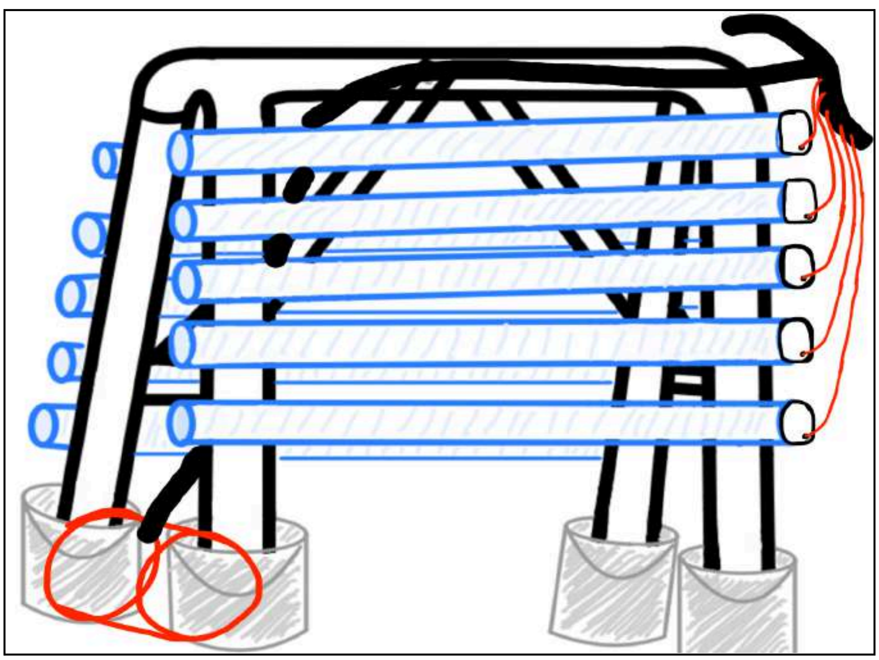

Figure 24: Sketch of the spaghetti tubes attached to their appropriate troughs. Image is not to scale.

- Insert a cap or marble into the end of the ½" tubing in order to seal the "T" and force all water down the ¼" spaghetti tubes.
- Attach the appropriate lengths of ½" rubber tubing to each ½" hole in the PVC caps, then zip-tie the tubes together and place the open ends into the tank (see Figure 25 and *Tank Set-Up* for more details).

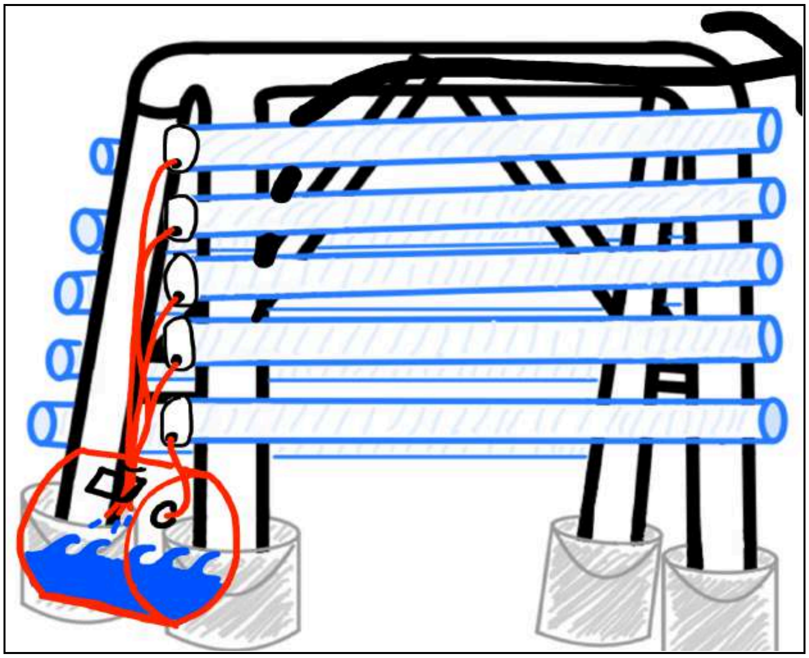

Figure 25: Sketch of ½" rubber tubes attached to their appropriate troughs and emptying into the tank. Image is not to scale.

Tank Set-Up

The tank is a 55 gallon blue drum which is safe for holding potable water. The tank will be placed horizontally on its side between the legs of the frame on the outflow side of the hydroponic. The outflow side uses the ½" tubes which will carry water back into the tank to be reused by the pump.

<u>Materials Needed:</u>

- Tools: handsaw, hand drill, ½" drill bit, 2" hole saw
- 55 gallon drum
- Wooden or PVC 2' by 1' plank
- Cinder block, bucket, excess pipes, or some form of anchor

Drilling:

- Remember to position the 55 gallon drum horizontally, laying on its side!
- Use a ½" drill bit and 2" hole saw attached to a hand drill to create a 2" hole on the side of the 55 gallon drum near the 5th trough outflow tube (see Figure 26).

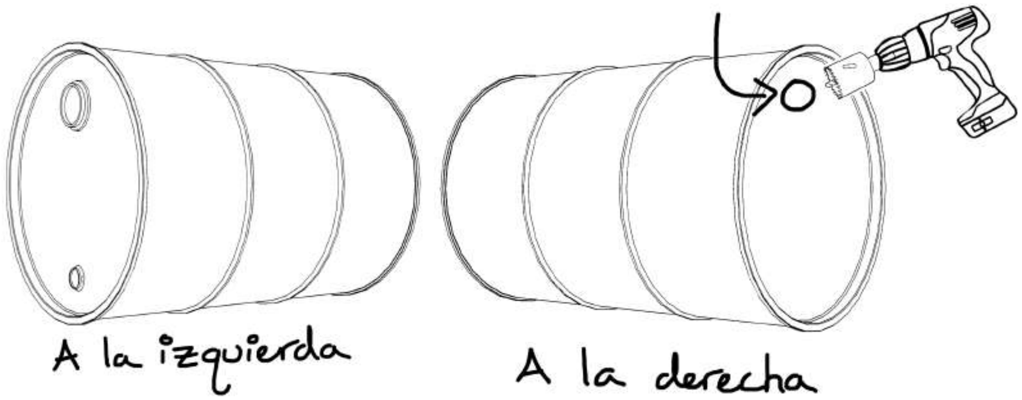

Figure 26: Sketch of the 55 gallon drum with a 2" hole drilled into the side without a cap already. Image is not to scale.[5]

- Use a ½" drill bit and 2" hole saw attached to a hand drill to create four 2" holes in a square on the top of the drum (see Figure 27).[6]
  - This will become the lid for inserting the pump, nutrients, etc.

Cutting:

- Use a handsaw or knife to cut the plastic between three of the 2" holes.
  - Leave one side of the square intact in order to create a makeshift lid for the tank (see Figure 27).

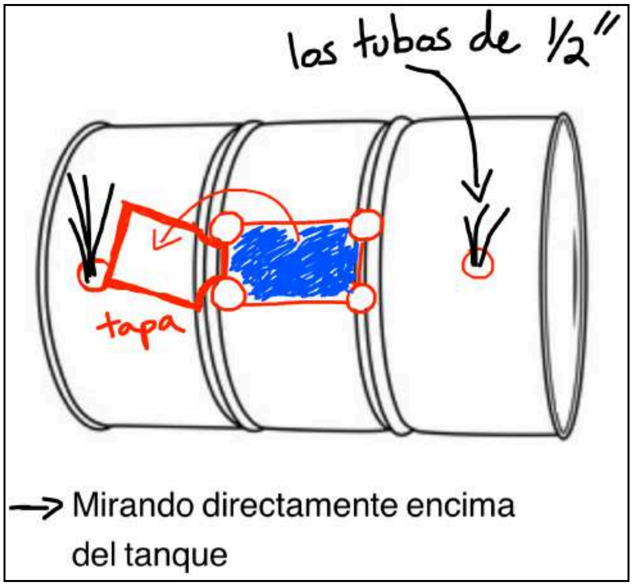

Figure 27: Sketch of the 55 gallon tank with a square cut out of it by drilling 2" holes. The ½" tubes have their own holes, but this is not strictly necessary. Image is not to scale.[5]

Stabilize:

- Place a plank of PVC or wood underneath the 55 gallon drum.
- Place a cinder block, bucket, excess piping, or other anchor against the drum so it cannot roll.

Timer Set-Up

The Grow1 Mechanical Timer measures 24 hours in increments of 15 minutes, represented by small, black panels/switches that surround the clock. To set the hydroponic to be powered for 15 minutes then off for 15 minutes in a cycle, simply flip each switch in an alternating pattern.

B) Plant Life Cycle

Timeline of Projected Cilantro Growth

Begin by planting cilantro seeds in a suitable medium like Rockwool cubes, ensuring they are kept moist and positioned under sufficient lighting. Seeds generally germinate within 7-10 days in conditions of 65-70°F with high humidity, developing several true leaves by the third week. At this point, start applying a gentle nutrient regimen tailored for herbs and adjust lighting to maintain 14-16 hours per day to promote robust growth.

As the cilantro enters the vegetative growth phase around weeks 5-6, it will grow rapidly, requiring careful monitoring of nutrient levels and pH adjustments. Look out for signs of pests or nutrient deficiencies and address them promptly. By weeks 7-8, the plants will mature and be ready for harvesting. If you notice signs of bolting, it's best to harvest immediately; otherwise, you can selectively harvest outer leaves to prolong the plant's productivity.

Maintenance (pH control, minerals, pest control etc.)

Regularly check the pH of the nutrient solution with a pH meter, maintaining a range of 5.5 to 6.5 to optimize nutrient uptake. Use an EC meter to monitor the nutrient strength, aiming for an EC level between 1.2 and 1.8, and adjust the nutrient mix weekly, ensuring it includes essential elements like nitrogen, magnesium, potassium, and calcium.

Pest control is crucial; inspect plants frequently for signs of pests such as aphids and spider mites, and use organic methods like insecticidal soap or neem oil for treatment. Ensure good air circulation and avoid excess moisture on foliage to prevent fungal diseases. Additionally, clean and sterilize the hydroponic system between growth cycles to eliminate disease and mineral build-up, replacing all water and nutrients periodically to maintain a fresh environment for the plants.

Transplanting and Harvesting Cilantro

When cilantro seedlings develop 2-3 true leaves, they should be carefully transplanted to their final hydroponic system. Gentle handling is crucial during transplantation to avoid damaging the delicate roots, which could stress the plants and inhibit their growth.

Harvesting begins when the cilantro reaches about 3-4 inches in height. It's best to harvest the outer leaves first, allowing the inner leaves to mature further, which promotes continuous growth. Frequent harvesting, ideally not removing more than one-third of the plant at a time, helps prevent the plant from bolting and maintains a steady production of fresh leaves. Harvesting before the plant flowers ensures the leaves retain their flavor and are most aromatic.

C) Other Considerations

Health and Safety

Particularly during the construction period of hydroponic gardens, there are a number of safety regulations to follow and be aware of.

Handling PVC Materials in Hydroponics:

When working with PVC (polyvinyl-chloride) pipes in hydroponic systems, it's essential to consider the health risks associated with PVC shavings. Cutting or sanding PVC can produce fine dust and shavings that pose respiratory hazards if inhaled, leading to irritation of the nose, throat, and lungs. Extended exposure could result in more severe respiratory issues.

To mitigate these risks, always wear protective gear such as a dust mask or respirator and work in a well-ventilated area to ensure PVC particles are efficiently dispersed. Following the completion of work, thoroughly clean the area to remove all PVC residues and wash your hands to avoid skin contact with these particles.[2]

[13]

Using Power Tools (Hand Drills and Saws):

Hand drills and saws are commonly used in constructing hydroponic systems but come with risks like cuts, abrasions, and eye injuries from flying debris. To safeguard against these dangers, it’s critical to always wear safety goggles or a face shield during operation. 

Ensure all tools are in good working condition and that you are properly trained to use them. Secure materials firmly before beginning any cuts or drilling to prevent movement that could cause accidents. Wearing gloves can also help absorb vibrations and protect your hands from injuries while using these power tools.[2]

General Hydroponic System Safety:

Managing a hydroponic system involves careful handling of chemicals and ensuring electrical safety due to the close proximity of water and electricity. When dealing with hydroponic nutrients and pH adjusters, which can be corrosive or toxic, wear appropriate protective clothing like gloves, aprons, and eye protection. Store chemicals in a cool, dry place in properly labeled, sealed containers to avoid accidental ingestion or contact.

Electrical installations should be handled by qualified professionals and protected against water exposure. Utilize GFCI (Ground Fault Circuit Interrupter) outlets to prevent shock risks. Keep the hydroponics area well-lit, tidy, and free of obstructions to prevent accidents such as trips and falls, ensuring a safe and efficient work environment.[2]

D) Design Alternatives

Awning

An awning poses as a great alternative to a tent cover roof. Awnings are a sheet of some material stretched along a frame that works to protect from rain, sun, and other environmental factors.

Clear plastic or tarp would be suitable materials to stretch over the awning frame. The awning would require a solid foundation into a wall in order to hold itself up.

Table Structure

In this design, the table supports trays or channels filled with a soilless growing medium, where plants are placed. A nutrient-rich solution is circulated to the plants' roots by a pump from a reservoir situated beneath or next to the table. The solution can be recirculated, minimizing waste. Air stones placed in the reservoir ensure the water remains oxygen-rich, which is critical for healthy root development. The system can be automated using timers to regulate the water and light cycles, making it efficient and straightforward to manage.

Pros and Cons of Table Structure Hydroponics:

Pros:

- The table structure design maximizes plant density and yield per square foot, making it an efficient choice for high production.
- Easy access to plants for maintenance and harvesting, as they are raised to a convenient height.
- Water and nutrient-efficient design which recirculates the solution, reducing overall consumption and waste.

Cons:

- Initial setup for a table structure hydroponic system can be costly, particularly if opting for durable materials like metal and automated controls.
- Reliance on electricity for pumps and lighting systems introduces vulnerability during power outages and increases operational costs.
- This design generally requires a larger available space.

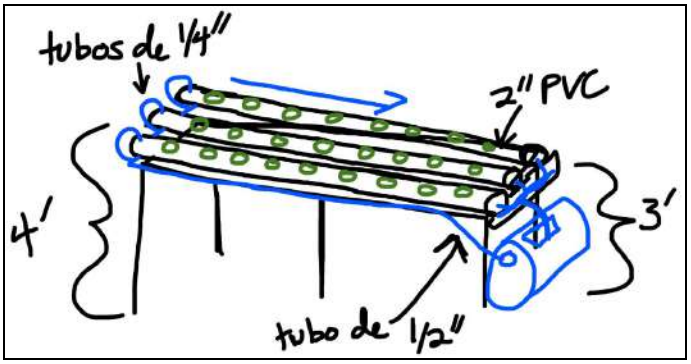

Figure 28: Sketch of the hydroponic table design. Image is not to scale.

Pyramid Structure

The pyramid structure involves placing PVC tubes in a square which has wooden or PVC support beams to hold up higher levels of tubing. These tubes hold plants in holes which would be 5 inches apart, and water can flow down the square spiral shape (see Figure 29).

A tank and pump would be located underneath the center of the pyramid, since the PVC would be elevated on beams. A rubber tube connected to the water pump brings water up a central support beam, where the tube opens onto the tallest PVC trough. At the bottom of the pyramid, an elbow with a channel delivers the water back to the tank for reuse. While this design has not been built yet, it has the potential to grow plants in small spaces or in homes since the design is about the size of a small coffee table.

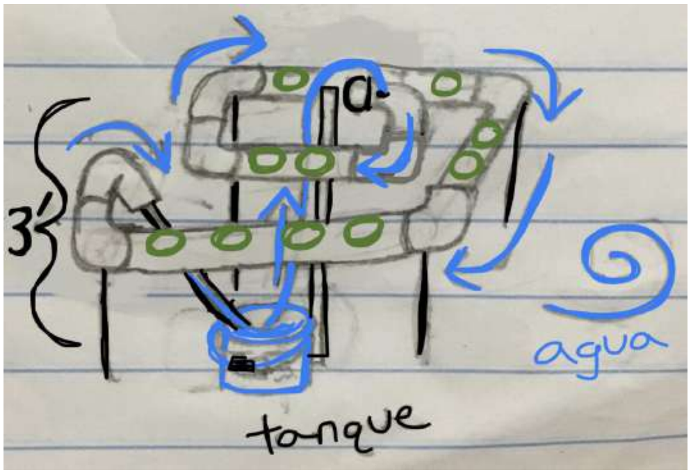

Figure 29: Sketch of pyramid hydroponic design made from 2" PVC and 1 ½" PVC poles. Image is not to scale.

Sources:

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