Rosebud Continuum Project Team #1

Functionality of Bell Siphon Flood and Drain Aquaponics System

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Concepts and Principles of Sustainability IDS 6233.001F21.88321

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November 29, 2021

Fall 2021

I. Executive Summary

At the Rosebud Continuum Education Center in Land O' Lakes, Florida we are identifying and monitoring the functionality of the flood and drain system installed within an aquaponics system. Improper functioning of the bell siphon system has caused impurities in the aquaponic system which has possibly led to nonflowering of the plants and insufficient water quality levels. Trial-and-error testing of siphon and piping materials will be done as well as analyzing the water flow rates will help explain and determine the problem. Testing over a four-week period will not only enable us to investigate the problem and strive to solve it, but also create awareness of the quality and character of the fish and plants. The goal is to fix the bell siphon, encouraging the system to completely cycle through flooding and draining and to stimulate the growth of the fish and plants.

II. Introduction

With the intention to work hands-on with and understand better the aquaponic system as a sustainable practice and for the purposes of this research we will be analyzing a bell siphon flood and drain aquaponics system. This system consists of aquaculture (the cultivation of fish or other marine animals) and hydroponics (the production of food in a soilless medium), specifically, including two goldfish and a variety of tomato plants and herbs. The flood and drain system flows through cycles of filling the hydroponic system with nutrient-rich water produced by the fish waste, then the release of the water into the aquaculture basin (Pattillo, 2017). "Fish waste from the aquaculture portion of the system is broken down by bacteria into dissolved nutrients (e.g., nitrogen and phosphorus compounds) that plants utilize to grow in a hydroponic unit" (Pattillo, 2017). "This nutrient removal not only improves water quality for the fish but also decreases overall water consumption by limiting the amount released as effluent" (Pattillo, 2017). After reviewing the system's deficiencies and weaknesses, we discovered the need to understand and implement a functional bell siphon system. A compilation of literature reviews and studies on this system equips us with the methodology and knowledge required to evaluate and possibly redesign the system. Research and expertise in flood and drain mechanics will be beneficial for the findings and results of this project.

III. Sustainability Principle - Literature Review

As environmentalists, we noticed that this closed-loop, aquaponics system needed assistance to efficiently cycle through in order to work properly. The most significant factors in a well maintained aquaponics system are water quality and water flow. This desired water flow can be accomplished by the bell siphon system that works in an automatic way, without an electric timer or manual intervention.

A bell siphon works through the increasing of water in the growbed, which then allows the water in the bell or the outside pipe's water level to also increase. This water level then creeps up the walls of the standpipe. Once the water has climbed all the way past the walls of the standpipe, this causes the water to drain thus making a siphon. The siphon will then drain most of the water into the aquaculture tank, where the fish live. After most of the water drains the cycle begins again (Fox, Howerton, & Tamaru, June 2010) .

Done correctly the bell siphon automatically lowers and raises the water levels in the mediabed; the tank with the growing plants. This action allows the plant roots to alternate between air and water. The process ameliorates the oxygen in the ongoing filtered water. This enriched oxygen caused by the ebb and flow of water levels, further creates a healthy environment for the fish to live within (Romli, Daud, Raof, Ahmad, & Mahrom, 2017). The whole system is circular and recyclable, thus the raising and lowering of the water levels adds a breathing aspect to the entire system. "It is essential to monitor water quality including, ammonia, nitrite, nitrate, pH, temperature and dissolved oxygen, because fish, bacteria and plants can experience increased levels of stress, which can result in reductions in growth, disease or death if not properly managed" (Nitrification and Maintenance in Media Bed Aquaponics - Oklahoma State University, 2021).

In order for the bell siphon to work properly proper water inflow is required. If the inflow is too fast or too slow, this will cause the siphon to not work. "If the siphon is unable to start, the inflow is too slow and the rate should be increased" (Garrett, 1991). On the other hand, if the siphon does not stop, the inflow is too fast and the rate must be decreased (Danso, Atta-Darkwa, Plauborg, & Sabi, 2018; Garrett, 1991).

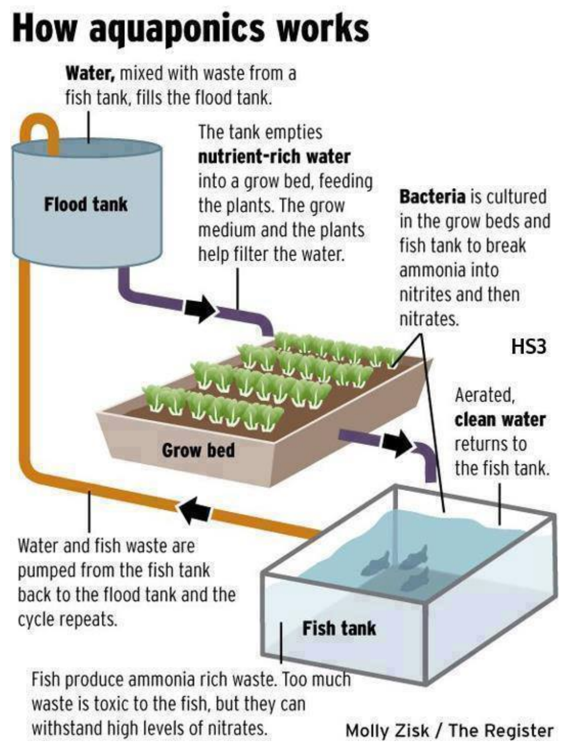

Figure 3.1 Closed-loop, aquaponics system

Understanding Bernoulli's principle will help understand how to stabilize the water flow and pressure needed to operate the bell siphon. Bernoulli's principle of hydrodynamics states that high fluid speeds are attributed to lower pressure areas and lower fluid speeds are related to high pressure areas (What is Bernoulli's equation?, 2021). Conceptualizing the water flow rate and suction ability will help us understand how the system can refill. The pressure created inside the siphon is caused by the water flow rate. If the water flow rate and pressure are aligned then the system will be able to suck up all the water, then create an air bubble to release the excess water and fully drain the system allowing it to recycle again. This concept is required for the examination of the water flow speeds and understanding how the speed and pressure affects the bell siphon. The pressure and flow rate supports the bell siphon ability and suction to correctly fill and drain the system.

As previously mentioned, effective water flow is also essential to the success of the aquaponic system, because it provides water oxygenation and nutrient distribution, essential for the fish; the bell siphon functionality is key to determine the water flow rate. "The water flow rate properties influence the contact time of the microorganisms and of roots with the water, which in turn influences both, the direct uptake of nutrients by plants, and the transformations of the microbial community. Intermittent cycles of flooding and draining in media filled beds provide uniform distribution of nutrients during the flood phase and improve aeration during the drain phase. In continuous flow systems, high water retention time increases its contact time with roots and organisms, but it can lead to lower oxygenation rates and reduced nutrient availability". (Maucieri et al., n.d., #)

Water flow rate can be determined simply by the following formula, where ***Q*** represents the rate, ***V*** represents the volume of liquid measured and ***t*** represents the time frame in which this volume is analyzed. The resulting rate's unit can be expressed in L/s(liters per second) or m3/s(cubic meters per second), depending on the tool used to determine the volume. (*Flow Rate and Its Relation to Velocity | Physics*, n.d.)

$$Q = \frac{V}{t}$$

Similar to water flow, the water quality within an aquaponic system plays a large factor in its overall success- as it is the base of nutrients necessary for growth. Without solid soil, water is the medium of which the plants and fish receive nutrients, making the maintenance and balance of these key elements essential. "There are five key water quality parameters for aquaponics: dissolved oxygen (DO), total nitrogen concentrations, pH, hardness, and water temperature. Factors that are equally as important, but not as often attended to by growers are alkalinity, carbon dioxide, settleable solids, and suspended solids." (Masabni & Sink, 2020) Therefore, regular water quality testing within an aquaponics system is necessary for its maintenance.

While testing is important, it is also vital to note that each aquaponic system is unique and comes with its own sets of challenges. We will discuss parameters suggested for each water quality factor as we test our system but acknowledge that, "...the optimal values of these parameters differ among fish, plants, and bacteria. Therefore, compromises are made for some water quality parameters to meet the needs of all organisms in an aquaponic system at the same time." (Masabni & Sink, 2020)

It is important to note that, "Before constructing a bell siphon, you need to decide which size of drain is appropriate for your grow-bed. The appropriate size of the bell siphon depends on the size of the individual grow-bed. In general, the larger the grow-bed, the greater the volume of water it can hold, and a larger standpipe and bell siphon is necessary to drain it. The recommended ratio of bell siphon size to drain is 2:1; that is, the diameter of the pipe used to build the bell siphon should be twice that of the standpipe (e.g., if the standpipe is 1⁄2 inch in diameter, the bell siphon should be made using a 1-inch diameter pipe)" (Fox et al., 2010).

A collection of research and informational physical and mechanical concepts will strengthen our knowledge and power to fully understand and develop scientific based explanations and results. Research limitations on studies relating to structural and mechanical design of a bell siphon aquaponics system fosters a need for proper design testing and further hydromechanical research.

IV. Overview of the Project

a. Background information of the project/activity

A previous group in the Spring of 2021 worked on the development and construction of the “chop and flip” aquaponics system; which included the piping and pump structure, germination and growth of cucumber plants, and they also added goldfish to encourage growth of the system. This group’s hypothesis of a working bell siphon - was in order to engage the bell siphon, a bubble must be present to initiate the drawdown of the water. In addition they included steps to follow to initiate and test the siphoning. First, remove the standpipe and bell siphon. Second, turn off the water to drain the bed. Third, reinstall the standpipe (w/uniseal) and the bell siphon. Finally, turn on the water to refill the bed. And, once the water reaches the height of the standpipe, the bell siphon will engage.

They implemented two different “chop and flip” systems at Rosebud, each system had a grow bed and a fish tank below. One system had a filtration system made from clay media balls and the other had a small media filter made out of a bucket to sift out any solid waste. They attempted different methods of water flow to the grow bed and started out with a long pvc pipe over the grow bed with small holes to allow even water distribution to the plants.

Bell siphoning experiments in two different aquaponics systems. In the second system, they tested a clear blender bottle for the bell siphon. As for the clear bottle they proposed that the holes at the bottom of the bell siphon were too high, which was part of the reason the siphon could not complete a full cycle. It worked sometimes and didn’t work other times. From the results and data presented in their research, we acknowledged that there were some difficulties with correct measurements of the holes in the bell siphon as well as getting the system to completely cycle through. We determined that the yellow container chop and flip system required further experimentation and understanding to advance and revitalize the system through proper bell functioning.

b. Sustainability efforts already included in the project

Due to the research limitations, we will examine, experiment and test diverse methods on bell siphon placement, water flow rates, suction abilities, and differing bell siphon equipment each week. This testing will be done over a period of four weeks to further investigate proper bell siphon functionality to advance the productivity of the flood and drain system at the Rosebud Continuum Education Center. Our main strategy is to develop real results by providing weekly documentation of the processes and procedures as well as taking photographs of the different tools and methods used. Documentation will enhance the project goals by engaging in a comprehensive project scope utilizing trial and error while monitoring and adjusting the flow rate.

The aquaponic system in which we will be developing our research is already built and follows the sustainability principles of a closed loop system, which is the purpose of aquaponics. The use of the bell siphon adds to this sustainability principle because it allows the system not to rely on electricity through a timer for the water flow exchange, instead it uses physics principles so it can be done in an automatic way. In ***Figure 1.1***, we can appreciate the initial status of the bell siphon system, which was composed of an external metallic mesh working as a gravel guard, a 1”diameter PVC tube of 1.5” of height working as the stand pipe, and a plastic cup of 3.25” of height and ~3” diameter as the bell. We found the bell siphon system has been having trouble with filling up the bell and has been needing a little turn on the bell so it can function properly, hence not automatically functioning as designed.

Figure 4.1 Initial state of the bell siphon system (10/22/21)

According to our measurements of the original state of the bell siphon on site documented in ***Table 4.1,*** a 2:1 ratio for the bell siphon to stand pipe is currently not demonstrated. Adjustments to the sizing of the bell siphon should be tested to better fit this ratio.

Bell Siphon System Element	Current Measurement (inches)	Proposed Correction
Grow Bed	36 x 42.5 in	n/a
Stand Pipe	1.5 in	n/a
Bell Siphon	3.25 in	3 in
Bell Siphon Grooves	2.5 in	0.75 - 1 in

Table 4.1 Dimensions of the initial bell siphon system

Water Quality Factors	Target Ranges (Masabni & Sink, 2020)	Current Ranges as of 10/24/21
Dissolved Oxygen	5–8 ppm	n/a
Ammonia	0 ppm	0.50 ppm
Nitrite	0 ppm	0 ppm
Nitrate	5-150 ppm	0 ppm
Water Hardness	60-140 ppm	n/a
Water Temperature	64–86ºF	77.9ºF
pH	6–7	7.6

Table 4.2 Tested water quality factors of initial status compared to target ranges

To begin our water quality testing, we utilized a kit at Rosebud that required samples of the water found in our aquaponic system. Samples of water were tested with each specific factor's solution and compared to a color chart to give readings. As noted in ***Table 4.2,*** the current state of the water quality within the aquaponic system needs various adjustments. The aquaponic system has a higher pH than noted in the target ranges, at 7.6 which resides outside of the 6-7 range. Similarly, we found that currently the water has a higher ammonia level at 0.50 ppm rather than the suggested 0 pmm. We also discovered that the nitrate is at 0 ppm, when it should be between 5-150 ppm. During our testing process, we were unable to find tests for dissolved oxygen and water hardness, and will be allocating resources into acquiring these.

Challenges and limitations to this project are the given length of the project, sizing and capabilities of constructing different siphons, accurately measuring the water flow and the placement/location of the bell siphon in relation to the water spigot.

c. Strength and weakness of the applied sustainability strategies

Strengths

After four weeks of observation, tests and trials on the bell siphon system, there are several positive outcomes for the proper function of the aquaponics system. We have come to two successfully functioning bells made of different materials; one is the PVC tube with PVC cap and handmade groves on the base, and the second one is made of a clear tube with a glued twisting cap and handmade groves at the base as well.

The correct function of these bells has brought flourishing of the plants in the grow bed, specifically the tomato plant has started to show growth of several little fruits. As for the fishes, they were added in the latter part of the process and their growth has not been prominent, nevertheless their environment has improved significantly regarding algae growth which has been kept at a low level leading to improvement in the clearness of the water as well.

For the successful functionality of the system, the water flow rate has been determined for both of the successful functioning bells and it comes to 0.09L/s. The second factor that added to the proper functioning of the system is the L pipe drain.

Weaknesses

The shortcomings of the project are the inability to recognize and establish explanations for the poor and inefficient water quality. Throughout the semester the water quality levels have not been up to standard. The pH has been abnormally high, ammonia has fluctuated from high to low levels, nitrite has stayed at a good consistent level and nitrate has been below appropriate levels for this aquaponics system. We have noticed that these fluctuating and atypical water quality levels have affected the plants growth. Also, the inconsistencies in the flood and draining of the system may have impacted the growth of the basil plant causing it to be oversaturated and in turn, it changed the leaves to yellow and brown. The tomato plants have been growing over time, however, we have observed very little flowering and no tomato production over the course of our time there. Non-flowering and non-producing plants may signify that something needs to be systematically changed. Overall, the fish seem to be thriving in the aquaculture basin and no fish have died.

Testing Trials

Figure 4.2 The three bells utilized in trials; (1) on the left there's the clear flexible tube with glued twisting cap, (2) on the center the PVC tube and cap, (3) at the right PVC tube and cap with a snorkel incorporated

10/24/21

Our first attempt at understanding the bell siphon and its water flow issues. We attached a L pipe underneath the hydroponics container to increase airflow into the siphon. Then, we used a pvc pipe bell siphon that a group made before us. The pvc pipe was 7" and had a cap and manmade groves in the bottom to allow the water to flow into it. In this case the water fully drained out of the system and the water stayed at a low level in the hydroponics container and never fully drained and restarted the cycle - the low water levels stayed stagnant. It never completely stopped or broke the cycle.

We also tried to change the bottom pipe to encourage the system to break by allowing air up into the system. We added an extended L pipe with a slight curve at the end of it to allow air into it. We utilized the same bell and adapted a rubber piece to the bottom of the bell siphon to create stabilization. This in turn created smaller groves in the bell siphon and didn't let the water properly pass through the bell. This attempt did not enable the water to fill and drain the system. Lastly, we adjusted the L pipe from underneath slightly down to possibly make the water break the cycle. The water was at its strongest water flow, however, the system never broke and the water stayed at a drizzle below and it didn't properly fill. It just constantly drained little by little. In

Table 4.2 we can see the results of the water testing done on this day, therefore the goals for adjustments the system needs, e.g. ph levels.

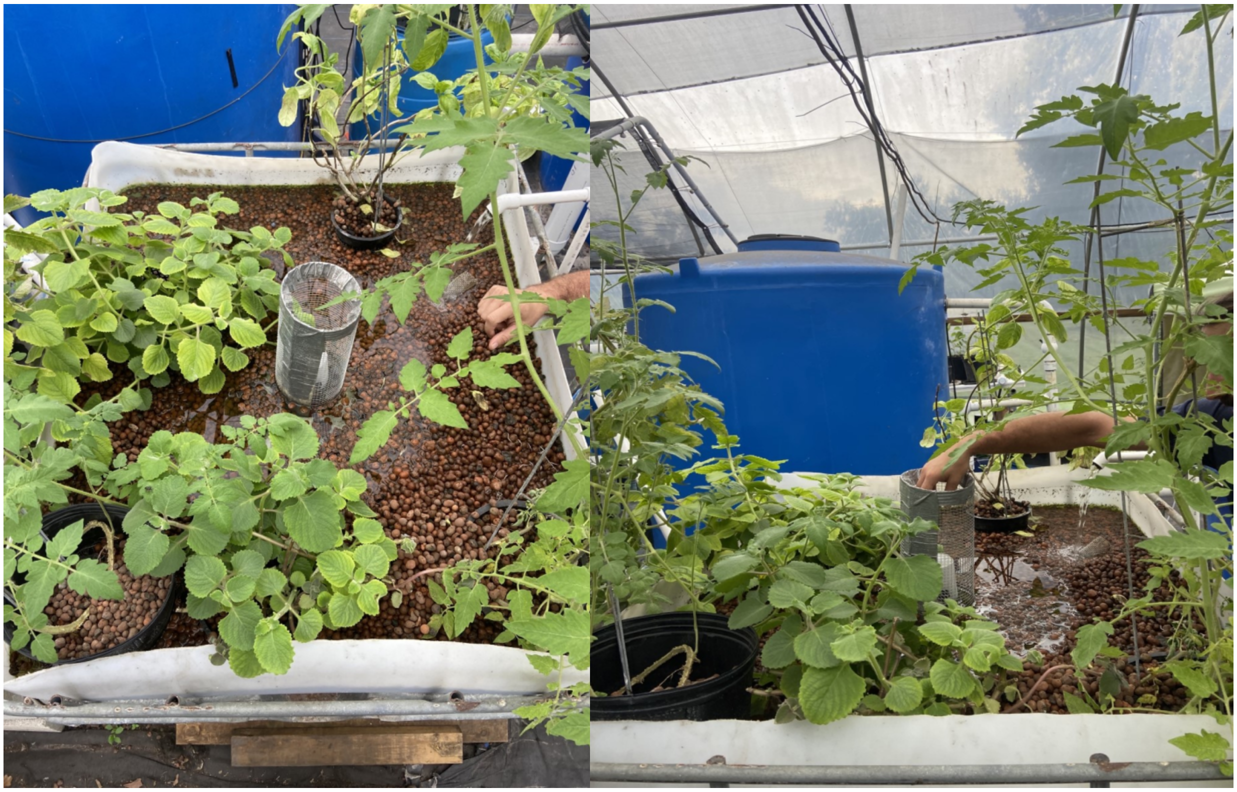

Figure 4.3 Plants' status on 10/24/21

Figure 4.4 Basil leaves appearance on 10/24/21

10/26/21

The observing and testing continued due to the bell siphon's inability to restart the filling process. As part of the observation process, we recorded the times that took the system to fill and drain, they both were around 3 minutes. The water flow was at full speed out of the spigot and the groves on the bell were about 1 cm. We placed the rubber donut piece around the bell standpipe to create suction and later tried different water flow rates for the incoming water: very low, highest and intermediate. The lowest and highest water flows were not successful to make the system restart. For the intermediate flow the restart was successful nevertheless when the water started to drain it got stuck, taking over 11 minutes to drain, much longer in comparison to the previous recorded times. While this happened, and checking every part of the system, we observed that the draining L tube below the bed had a slight upward inclination, and due to a recommendation from, we pushed it downward a little and it was successful to help the system drain completely. After that the system was again able to restart, taking 6 minutes and 36 seconds to fill and then successfully draining for 2 minutes and 40 seconds; these times were consistent with the subsequent cycle.

To be able to determine the exact intermediate water flow rate that successfully made the system restart, we filled a 1L cup that took 11 seconds to fill, therefore using the formula for rate r= volume(liters)/ time(seconds) we concluded the successful water flow rate was 0.09 L/s.

Water Quality Factors	Target Ranges (Masabni & Sink, 2020)	Current Ranges as of 10/26/21
Dissolved Oxygen	5–8 ppm	n/a
Ammonia	0 ppm	0.50 ppm
Nitrite	0 ppm	0 ppm
Nitrate	5-150 ppm	0 ppm
Water Hardness	60-140 ppm	n/a
Water Temperature	64–86ºF	77.9ºF
pH	6–7	6.0

11/2/21

The hydroponic system is continuing to work properly in both flooding and draining stages.We monitored the flood and drain process and completion of cycles. We then tested the water quality. The pH levels have been shifting between mid range and high range - this time it was measured at 7.6 pH which is high for this system. Then we added pH downer to the system to level it out. The ammonia was down from the last test and is getting closer to target levels. Nitrite has been doing well and staying constant at 0 ppm each time we have tested it. The Nitrate has difficulties with getting to appropriate levels and this could be due to the inconsistency in the flood and draining of the system.

We noticed that the tomato plants have been flowering which could be a product of the system functioning properly. We will keep monitoring the growth of the plants, the water quality and the fish. It is important that we do more research to understand the importance and accuracy of the water quality and how it impacts the fish and the plants prospectively.

Water Quality Factors	Target Ranges (Masabni & Sink, 2020)	Current Ranges as of 11/2+/21
Dissolved Oxygen	5–8 ppm	n/a
Ammonia	0 ppm	0.25 ppm
Nitrite	0 ppm	0 ppm
Nitrate	5-150 ppm	0 ppm
Water Hardness	60-140 ppm	n/a
Water Temperature	64–86ºF	77.9ºF
pH	6–7	7.6

Figure 4.5 Top view of the grow bed with extended width of the guard (Basil on the top, oregano to the left, and tomato over oregano on the bottom)

11/11/21

Sheila from the Rosebud team added 70 tilapia fish, 35 blue and 25 white on 11/-. The management of this process caused alterations in the bell siphon system functionality, on our visit we found that it was not working. The original pvc pipe bell had been working over the last week and a half. On this visit the first attempt was to work with a clear bell, made of a clear flexible tube with a twisting cap; the bell was not successful because the cap was not sealed completely, thus it was leaking air. The second attempt was to work with a PVC tube bell with a snorkel and a cup; this bell was not successful either possibly because the tube material for the snorkel is a little hard and we were not able to work with it at the base level of the bell. The last attempt was to work with the original PVC tube bell, and make the whole system go back to its previous successful characteristics, that meant checking the flow rate and setting it back to 0.09L/s. This last attempt was successful in the functionality of the bell siphon system, nevertheless it is important to note the times recorded for flooding and draining varied from the previous successful system on 10/26.

The levels of water in the system have been consistent, which has reduced the amount of algae growth. We attempted the clear bell as an alternate bell for the system in our experiment and it didn't siphon correctly and the water continued to flow out of the growbed. After the attempt with the clear bell, then we decided that the clear bell needed to be fixed by enlarging the grove sizes. Then, we got the white pvc bell pipe to work again after playing with the water flow rate. For the white pvc bell pipe - we have measured that the water flow rate takes 11 seconds to fill up a 1 liter measuring cup, consistent with the flow rate of 0.09 L/s that worked previously on October 26.

Water Quality Factors	Target Ranges (Masabni & Sink, 2020)	Current Ranges as of 11/2+/21
Dissolved Oxygen	5–8 ppm	n/a
Ammonia	0 ppm	0.25 ppm
Nitrite	0 ppm	.25 ppm
Nitrate	5-150 ppm	0 ppm
Water Hardness	60-140 ppm	n/a
Water Temperature	64–86ºF	77.9ºF
pH	6–7	7.6

11/15

The clear plastic tube bell has been tested for a few days, however it seems to work just a bit more slowly and every other two days would stop working completely. Although it is a nice benefit to see the bell siphon vacuum work on the inside. It worked well for about four days in a row, but on the fifth day it needed to be "restarted." The bell was improved by adding some more glue to make it water sealed. Tested the time and got 10.04 minutes to fill and 5.00 minutes to fill.

11/19

The bell continues to work properly, the system takes 9 minutes and 12-18 seconds to flood and takes 4 minutes and 45-53 seconds to drain with the original PVC tube bell. Little fruits on the tomato plant have started to flourish (see Figure x.x). Due to the nature of the oregano plant, its leaves hang downward, the water level reaches them when flooding and might deteriorate them. The basil plant has dried up and leaves have become wilted and fallen, this could lead to hypotheses that this water flow is not suitable for basil.

11/ 27

A short test was done with the snorkel bell siphon and due to the grow bed having an indentation in the center there was no way to balance the snorkel properly. Also, the snorkel tube wasn't too flexible, so this made the cup that the tube rested in placed in an odd angle.The original bell siphon replaced the snorkel and was working for a few days but as of the 27th it stopped and needs to be restarted. Water flows remained the same for both test subjects.

Figure 4.6 Deterioration of basil

V. Recommendations for the Project

a. What is missing and what do you propose for improvement?

After the aquaponics system has been successfully built and the bell siphon system has worked properly for certain periods of time, then we propose that it is important to understand the essentials of the circulatory system. It is beneficial for people working with an aquaponics system that they become familiar and knowledgeable about the types of plants, the type of nutrients and water quality they need, and how much nutrients they give off into the water for the fish to thrive.

Next, educating and researching about the types of fish, the water quality that they best survive in and how the water quality affects the plants growth. Another improvement would be documenting and establishing instructions both online and in-person at Rosebud about the proper functioning of the bell siphon to preserve and promote further education.

With Rosebud being a voluntary experimental farm, it lacks constant monitoring which is essential for this aquaponic system that presents setbacks in the bell siphon functionality. The knowledge gained through this and previous research can build up background information for further work on the system and for continuous monitoring as well, nevertheless time is most needed for the success of it. This system could become a constant target for future research and in that manner receive constant monitoring.

Our system would be defined as an Ebb and Flow (EAF) aquaponics system. There are two other systems, the Nutrient Film Technique (NFT) and the Deep Water Culture (DWC)(Oladimeji, Olufeagba, Ayuba, Sololmon, & Okomoda, 2020). All have been tried and tested in different parts of the world and in addition, Rosebud has a few of each. Compared to the system right next to the one that our group worked on, was another Ebb and Flow system. It produced a bounty of produce. However rather than rely on the bell siphon, this one was soaked and drained on a timer. What made this system work so thoroughly, was that it was consistent. The consistency allowed for the plants of all sorts to thrive. However, this system relied on a timer, which in the worst case situations is not reliable without electricity.

Strengths and weaknesses in that technology ex) water flow, weakness is the bell siphon that can be clogged, stop working. Limitations within that system.

b. What are the limitations to address your proposed ideas?

The main limitation to our proposed improvements is the amount of time we are able to dedicate to this project. If we continued to develop and work on this system for an extended period of time, then we could accomplish the identified “in-progress” areas such as detailed knowledge of the system and its needs, as well as, create a manual as a source of helpful guidance. Testing for each variation of bell siphon, along with the logging the water quality, plant growth and fish populations should be observed for months and even years- rather than the weeks that our project timeline allotted.

A big setback was the amount of material that is required for this project. In order to have a more thorough project more bell siphons such as twenty or more would need to be created and applied; taking a great deal of time as mentioned. We spent about $50 in all on parts and pieces had we doubled or even tripled that cost we would have had far more research to provide.

With a prolonged investigation, we could also analyze the flourishing of the different plants compared to the flow rate and water characteristics, record tilapia growth times and sizes and compare it to regular expected growth rates. The addition of time would allow us to make a comprehensive and repeatable guide for the future groups who maintain this bell siphon system, and for those who also wish to learn about aquaponics. Rosebud Continuum emphasizes the continuation of projects to fruition, and this particular project is no exception. It is essential to maintain the projects at Rosebuds so they can continue to be the educational tool that they are today.

Recommendations for The Project

Our group will mainly build upon previous students' works regarding the aquaponics system that is currently in use. However, there are still some areas we find we can improve upon. We want to fix and improve the current bell siphon, which has fallen into neglect and ceases to work properly. We propose managing and monitoring the inflow of water, drainage, and the kind of bell siphon. We plan to use the same overall structure of the bell siphon, however, we may change some of the material and hardware. We will compare and contrast two to three different bell siphons that work similarly, but may have different parts or minor design differences to implement the most feasible option.

A snorkel feature attached to the bell siphon is one recommendation that could help the timing and release of the water from the bell. Incorporation of a snorkel attached to the bell will aid the siphon to break by bringing a bigger amount of air inside the bell. Attachment of the snorkel can be placed on the bell or placed under the standpipe to create a snorkel underneath the growbed.

Testing for water quality should be maintained and tracked weekly to further assess improvements or challenges within the aquaponic system. Allocating time and funding into testing for dissolved oxygen and water hardness might also be beneficial, along with further research into regulating water quality factors in a system. Adding downer to regulate the pH is something our team did, however research into long term solutions for pH regulation could also be beneficial. Similarly, investigating which fish produce less ammonia and manage waste in different ways

A flood and drain aquaponics system is a relatively inexpensive system that people can make at home. However, the challenges that may arise are sizing and constructing different siphons, measuring the exact placement/location of the bell siphon in relation to the water spigot as well as accurately measuring the water flow. This system needs space for the water, pumps and equipment, which would make it difficult for residents living in urban, apartment-style living to install and operate. On the same note, affordability and accessibility to these systems creates inequalities and inequities for people who do not have space, access nor resources.

VI. Conclusion - Reflections on the Sustainability Principle

In conclusion, our team was able to collectively research bell siphon systems, manage and maintain the current system at Rosebud and to curate three different variations of bell siphons to test. We observed as the bell siphon system transformed from its original flooded state to functioning with flowering tomato plants, added tilapia and a flourishing ecosystem. As previously discussed, the water pressure had the largest impact on the success of the bell siphon.

Although we were able to get the original bell siphon to work for a week and half, eventually it succumbed to needing to be "restarted." This was followed by testing the plastic tubed sipon which worked for about half a week. The snorkel siphon was the most disappointing, because it wouldn't last a few rounds without having to be "restarted." All in all, the bell siphon at its most basic structure, at least here on Rosebud is not perfect and even with proper flow and a better drainage system it is still not 100% consistent. Which is the goal, to not have to "restart" it every few days or every other week. It still seems as if the bell siphon remains up to chance, and this is not acceptable.

The whole system is quite complex, there are many parts that influence the bell such as the flow, the drain, the gate/ media guard, and the standpipe's height. Although the bell siphon is an easy and straightforward concept there are many other factors that can hinder its job. Some factors we did not add to the paper which may have influenced its mechanics is its weight, volume, density, the vacuum inside the bell, and perhaps the amount of water drains out of the drain pipe.

Another takeaway from this project is the significance of what sort of plants grow together in the grow bed. During this research there were tomatoes, oregano, and basil growing simultaneously, while the tomatoes and oregano thrived, the basil did not fare well at all. Basil needs a pH of between 5.5 to 6.5 to grow properly and oregano needs a pH of 6.0 to 8.0 to flourish (Guide & Vergeer, 2021). Due to this, we preliminarily conclude from our observation that the basil possibly received too much water and from our testing the pH being normally on the higher end did not allow the basil to thrive like the tomatoes and oregano. Therefore it is preferable that plants with specific needs should be paired with similar plants. This is something we did not consider initially,however, if we were starting from scratch, this would be a factor we would implement.

During the course readings and our research of bell siphons; thus Aquaponics. Exposed us to the four principals: Environmental, Ecological, Economical, and Social. This aquaponic system recycled and reused its waste, nutrients, and most of all water in an environmentally friendly way. This is due to the system being separated from the greater environment. It recycled its basic resources, and therefore fulfilled its basic environmental principle. Also, since this system is a microcosm of the greater environment, it meets the ecological principle too. Regarding the economic principle, this specific system can meet the standards because it is eco efficient and an ethical investment. Now, there needs to be more capital invested into this system to make it profitable, in the very least to produce larger quantities of goods. Lastly, the social principle, which as a team found out first hand. This system brings about social responsibility. This project had many hands involved and not just our group but previous groups as well, which we all in a way collaborated and worked together to bring about a more efficient aquaponics system.

We have come to understand that the aquaponic systems are built upon the idea of harvesting plants and growing fish while using the same water resource in a closed loop system, we could even say, mimicking nature in a way. Sustainability refers to things working in a manner that most resembles nature, using resources at a rate where we can assure to have them back before needing them again. The aquaponic system complies with this sustainability principle completely and the bell siphon system is a key participant of that cycle. For the aquaponic systems that implement bell siphons, comprehension of its parts and how they work will help with the maintenance and success of the system, bringing flowering plants and fish production. Aquaponics systems bring hope to food production and water management for the current global situation, which can be handled at a small scale in our backyards or even on a larger scale.

VII. References

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