Hydroponics System Comparison

By

Isaac Bradford and Nathan Lewis

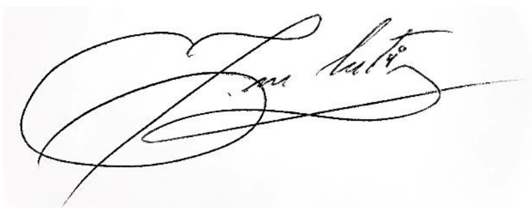
PERCIVAL

Foreword

Hello Reader,

> This paper is an internal reflection on research done testing Percival Scientific equipment and innovations. Use of this paper is for reference and internal instruction. Sharing to external groups is allowed but paper is property of Percival Scientific.

Henry Imberti, Sr VP of Engineering



Introduction

Hydroponics is growing plants with only water and no soil. In hydroponics, plants are grown in an often-inert substrate. This means there are no nutrients from soil. Because plants are unable to uptake nutrients from the soil they need to be watered with supplemental nutrient mixes.

There are many systems and methods in hydroponics that use these nutrient water mixes to grow. Some of these systems include Nutrient Film Technique (NFT), Deep Water Culture (DWC), Tower Hydroponics, Capillary Water Systems (Slab Watering), Dutch Buckets (DB), Drip Irrigation, Channel Irrigation, and the Kratky Method. When designing the Percival Hydroponics Research System several types of systems were considered. As leafy greens were chosen as the initial crop to design for, systems common for leafy green growth were considered. In commercial lettuce production DWC, NFT, and Tower Hydroponics are common practices.

DWC uses a reservoir that has rafts that float on the top of the water. Plants then grow with roots directly in the rafts. This has the benefits of minimal equipment and low cost. However, this system utilizes lots of water and it would be too heavy in a chamber.

Figure 1: Deep Water Culture (DWC) (Suncrest)

To better simulate commercial lettuce settings a system of Tower Hydroponics and NFT was designed as these options were more manageable inside chambers.

The goal was to design the most consistent and similar system to commercial production conditions and outputs. This report will seek to find a conclusion on what hydroponics design should be suggested for manufacturing and consumer use in research chambers.

Materials and Methods

During design, the Tower Hydroponics Unit and NFT systems were adapted from preexisting designs. The tower design was made in duplicate except one rotated and the other was stationary. This was intentional in discerning if the light was utilized by the lettuce better or more evenly in a rotating system. The NFT design was designed from HydroCycle channels and fitted to a Percival 41 chamber. All systems were optimized to maximize the number of plants in one chamber, not the space for each plant.

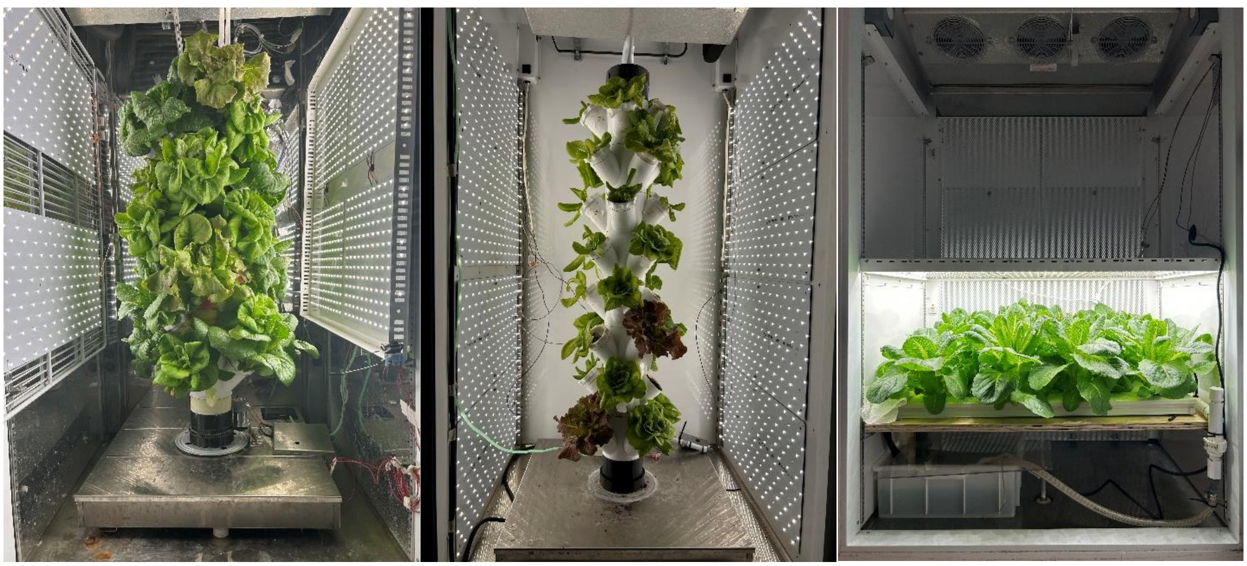


Figure 2-4: Rotating tower, stationary tower, and NFT system

With lettuce it has been found that spacing leads to different effects on both the structure and size. The ideal spacing for lettuce, specifically romaine varieties, is around 20cm (roughly 8.5in) (Lefsrud). The parallel spacing present in the HydroCycle channels is 8in, and diagonal spacing is 5.7in. The spacing is different for the towers at 10in vertically and 8in diagonally (with 3 plants on each level), and 10in vertically and 6in diagonally (with 4 plants on each level). All the tested designs were close to the suggested distances.

The tower systems were constructed with 3D printed pieces of various filaments. The NFT HydroCycle channels are made from recycled plastic and a sealant that makes the recycled plastic food safe (FarmTek). Both systems would be slightly complicated to manufacture without special tools or machinery. For the rotating system, a small 12V, 5RPM motor was used to turn the tower. Both tower systems had Percival SciWhite panels attached to two sides to maximize light distribution. Panels could not be easily affixed to the door and back wall and the rotating system in theory would rotate allowing even distribution so that is why there were not four panels.

To optimize growth the lettuce was grown at ideal parameters according to HortAmericas "The Guide to Growing Leafy Greens." Using Humbolts Secret Nutrient (Figure 5) mixes the nutrient content of the water was 1800 to 2400 uS/cm of EC and pH of 5.6-6.0. The growing conditions were
16-hour 22°C daylight, 8hour 20°C nighttime.

Figure 5: Humbolts Secret Liquid Fertilizer

The plants were seeded in rockwool and some in peat starters with 4 types of *Lactuca sativa* seeds, Rex Butterhead, Skyphos Butterhead, Sunland Romaine, and Sunland Romaine. These plants germinated in roughly 3 days, grew into seedlings until 21 days and were harvested around 42 days after seeding. 42 days or 6 weeks is a common harvest time in commercial growing which was meant to be emulated.

Results

Data was gathered after 6 weeks since seeding in all three systems. The data for the stationary tower was from a vertical difference test that consisted of 8 plants 4 Rex and 4 Romaine. The NFT and rotating systems were seeded 1 day apart and harvested after 6 weeks from the latest seeding. Various cultivars were evaluated to determine if the cultivar makes much difference in terms of harvest weight.

Bar graphs with standard deviation bars illustrate the average harvest weight with the standard deviation or total range of values. You can visualize the precision or closeness of the data by looking at the bottom half of the bars in relation to the bar. The smaller the percentage of the bar that the bottom half of the standard deviation covers, the more precise that system is (the coefficient of variance).

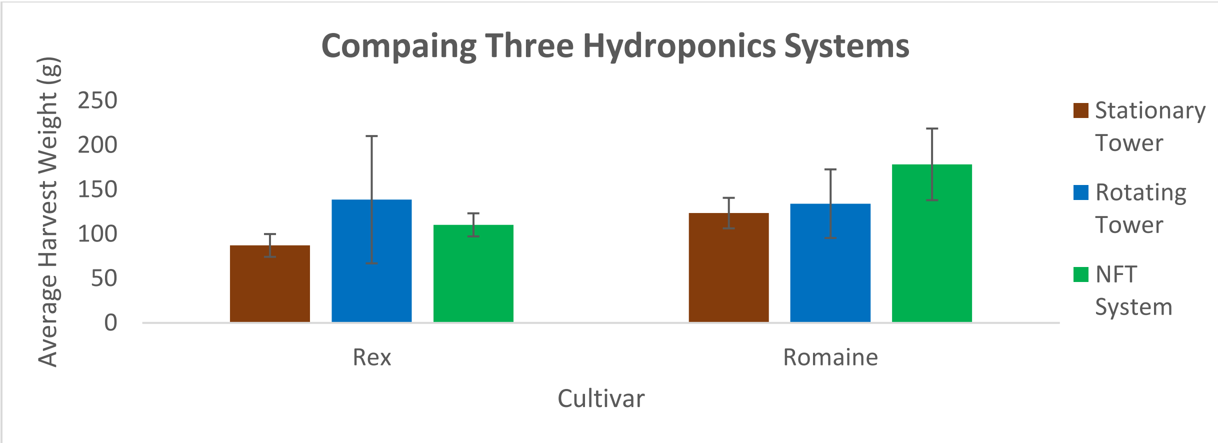


Figure 6: Graph illustrating data used in comparisons between systems

After looking at all the data, Rex and an average of all Romaine cultivars (Sunland and Sparx) were used. You can see in the photo below it is hard to determine the separation between the Romaine cultivars.

Figure 7: NFT system (pattern in front row from left

to right was Sunland, Sparx, Sunland, Sparx)

To compare the tower systems, first it must be determined that nutrient uptake and light concentration are not height differentiated. To test this, data was collected on two sides of the stationary system on four levels. Four plants of Sparx on one side and four plants of Rex on the other.

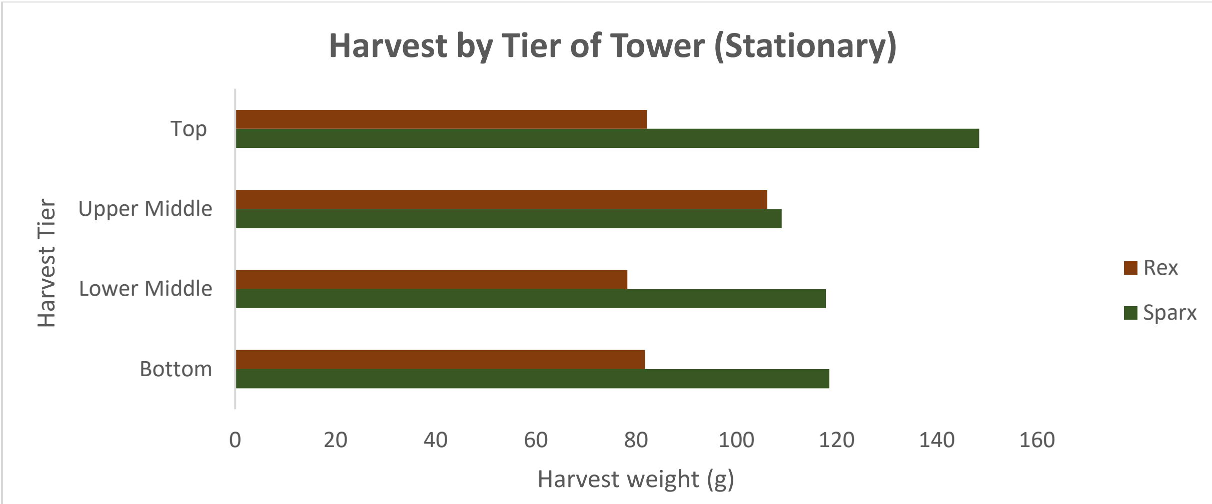


Figure 8: Vertical differentiated harvest weight analyzed (Stationary Tower)

One can assume that because the plants were faced toward the lights, the height harvest data can be used to evaluate both the stationary and rotating tower. The main problem that was to be tested was if conditions were altered by location. The data says that the location by height does not alter the harvest weight predictably. This also means nutrient uptake does not differ with height or closeness to irrigation output.

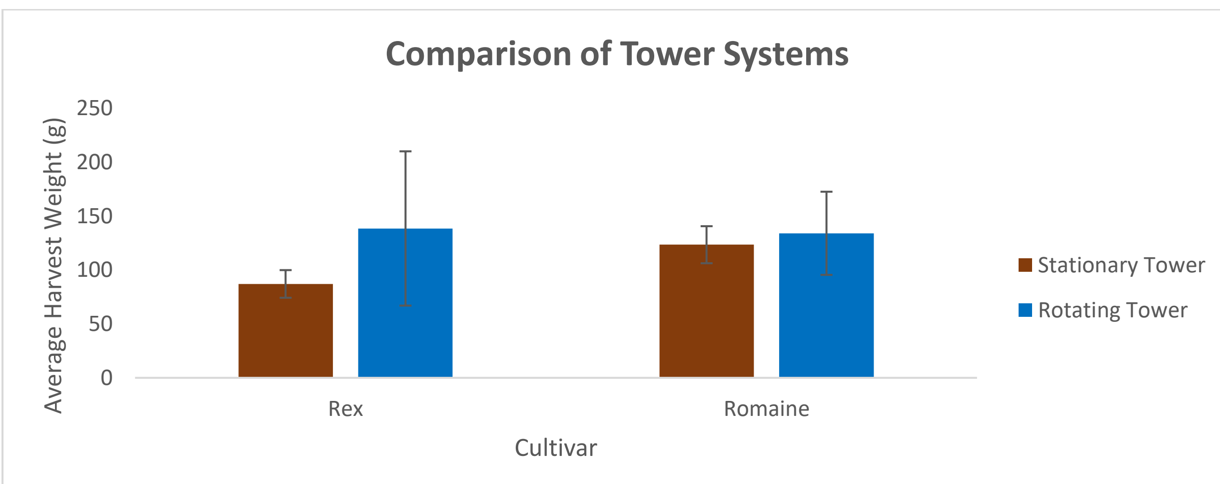


Figure 9: Tower system comparison

You can see the rotating tower has a lower precision than the stationary tower design. The stationary tower may be consistent but has a lower average harvest than the rotating tower in all scenarios. In the same conditions the rotating tower can be decided to be the better tower system. To determine the best system the difference between the rotating tower and the NFT system must be analyzed.

The next graph analyzes this difference but omits the Rex cultivar because of intracultivar mixing in the NFT, the Rex got smothered by the Sparx and Sunland. This caused the Rex to be stunted and an incomparable data value. In the future one should make one division between species to create two environments to allow for success in both cultivars.

Figure 10-11: (Left) Romaine in back row, Rex in front row, (Right) Root growth shows degree of stunting, 2nd and 4th rows were where Rex was grown

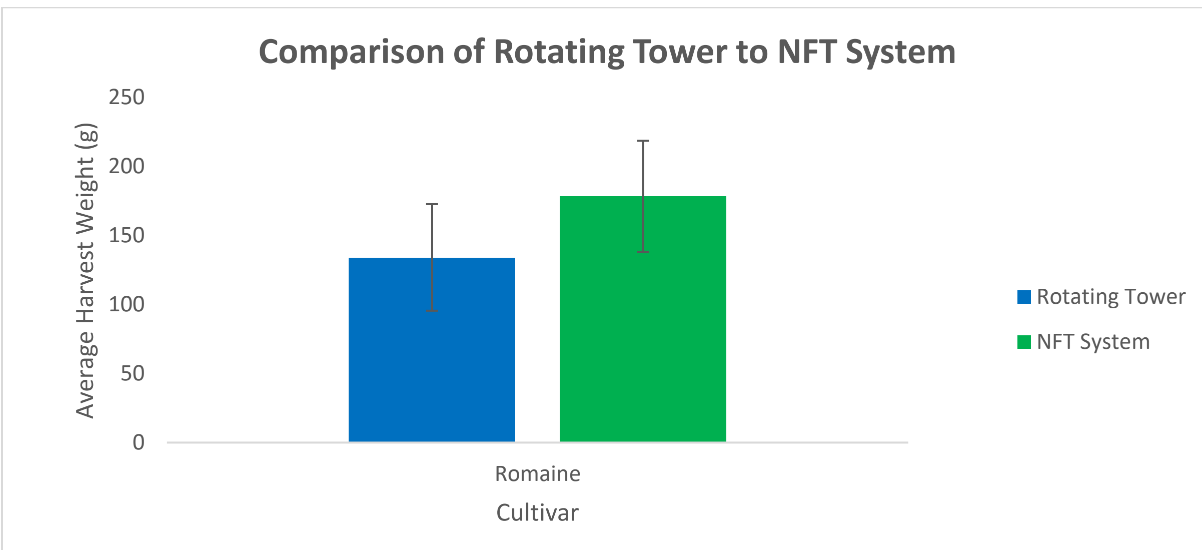


Figure 12: Romaine cultivar harvest weight difference analyzed

Both systems were precise to near the same degree (22.6-28.8%) and it was clear that the NFT system prevailed as the best design. If the rotating design is the best tower system and the NFT is better than the rotating system, then the NFT system should be the primary design. In this case, the NFT system is nearly as precise as the stationary tower, has a larger average harvest than both the rotating and stationary systems, and can be manufactured in house and so a design matrix was not necessary. The NFT system is the clear choice based off the data gathered.

Conclusion

Seeing that an NFT design would be easily manufacturable and better for the plants, the decision was to continue developing an in house NFT system from mainly stainless steel as it would not corrode as easily as other metals.

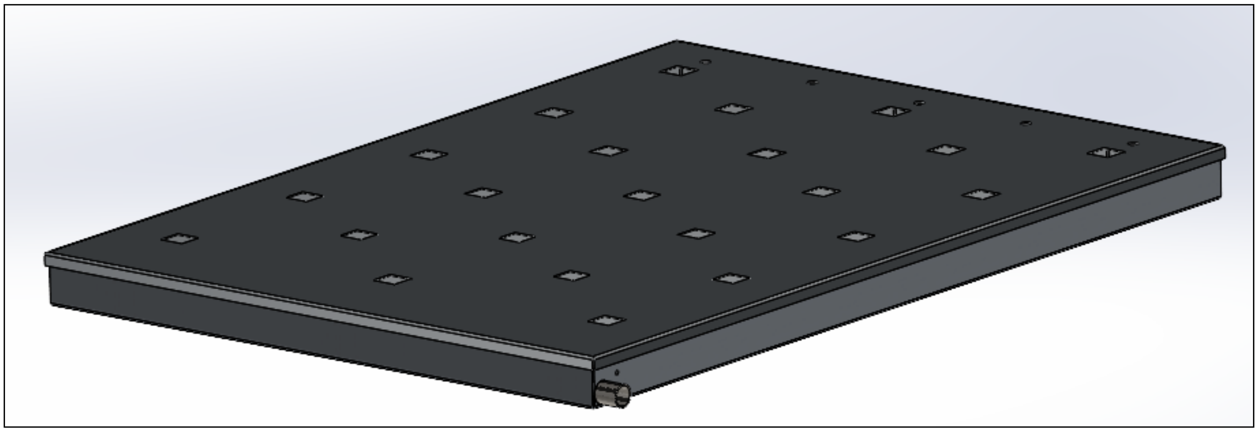


Figure 13: Stainless Steel NFT design to create in-house solution

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Additional Figures

Stationary Tower			Rotating Tower			NFT System		
Rex			**Rex**			**Rex**		
Average	STDEV.S	CofV (%)	Average	STDEV.S	CofV (%)	Average	STDEV.S	CofV (%)
87.13	12.84	14.73	138.60	71.60	51.66	57.72	12.96	22.46
Romaine			**Romaine**			**Romaine**		
Average	STDEV.S	CofV (%)	Average	STDEV.S	CofV (%)	Average	STDEV.S	CofV (%)
123.52	17.19	13.92	134.13	38.59	28.77	178.35	40.31	22.60

CofV = Coefficient of Variance = Standard Deviation/Average = Precision Metric