Sanderson Hydroponics



Greenhouse System Proposals for Students for Service

Prepared for: Students for Service - Kathy Soll Prepared by: David Sanderson[†] Rev A. - July 21, 2014

[†]With sections taken from 3rd party sources, please see references below.

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OVERVIEW

Objective

The objective of this document is to explore cost effective ways for Students for Service to expand its growing area in the Urban Farm space at Bedford Stuyvesant New Beginnings Charter School. It focuses on two types of crops: leafy greens such as Swiss chard, collard greens, Bibb lettuce or European butter-crunch; and vine crops such as tomatoes, and peppers. Three systems will be proposed. Two, a Nutrient film technique (NFT) system and a Recirculating deep water culture (DWC) System, are primarily intended for the production of leafy greens. One, a Flood and drain "Dutch Bucket" System, that is intended primarily for the production of vine crops.

Design Goals

There are several basic design goals that have been taken into account while considering the solutions enumerated below.

- 1. Safety
- 2. Cost effectiveness
- 3. Growing space maximization
- 4. The ability for the systems to be built, maintained and modified by students.

A note about material selection

In keeping with the first design goal, materials suggested for use as part of the water circulation and some other parts of the systems are, whenever possible, either approved for food use, fresh water distribution or made of materials suitable for same. The designs actively avoid some materials common in many systems, such as PVC (Polyvinyl chloride) which could potently outgas chemicals such as Di(2-ethylhexyl)phthalate (DEHP) into the water system. While there is little data available on whether or not such chemicals could be absorbed into plants in concentrations high enough to have an effect on human health, it seems best to err on the side of caution and avoid such materials when possible.



Fig. 1 Source: The Old Farmer's Almanac^{†1}

NUTRIENT FILM TECHNIQUE (NFT) SYSTEM

Principle of Operation

Nutrient film technique (NFT) is a hydroponic technique wherein a very shallow stream of water containing all the dissolved nutrients required for plant growth is re-circulated past the bare roots of plants in a watertight gully, also known as channels. In an ideal system, the depth of the recirculating stream should be very shallow, little more than a film of water, hence the name 'nutrient film'. This ensures that the thick root mat, which develops in the bottom of the channel, has an upper surface, which, although moist, is in the air. Subsequent to this, an abundant supply of oxygen is provided to the roots of the plants. A properly designed NFT system is based on using the right channel slope, the right flow rate, and the right channel length.

The main advantage of the NFT system over other forms of hydroponics is that the plant roots are exposed to adequate supplies of water, oxygen and nutrients. In earlier production systems, there was a conflict between the supply of these requirements, since excessive or deficient amounts of one results in an imbalance of one or both of the others. NFT, because of its design, provides a system wherein all three requirements for healthy plant growth can be met at the same time, provided that the simple concept of NFT is always remembered and practiced. The result of these advantages is that higher yields of high-quality produce are obtained over an extended period of cropping. A downside of NFT is that it has very little buffering against interruptions in the flow, e.g., power outages, but, overall, it is one of the more productive techniques.¹²

Proposed System

Structure

As proposed, the system will consist of 10 sections of 10-foot gully sections on a wooden support structure. The gully sections will be constructed of Amerimax Home Products 5 inch White K-Style Aluminum Gutter. The gutter sections measure 5 inches wide by 3.5 inches tall and 120 inches long. They will be covered with 1 in. x 6 in. x 10 ft. Board in which 1 inch holes will be drilled on 5 inch centers for plants to sit in. The plants will sit directly on the bottom of the gutter. The gutter system will be supported by four wooden support structures, each laser cut out of a piece of 4 foot x 8 foot 1/2 inch Plywood (see Fig. 2). The support structure will form a tiered ladder system allowing the maximum amount of natural sun light form the west facing widow to hit each row. The system in total would measure approximately 10 feet x 5.5 feet for a total foot print of 55



square feet. If the suggested plant spacing of 5 inches is used (6in is typically used in commercial greenhouses for lettuce crops) then we will have 24 plants per gully for a system total of 240 plants. This would give us a system density of 4.36 plants per square foot.

Operation

A reservoir constructed from a 5 gallon food grade HDPE plastic pail will sit under the the gully structure. The reservoir will be aerated by a PENN PLAX 10" Air-Stone connected to a Tetra Whisper Air Pump. In the reservoir, a

PP53016 : 530 GPH, Submersible pump will continually circulate water through the system. The pump will be connected to 1/2 inch distribution tubbing. The tubing will first extend to the top of the structure and then extend down to the bottom. It will be connected to each gully via 1/4inch distribution tubbing. This arrangement should maintain enough pressure in the 1/2 in tube to ensure reasonably even water distribution to each gully. On the opposite side of the gully, a drain will return the water to the main reservoir to be recirculated. If the support structure of this system is placed directly on the floor, a smaller collection point with a sump pump will be necessary for the first three tiers to ensure water does not back up into the system via the drain as the level of the water in the central reservoir could be above the level of the drains on these tiers.

Lighting

Additional lighting will be used as part of the system consisting of 18 ultra high output led arrays. Suspended above the system in two stings, Supported by wire rope attached to wooden pillars connected to the plywood base structure. Each array will put out about 2,000 lumens of light at a 120° beam angle. In total the lighting system should produce 36,000 lumens. Two high efficacy constant current power supplies will drive the arrays and altogether the system will consume 300 watts. This configuration should provide a luminous efficacy of about 120 lumens per watt.

A Note On Reservoir Temperature

For best results in a NFT system it is important to monitor the nutrient solution temperature. While the optimum temperature varies slightly between crops, in general the accepted optimal range is between 65 - 70 °F^{†3} (This is generalization made by the author based on the research done by Dr. P. Addams and presented in his 1993 research paper titled "NUTRITION OF GREENHOUSE VEGETABLES IN NFT AND HYDROPONIC SYSTEMS" See the "References" section below for more information) The system proposed does not include a mechanism for temperature regulation mainly due to cost considerations. In the winter months a aquarium heater could be used in the reservoir to maintain optimum temperature and can be found rather inexpensively. In the summer months a water chiller could be used. However, these units tend be reasonably expensive.

Budget

A detailed itemized budget for this system is provided in the spreadsheet below. The prices listed include shipping if being shipped, but do not include transportation costs if being purchased locally. As specified, this system will cost approximately \$655. This compares favorably against commercially available systems. While it is unusual to see complete NFT systems commercially, available there are several commercial offerings of NFT gullys that we can compare the specified solution to. For the proposed system the sub total for the gully system including the gutter, associated hardware, the topper and a food grade sealant is \$290.45 or \$2.9 per linear foot. The most popular offering of commercial gully systems found by this researcher is a system by AmHydro, a US-based company. There offering, which goes by the trade name GroClean™, is a Polyethylene NFT channel that comes in 12 foot sections. With shipping they price out at about \$48 per channel or about \$4 per linear foot. A competing system manufactured by Crop King Incorporated, priced out to \$363 plus \$56 for shipping, for 100 linear feet that works out to about \$4.19 per linear foot. Using the gutter system proposed offers about 25% cost savings versus commercial systems. That being said, it still might be worth considering the commercial solutions as they may end up being easier to work with and clean.

While great pains have been taken to try to include all items necessary for the basic operation of the system in the spreadsheet below, If this system were to be built I would suggest including a 15% contingency when budgeting.

NFT Project Budget Detail

)t	Item	Vendor	Price Ea	Price Ext.
10	Amerimax Home Products 5 in. White K-Style Aluminum Gutter 10ft	Home Depot	\$6.82	\$68.20
40	Amerimax Home Products 5 in. Hidden Hanger with Screw	Home Depot	\$1.68	\$67.20
10	Amerimax Home Products 5 in. Aluminum Left End Cap	Home Depot	\$1.54	\$15.40
10	Amerimax Home Products 5 in. White Aluminum Right End Cap	Home Depot	\$1.54	\$15.40
10	1 in. x 6 in. x 10 ft. Knotty Tongue & Groove Board (to cover gutter)	Home Depot	\$5.93	\$59.30
1	8400 Alkyd Enamel, Dairy White, 1 gal. Food Grade Paint	Grainger	\$64.95	\$64.95
4	15/32 in. x 4 ft. x 8 ft. BC Sanded Pine Plywood - For structure	Home Depot	\$25.85	\$103.40
2	2 in. x 3 in. x 120 in. #2 & Better Kiln-Dried Whitewood Stud - For structure	Home Depot	\$2.38	\$4.76
1	Laser Cutting Service for Plywood		\$100.00	\$100.00
1	PP53016 : 530 GPH, Submersible, Fountain, Pond, Waterfall Pump - 45W, 16' Cord	<u>Amazon.com</u>	\$32.99	\$32.99
1	PENN PLAX Add-A-Stone Air Pump Accessories, 10-Inch by 2-Inch	Amazon.com	\$6.44	\$6.44
1	Flexible Aquarium Air-Line Tubing	Amazon.com	\$6.48	\$6.48
1	Tetra Whisper Air Pump	Amazon.com	\$14.09	\$14.09
1	5 Gallon White Bucket & Lid - Durable 90 Mil All Purpose Pail - Food Grade - BPA Free Plastic	<u>Amazon.com</u>	\$9.95	\$9.95
1	Orbit Underground 67346 1/2x100Univ Dist Tubing	Amazon.com	\$16.37	\$16.37
1	Rain Bird BC25-10PK Landscape Dripline System 1/4-Inch Barbed Coupling, 10-Pack	Amazon.com	\$7.14	\$7.14
1	Rain Bird Landscape Dripline System 1/4-Inch Tubing - 100-Foot Roll T22-100	Amazon.com	\$8.23	\$8.23
1	Orbit Underground 67462 1/2" DL End Cap	Amazon.com	\$6.62	\$6.62
1	Misc Plumbing	Home Depot	\$40.00	\$40.00

Qt	Item	Vendor	Price Ea	Price Ext.
1	Type 304 Stainless Steel Wire Rope - 100ft	McMaster-Carr	\$20.00	\$20.00
20	Cast Malleable Iron Wire Rope Clip	McMaster-Carr	\$0.31	\$6.20
3	2 in. x 3 in. x 96 in. Prime Kiln Dried Heat-Treated Untreated SPF Stud	Home Depot	\$2.15	\$6.45
18	High Power LEDs - White ZC18 POWER COB WARM WHITE 3000K	(C), Mouser	\$6.23	\$112.14
2	LED Power Supplies 150W 26-36V OUT LED DRIVER	Mouser	\$72.87	\$145.74
18	Aluminum SMT Heat Sink - 0.5"x0.5" square	<u>Addafrouit</u>	\$2.75	\$49.50
4	Heat Sink Thermal Tape - 3M 8810 - 80mm x 80mm	Addafrouit	\$4.50	\$18.00
1	Misc Wireing	Home Depot	\$50.00	\$50.00
		Gutter System Subtotal		\$290.45
		Support Structure Subtotal Pumps and Tubing Subtotal Lighting		\$208.16
				\$148.31
				\$408.03
			Total	\$1054.95

RECIRCULATING DEEP WATER CULTURE (DWC) SYSTEM

Principle of Operation

Deep water culture (DWC) is a hydroponic method of plant production by means of suspending the plant roots in a solution of nutrient-rich, oxygenated water. A more accurate definition for the acronym DWC is Direct Water Culture. Direct Water Culture can be performed in deep or shallow water.

Traditional methods favor the use of plastic buckets with the plant contained in a net pot suspended from the center of the lid and the roots suspended in the nutrient solution. An air pump oxygenates the nutrient solution; if sufficiently oxygenated, the plant roots can remain submerged for extended periods of time. For some species, once the plants are ready to flower, the level of the nutrient solution is gradually reduced to expose the roots to the air. Plants absorb vastly more oxygen directly from the air than from the oxygen dissolved in water. Deep water culture allows plant roots to absorb large quantities of oxygen while also allowing the uptake of nutrients. This leads to rapid growth throughout the life of the plant.

Recirculating direct water culture systems (also known as RDWC) use a reservoir to provide water for multiple buckets. Traditional methods using unconnected buckets require individual testing for pH and conductivity factor (CF). This has led to innovations that have seen the removal of air stones in favor of connecting multiple buckets together and recirculating the water. As the water is reintroduced to the bucket it is broken up and aerated with the use of spray nozzles. Constant recirculating oxygenates the water and ensures a good mix of nutrients CF and stabilizes pH throughout the entire system so testing is required only at one point.

The solution is oxygenated (possibly near, or equal to, oxygen saturation) from an air pump combined with porous stones. With this method the plants may grow faster because of higher amounts of oxygen that the roots receive, versus other forms of deep water culture.^{†2}

Proposed System

Structure

As proposed, the system will be self contained on a rolling wire shelving unit. (see Fig 3) The bottom level will hold a 5 gallon reservoir constructed from a 5 gallon food grade HDPE plastic pail. The next three levels will each hold two straight walled containers (also made of HDPE plastic) measuring 24 inches long, by 15 inches wide and 5.5 inches deep. These will be covered with matching plastic lids in which 2 inch holes will be created for net pots. The plants will sit in the net pots with toppers to prevent light form leaking into the root zone. The plants will be set in three rows of five





plants per container. (the lids are available separately and different spacing could be used for different plants or as a teaching experiment) With this spacing the system could hold 90 plants while covering only 6 square feet of green house space giving this system a density of 15 plants per square foot.

Operation

The reservoir will be connected to all 6 of the plant containers with 1/2inch distribution tubing, fed by a PP53016 : 530 GPH, submersible pump. To avoid the top tiers from receiving less water than the lower ones, the water will first be pumped to the top of the structure along a single piece of tubing and then sent down different distribution tubes to all of the plant tubs. In each of the tubs there will be a open drain at about 4.5 inches up the container that will drain excess water back to the reservoir, thus maintaining an even level. As the pump will need to drive a vertical climb of approximately 6 feet; it should be able to circulate about 251 gallons per hour (GPH). Assuming that we successfully distribute the water evenly across all of the tubs, that would mean we would see a flow rate of about 62.5 GPH across each tub. To put it another way, the pump will refill each tub once every 7.1 min. This is important because instead of aerating each tub individually, the system will instead just aerate the central reservoir. This will be achieved using a Hydrofarm AAPA45L 20-Watt 45-LPM Active Aqua Commercial Air Pump with a PENN PLAX Air-Stone. The central reservoir will also provide a convenient place to monitor water reserves, pH, ORP, CF, nutrient levels and to adjust.

Lighting

Additional lighting will be used on each tier of the system consisting of 3 ultra high output led arrays, for 9 arrays in total. Each array will put out about 2,000 lumens of light at a 120° beam angle. In total the lighting system should produce 18,000 lumens. A high efficacy constant current power supply will drive the arrays and altogether the system will consume 150 watts. This configuration would provide a luminous efficacy of about 120 lumens per watt.

A Side Note On Wight

It should be noted that the system as specified is rather close to the maximum weight allotment of the the shelving unit. The rated maximum per shelf is 160 lbs. Each tub measures 24-Inches long, by 15-Inches wide and 5.5-Inches deep and we plan to fill them with 4.5 inches of water for a total of 1620 cubic inches of water per tub. That works out to .9375 cubic feet of water. There are 7.48 gallons of water in one cubic foot (at STP) so that means that each tub should hold 7.0125 gallons of water. Water weights approx. 8.35 lbs / gallon (again at STP) so that means that each tub will weight 58.5 lbs for a total of 117 lbs per shelve, this puts us to within 43 lbs of the working weight limit of the shelves. While I would not expect anything grown in this system to weigh 43 lbs., it should be noted that using larger tubs or filling the suggested tubs higher than 4.5 inches may cause the system to fail.

It is also worth noting that when this system is fully loaded it will weigh more than 400 lbs and as mentioned before the foot print of the system is 6 square feet. It should be ensured that the structure that it is sitting on can hold it is weight, especially if more than one of the systems are to be built.

Budget

A detailed itemized budget for this system is provided in the spreadsheet below. The prices listed include shipping if being shipped, but do not include transportation costs if being purchased locally. As specified, this system will cost approximately \$675.

While great pains have been taken to try to include all items necessary for the basic operation of the system in the spreadsheet below, If this system were to be built I would suggest including a 15% contingency when budgeting.

Recirculating deep water culture (DWC) System Budget Detail

t	Item	Vendor	Price Ea	Price Ext.
6	Buckhorn SW2415060206000 Plastic Straight Wall Storage Container Tote, 24-Inch by 15-Inch by 5.5-Inch, Dark Grey	Amazon.com	\$24.78	\$148.68
6	Buckhorn Straight Wall Container Lids Model SL24150100 Cove	CEC	\$7.44	\$44.64
1	100 2 Inch Net Slit Pots and Neoprene Inserts Combination	Amazon.com	\$45.49	\$45.49
1	TRINITY 5-Tier NSF Outdoor Rack, 48 by 18 by 72-Inch, Gray	Amazon.com	\$119.00	\$119.00
1	PP53016 : 530 GPH, Submersible, Fountain, Pond, Waterfall Pump - 45W, 16' Cord	Amazon.com	\$32.99	\$32.99
1	PENN PLAX Add-A-Stone Air Pump Accessories, 10-Inch by 2-Inch	Amazon.com	\$6.44	\$6.44
1	Flexible Aquarium Air-Line Tubing	Amazon.com	\$6.48	\$6.48
1	Hydrofarm AAPA45L 20-Watt 45-LPM Active Aqua Commercial Air Pump with 6 Outlets	Amazon.com	\$38.06	\$38.06
1	Orbit Underground 67346 1/2x100Univ Dist Tubing	<u>Amazon.com</u>	\$16.37	\$16.37
3	Orbit 65452 DripMaster 1/2" DripLock Tee, Bag of 5	Amazon.com	\$4.89	\$14.67
3	Orbit Underground 67462 1/2" DL End Cap	Amazon.com	\$6.62	\$19.86
1	5 Gallon White Bucket & Lid - Durable 90 Mil All Purpose Pail - Food Grade - BPA Free Plastic	Amazon.com	\$9.95	\$9.95
10	High Power LEDs - White ZC18 POWER COB WARM WHITE 3000K	(C), Mouser	\$6.23	\$62.30
1	LED Power Supplies 150W 26-36V OUT LED DRIVER	Mouser	\$72.87	\$72.87
9	Aluminum SMT Heat Sink - 0.5"x0.5" square	<u>Addafrouit</u>	\$2.75	\$24.75
2	Heat Sink Thermal Tape - 3M 8810 - 80mm x 80mm	Addafrouit	\$4.50	\$9.00
		Plant Contai	nment System Subtotal	\$238.81
		Support Stru	cture Subtotal	\$119.00
		Pumps and Tubing Subtotal		\$144.82
		Lighting System Subtotal		\$168.92
			Total	\$671.55

FLOOD AND DRAIN "DUTCH BUCKET" SYSTEM

Principle of Operation

In its simplest form, there is a tray above a reservoir of nutrient solution. Either the tray is filled with growing medium (clay granules being the most common) and planted directly, or pots of medium stand in the tray. At regular intervals, a simple timer causes a pump to fill the upper tray with nutrient solution, after which the solution drains back down into the reservoir. This keeps the medium regularly flushed with nutrients and air. Once the upper tray fills past the drain stop, it begins recirculating the water until the timer turns the pump off, and the water in the upper tray drains back into the reservoirs.



Proposed System

Structure

As proposed, The system will be supported by a structure made out of Steel Strut

Channel (see Fig. 4). The frame structure will stand 8 feet tall 2 feet wide and 6 feet 8 inches deep. A reservoir





ground at one end of the structure. The structure will support two rows of six plants. They will sit in 5 Gallon HDPE plastic pails that will be filled with PrimeAgra Ceramic Growing Medium. The pails will be supported by a platform that sits 14 inches above the floor to allow for a gravity-fed water return to the reservoir. Above the plants, about 8 feet off the ground, will be two horizontal supports also made out of Strut Channel. These will support two LED light modules as well as providing an anchor point for plant supports. This system will hold twelve plants and occupies 13.3 square feet of space giving this system a density of about .9 plants per square foot.

constructed from a 5 gallon food grade HDPE plastic pail will sit on the

Operation

Water will circulate through the system driven by a PP53016 : 530 GPH, Submersible pump placed in the reservoir. One half inch distribution tubing will be connected to the pump and extend up to the growing bed. It will run between the two rows of plants and extend to the opposite end of the platform. The water will be fed to the plants via 1/4 inch tubing connecting the 1/2inch distribution tubing to the buckets. The water will filter through the growing medium to the bottom of the buckets. The buckets will fill with water until a syphon is activated. Then, via a gravity-fed return made out of 1/2 inch distribution tubing, the water will return to the central reservoir.

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Lighting

Lighting will be provided by 2 LED lighting units each made out of 9 LED array chips. Each array will put out about 2,000 lumens of light at a 120° beam angle. In total each lighting unit should produce 18,000 lumens. A high efficacy constant current power supply will drive the each unit and altogether the system will consume 300 watts of electricity and produce 26,000 lumens of light. This configuration should provide a luminous efficacy of about 120 lumens per watt.

A Note About Density

This system is significantly less dense than the other systems suggested by this document and many systems currently commercially available. The system is designed to allow room for large vine crops like tomatoes and tomatillos and the infrastructure needed to support them. This will allow for maximum yield per plant so while the number of plats might be lower the yield per square foot of growing space will be increased.

Budget

A detailed itemized budget for this system is provided in the spreadsheet below. While all of the prices listed include shipping if being shipped some of the shipping charges have been estimated and could very significantly. The prices listed do not include transportation costs if being purchased locally. As specified, this system will cost approximately \$1005.42. While this is more expensive than the otter systems suggested it still compares favorably agent many comparable commercially available systems. One popular system the EuroGrower system, witch has a street prince of about \$600 delivered, has 6 grow sites for a cost per plant site of about \$100 and does not include plant support or lighting. The proposed system has 12 grow sites for a cost per plant site of \$83.79.

While great pains have been taken to try to include all items necessary for the basic operation of the system in the spreadsheet below, If this system were to be built I would suggest including a 15% contingency when budgeting.

Flood and Drain "Dutch Bucket" System Budget Detail

Qt	Item	Vendor	Price Ea	Price Ext.
4	Steel Strut Channel, Slotted, 1-5/8" x 1-5/8", Green-Painted, 8' Length	Mcmaster	\$28.30	\$113.20
4	Steel Strut Channel, Slotted, 13/16" x 1-5/8", Green-Painted, 6'8" Length	Mcmaster	\$17.94	\$71.76
4	Steel Strut Channel, Slotted, 13/16" x 1-5/8", Green-Painted, 2' Length	Mcmaster	\$5.98	\$23.92
4	Strut Channel Accessory, 90 Degree Angle Bracket, 2-Hole, Green- Painted Steel	<u>Mcmaster</u>	\$1.82	\$7.28
4	Strut Channel Accessory, 90 Degree Angle Bracket, 4-Hole, Green- Painted Steel	<u>Mcmaster</u>	\$2.62	\$10.48
12	Cap for 1-5/8" Single Strut, Plastic	Mcmaster	\$0.62	\$7.44

Qt	Item	Vendor	Price Ea	Price Ext.
3	Nut for Strut Channel, Zinc-Plated Steel, for 1-5/8" Wide Strut, M8 Thread - Pack of 5	<u>McMaster</u>	\$4.85	\$14.55
3	Nut for Strut Channel, Zinc-Plated Steel, for 1-5/8" Wide Strut, M8 Thread - Pack of 5	McMaster	\$4.85	\$14.55
2	Metric Pan Head Phillips Machine Screw, Zinc-Plated Steel, M8 Size, 25mm Length, 1.25mm Pitch - Pack of 25	McMaster	\$8.48	\$16.96
1	24 in. x 80 in. Composite Unfinished Interior Door Slab	<u>HomeDeopt</u>	\$24.00	\$24.00
13	5 Gallon Plastic Pail - White	<u>Uline</u>	\$4.89	\$63.57
1	PP53016 : 530 GPH, Submersible, Fountain, Pond, Waterfall Pump - 45W, 16' Cord	Amazon.com	\$32.99	\$32.99
1	Orbit Underground 67346 1/2x100Univ Dist Tubing	Amazon.com	\$16.37	\$16.37
1	Rain Bird BC25-10PK Landscape Dripline System 1/4-Inch Barbed Coupling, 10-Pack	Amazon.com	\$7.14	\$7.14
1	Rain Bird Landscape Dripline System 1/4-Inch Tubing - 100-Foot Roll T22-100	Amazon.com	\$8.23	\$8.23
3	Orbit 65452 DripMaster 1/2" DripLock Tee, Bag of 5	Amazon.com	\$4.89	\$14.67
3	Orbit Underground 67462 1/2" DL End Cap	Amazon.com	\$6.62	\$19.86
10	PrimeAgra Ceramic Growing Medium - 20 Liters	First Rays LLC	\$18.00	\$180.00
20	High Power LEDs - White ZC18 POWER COB WARM WHITE 3000K	(C), <u>Mouser</u>	\$6.23	\$124.60
2	LED Power Supplies 150W 26-36V OUT LED DRIVER	Mouser	\$72.87	\$145.74
9	Aluminum SMT Heat Sink - 0.5"x0.5" square	Addafrouit	\$2.75	\$24.75
2	Heat Sink Thermal Tape - 3M 8810 - 80mm x 80mm	<u>Addafrouit</u>	\$4.50	\$9.00
2	Heat Sink	Mouser	\$27.18	\$54.36
		Plant Containment System Subtotal		\$243.57
		Support Structure Subtotal		\$304.14
		Pumps and Tubing Subtotal		\$99.26
		Lighting System Subtotal		358.45
		Total		\$1005.42

REFERENCES

1 - [1] The Old Farmer's Almanac (2014, Yankee Publishing, Inc., P.O. Box 520, Dublin, NH 03444, (603) 563-8111) "Plastics"

2 - [2] Wikipedia (29 March 2014), "Nutrient film technique"

3 - [3] ADAMS, P. (1994). "NUTRITION OF GREENHOUSE VEGETABLES IN NFT AND HYDROPONIC SYSTEMS. Acta Hort. (ISHS) 361:245-257"

- 4 [3] Wikipedia (1 April 2014) "Deep water culture"
- 5 [4] Wikipedia (9 May 2014) "Hydroponics"

REVISION HISTORY

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NFT system edited to include supplemental lighting.

- -System overview updated to include structure for lighting.
- -Lighting section added. -Budget updated.