THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF PLANT SCIENCE

A Proposal to Supply University Park Campus Dining with Local Hydroponically Grown Lettuce

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FALL 2020

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Plant Sciences
with honors in Plant Sciences

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ABSTRACT

Growing public interest in local food has sparked many new growing enterprises closer to population centers. These enterprises often focus on providing fresh produce, and especially fresh greens such as herbs and lettuce, as these crops can be grown intensively in indoor spaces. Hydroponic systems offer an exciting opportunity for local produce to become more accessible. Penn State has a unique opportunity to expand current hydroponic lettuce production to supply a significant portion of fresh lettuce to on-campus dining at Penn State's University Park campus. An existing relationship between the Student Farm Club and Redifer Dining Commons inspired the proposal of a larger operation. This thesis describes a hydroponic system that is resource and cost efficient, and productive enough to provide fresh salad greens at a competitive price. I hypothesize that a nutrient film technique (NFT) system, rather than a deep-water culture system, is the best option for growing at Penn State. An NFT system is a popular commercial growing system that supports the plants with roots hanging down in a narrow channel, while running a thin film of nutrient salt solution over the roots. A 12,288 square foot greenhouse space will be sufficient to provide all of the lettuce for one resident dining hall on campus. This operation will provide employment and learning opportunities for students, and help Penn State reduce its carbon footprint.

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ACKNOWLEDGEMENTS

My sincerest thanks go to Dr. Berghage and Dr. Karsten, who both worked with me through the most difficult and unusual circumstances of this year. Thanks to Tarrah Geszvain, my advisor, for keeping me on track and giving me confidence to finish my degree requirements.

I would like to thank the Student Farm Club and Leslie Pillen for providing me with a chance to learn more about hydroponics and crop production.

Lastly, I would like to thank my family for providing me with unwavering emotional support to pursue a field that I love.

Chapter 1 Introduction

Penn State's Operations

Penn State's University Park campus has 5 residential dining districts. Penn State prides itself on providing students, staff, and visitors with quality food. A selection of fresh produce is an important part of the offerings. Fresh salad greens are a staple, and Penn State currently receives weekly shipments of produce from suppliers around North America. A small portion of their lettuce is sourced from the Student Farm's hydroponics project. Table 1 includes the volume, weekly use in pounds, and total price paid per week at one of these resident dining halls, Redifer Dining Commons.

Table 1 Current salad consumption at Redifer Dining Hall on University Park campus (S. Gawlowicz, personal communication, Sept. 2, 2020).

Current Salad Use per Semester			
Produce type	Price per pound	Weekly use in pounds	Total price per week
Iceberg/ Romaine Mix	$ 0.95	400	$380
Chopped Romaine	$ 1.65	400	$660
Whole leaf Lettuce	$ 1.88	20	$37.60
Salad Mix 3 leaf (from commercial suppliers and Student Farm)	$ 2.30	200	$460
Total per week		1020	$1,537.60
Total per semester		16,320	$24,602

The Student Farm at Penn State

The Student Farm at Penn State (SFC) is a student-led organization that provides a great opportunity for students and the community to engage with sustainable food production. For four years (2016—2020), a project operating within the SFC has been growing hydroponic baby leaf lettuce to supply Redifer Dining Hall’s salad bar, comparable to the salad mix they receive from commercial suppliers. The dining hall pays the same prices for lettuce from both the commercial suppliers and the Student Farm. This hydroponics project used a deep-water raft system, a premixed hydroponic fertilizer such as Masterblend fertilizers for continuous liquid feed, and student volunteer laborers for seeding, maintenance, and harvest (Water-Soluble, 2019). Growing occurred inside on-campus greenhouse space in a single section of greenhouse, approximately 2500 square feet, with no additional grow lighting. A deep water culture system was used with between five and fifteen fifty-gallon tanks in production at one time. This operation focused on student engagement, and not production, so the harvests were small and irregular, not providing a significant source of lettuce for the dining hall. The crops produced included lettuce, basil, and tomatoes (L. Pillen, personal communication, Aug. 11, 2020).

Since this relationship is already established, Penn State is in a prime position to expand this process to supply a greater portion of their fresh salad greens with locally grown produce.

Chapter 2 Review of Literature

At its very essence, a hydroponic growing system is any system that grows plants in water rather than soil. Hydroponics has been in commercial practice since the 1930s, when greenhouse vegetable producers began to have an interest, although experiments in growing plants in a nutrient solution began in the 1800s. W. F. Gericke of the University of California took these preliminary laboratory experiments to the commercial scale, and termed the coin *hydroponics*, solidifying it in the industry, and the method continues to grow in popularity and scale (Resh, 2013). The term hydroponics describes a wide variety of systems that combine irrigation and fertilization in a buffered nutrient salt solution applied to roots (Riggio et al., 2019). Different systems use still or flowing water, with or without recirculation, and with or without a solid medium to house roots. The most common systems used commercially for leafy vegetables and salad greens are nutrient film technique (NFT), deep water culture (DWC), flood and drain, continuous drip, and the wick method (Riggio et al., 2019). The NFT and the DWC systems are the most popular by far in commercial production for lettuce (Brechner & Both, 2013).

System Descriptions

Deep water culture (DWC) is the most prominent form of hydroponics, and also the simplest (Resh, 2013). This system utilizes relatively deep beds filled with a mostly static nutrient solution. The beds can be individual, or connected by water pumps as in a recirculating DWC. The plants are supported by a raft of foam core that floats on the surface of the water, letting the roots hang down into the solution, doubling to exclude light from the nutrient solution and reducing algae growth, as well as insulating the water from temperature changes. This system requires aeration, usually by placing air stones attached to a pump in each bed. Water culture also requires UV sterilization of irrigation water to destroy pathogens spread through moisture, like *Botrytis cinerea*, *Cladosporium sp.*, *Fusarium spp.*, *Sclerotinia sclerotiorum, Verticillium albo-atrum*, and several others (Resh, 2013).

Figure 1 Deep Water Culture at PSU greenhouse. (Photo credit: Dr. Robert Berghage, PSU.)

Nutrient film technique (NFT) is another popular system. Contained in PVC tubes or channels, this system supplies a thin film or stream of nutrient solution over the roots. The aeration of roots in NFT is very good as the water only runs along the bottom of the channel, leaving space for air directly next to the roots. This system is especially suited for lettuce and short-statured plants, as a large root mass, from a vining plant for example, will clog the tray and impeded irrigation flow. This system is also highly customizable and can be scaled down or up to meet production requirements; and because the individual trays are smaller, they can be replaced if they are damaged for a low cost (Resh, 2013). The trays can be easily sanitized to eliminate disease issues that arise from hydroponics. NFT requires UV sterilization of recirculated water to cut down on pathogens. This is built into the recirculating system, as well as a chiller to keep the irrigation water cool. Due to its ease of sanitization, and lack of need for aeration pumps, I will recommend an NFT system for Penn State.

Figure 2 NFT system in production at Twinsprings Farm. (Photo credit: Dr. Robert Berghage, PSU.)

Benefits of Hydroponics

The benefits of hydroponics are numerous. These systems use water much more effectively than conventional production systems. They have higher yields, and can support year-round production. The nature of hydroponics reduces some environmental impacts of conventional agriculture, such as large land and water requirements, runoff and erosion (Barbosa et al., 2015). These systems can also produce a higher quality product, based on precise control over plant nutrition, and protection from environmental stresses (Koo et al., 2016). Greenhouse technologies are well-researched and established, and are able to supply a safer, year-round harvest, and can be constructed near population centers (Despommier, 2011).

Water Conservation

Seventy percent of withdrawn freshwater is used for agriculture. Being regularly hailed as the next generation of agricultural technology, hydroponics uses far less water than many traditional soil growing systems. In a comparison of water use in a greenhouse NFT system and conventional lettuce production in Arizona, NFT used 20 ± 3.8 L/kg/y while conventional methods used 250 ± 25 L/kg/y, a difference over tenfold (Barbosa et al., 2015). Water use is conserved by applying irrigation directly to plant roots and recirculating it. Flood irrigation or overhead irrigation used in conventional agriculture loses a large portion of water to the environment.

Sanitation

The lack of soil and control over the environment of the plant leads to reduced possible animal contamination (Riggio et al., 2019). Hydroponic cultivation systems do create a high moisture environment, as the humidity in greenhouses can rise quickly if not ventilated well, such as in cases when outdoor temperatures are not ideal. They also often reuse water, which can create a favorable environment for microbial growth. Preventing contamination is especially important for fresh greens like lettuce, as they are generally eaten fresh, and do not go through cooking or a "kill step" (Koo et al., 2016). This potential issue is avoided by many growers using a UV sterilizer component in their recirculating systems; this kills both plant and human pathogens. Growers have established other methods to deal with these issues, mainly rooted in prevention. Many commercial greenhouses require employees to wash or change clothes when switching in between greenhouse sections to prevent spreading insect vectors or disease. Keeping water off of leaves helps prevent the spread of plant diseases, another reason the irrigation system a key part of sanitation (R. Berghage, personal communication, Nov. 5 2020).

Local Production

Transportation accounts for 11% of greenhouse gas emissions related to food production (Weber & Matthews, 2008). The transport of fruits and vegetables in the U.S. represent 10% of freight requirements. The average final delivery of food is 1020 miles from its site of production (Weber & Matthews, 2008). By moving this production closer to campus, we can reduce the cost of transporting the lettuce from distant growers and reduce the associated carbon footprint. The

Penn State Sustainability Institute has been monitoring greenhouse gas emissions caused by Penn State campuses since 2005, and focusing on efficiency and energy conservation to draw down GHG emissions. Other initiatives exist as well, such as their extensive recycling program and compost collection in dining halls (Climate Action, 2020). This venture would be another way for Penn State to draw down its GHG emissions, by reducing food miles needed to bring our produce to campus. It would also present the opportunity for students to work at the facility, earn wages, stimulate the local economy, and teach about food production.

Yield Benefits

Hydroponics provides the crop a close-to-ideal environment to grow in. This results in a high yield increase over conventional field grown methods. (Barbosa et al., 2015) found that hydroponic yield can be 10 times that of a conventional crop, although results vary. The protected environment of a positively pressured greenhouse can greatly reduce the presence of insect pests and pathogens, both which have large detrimental effects on yield (Despommier, 2011). A year-round harvest is also possible with hydroponic greenhouse production with supplemental lighting and heat during the winter, as opposed to the season restrictions field production of central Pennsylvania. Given that the most students are present at University Park during the fall and winter months, this extra yield is a huge advantage over field production.

Barbosa et al., (2015) compared the yield and energy requirements of lettuce grown in an NFT system in a greenhouse with temperature controls, and supplemental lighting, compared to conventional, outdoor-grown lettuce. Their findings are presented in Table 2. The Barbosa paper uses an average plant density of 24 plants/m2, a harvest cycle of 30 days, and an average fresh weight of 144.6 g/plant. Barbosa found hydroponics had a much greater yield (11 +- 1.7 times greater) than conventional, while using 13 ± 2.7 times less water, but 82 ± 11 more energy per kilogram. There seem to be no major studies that directly compare lettuce yield in DWF versus NFT systems. Yields are affected by a wide range of factors, including quantity and quality of light, aeration of root zone, fertilizer mix, pest presence, etc.

Table 2 Yield comparisons of NFT and conventional production (Barbosa, 2015).

Yield Comparisons			
	Yield (kg/m^2/y)	Energy Use (kJ/kg/y)	Water Use (L/kg/y)
Hydroponics – NFT	41 ± 6.1	90,000 ± 11,000	20 ± 3.8
Conventional	3.9 +- 0.21	1100 ± 75	250 ± 25

Crop Information

Leafy vegetables are the most important ready-to-eat product (Manzocco et al., 2011). Leafy lettuce (*Lactuca sativa*) is especially suited to hydroponic growing methods, as it has a short production and harvest cycle, doesn't require support such as trellises, and grows to a uniform size. The most commonly grown edible crops on a hydroponic system include cucumber, tomato, pepper, and lettuce (Resh, 2013). As American diets shift toward preferences for larger quantity and variety of leafy greens, a more reliable market for those products can be capitalized on by specialty hydroponic producers. Schools are noted as an excellent potential market for producers, as they have a nearly year-round demand that is very constant. Lettuce has a short postharvest longevity, and shifting to local production will reduce transportation time, helping prevent food waste from spoilage during or shortly after shipping. There are a wide variety of colors and textures of lettuce seed available, with many varieties specifically suited for greenhouse growing. A high-quality hydroponic lettuce can fetch a higher price, making the extra capital investment worth it (Kaiser & Ernst, 2016.).

Chapter 3 Analysis

Cost Analysis

The Ohio State University Hydroponic Program has developed free enterprise budget calculations for hydroponic greenhouse production of lettuce on their College of Food, Agricultural, and Environmental Sciences webpage (Donell et al., 2011). These model costs and calculations were used to estimate the variable and fixed costs of greenhouse lettuce production on Penn State's campus. Relevant calculations are displayed in the table below. All figures are per year.

Model Assumptions

The model assumptions are that the greenhouse will support year-round production. A rotational harvest needs to be established so that a delivery can be made each week to the customer. Since each crop will need a minimum of 4 weeks to grow on, a rotation of 4 groups are needed to provide a weekly harvest. This deviates from the more common method of "turns", where the whole crop is harvested and then started again from transplants. The whole greenhouse will be growing on at once, with the 4-week rotation taking place for each step of the process—seeding, transplanting, and harvesting.

The model uses Quonset style houses which can be added upon; however, in this case, growing will be carried out in existing greenhouse space, so only square footage is considered. A facility of 12,288 square feet would provide enough space for each plant to occupy 64 square inches. An average head of lettuce is assumed to weigh 5 ounces.

Variable costs include production supplies such as fertilizer, pesticides and biocontrols, seeding media, seed; production labor, for seeding, harvesting, and packaging; packaging costs; and utilities. Fixed costs include the greenhouse structure, environmental control equipment, monitors and the NFT system itself. The NFT system included the PVC trays where the plants are housed, support structures, pumps, nutrient tanks, chiller, and UV sterilizer. If using existing greenhouse space at Penn State, most of the fixed costs can be omitted, but the cost of the NFT system still needs to be considered.

The model assumes that student workers will spend about 9 hours per week on production management; this position would be offered to a student with some experience or completed coursework in greenhouse crop production. Another 113 hours per week are attributed to seeding, transplanting, harvesting, and packing; 11 students each working 10 hours a week on rotating shifts could meet the weekly maintenance of the system.

Model Results

With the square footage of 12,288, and 90% of space utilized for growing to leave space for aisles, the maximum growing capacity is 24,883 heads growing on at a time. With the 4-week rotation and an assumption of a 5% loss, each week will see a harvest of 5,910 heads, equivalent to 1,847 lbs of lettuce. Over a 16-week semester, this equates to 29,552 lbs of lettuce. Over a year, that's 96,044 lbs of lettuce.

Variable Costs: Breakdown of individual costs are included in the appendix. Total production supplies, including fertilizer, pesticides, seeding media, seed, and biocontrol is estimated at $12,506 per year. Some examples of suitable lettuce varieties for greenhouses from Johnny's Seed are Rex Pelletted Lettuce Seed Product ID: 2967JP $120.10/5000 seeds; Truchas (Red) Organic Lettuce Seed $53.65/5000 seeds; Tropicana Organic Pelleted Lettuce Seed

Product ID: 2485GP $29.20/5000 seeds. Production labor is the most significant cost for this enterprise. With wages ranging from $8/hour to $10/hour for tasks such as seeding, transplanting, and harvesting, maintenance, production management, and delivery, approximately 137.6 hours of labor per week are necessary to maintain the operation. This equates to 7,154.4 hours per year, with a total cost of $60,744. Packaging costs, including the boxes, liners, and labels, are estimated at $20,290. Crispers are not necessary as we are selling wholesale and do not need to display the lettuce as retailers would. Utilities such as natural gas, electricity, water and sewer, are estimated at $27,570. Another $2,870 is attributed to miscellaneous costs, such as laboratory fees for leachate testing and tissue analysis. Total variable costs come out to $123,980.

Fixed Costs: The purchase and construction of an NFT system is necessary. The system and the support system to cover 16588.8 linear feet of channels, at $2 per linear foot, will cost $43,131. EC and pH meters, humidity and CO_2 sensors add another $955. Supplemental lighting will need to be installed for the shorter days of winter, which adds $17,500. Rent will also need to be paid to Penn State for use of their space; $0.19/square foot/month is the current rate. With a square footage of 12,288, that comes out to $2,334.72 per month, or $28,016.64 per year. Fixed costs sum at $89,603. Total annual costs are $202,322 for the first year of production.

Redifer Dining Common's current use is 1020 lbs of lettuce per week; this includes the 3 leaf salad mixed, chopped romaine, and whole leaf lettuce. All of Redifer's salad mix and fresh leaf lettuce could be provided by this proposed system. Excess could be sold to other dining halls on campus. The highest price the dining halls pay for fresh salad mix is $2.30/lb, or $0.72/head. At this price, the first year of production would not be profitable, and would lose $32,129. However, the NFT system will last several years, and the second year would be profitable with a return on investment of $11,002. After the second year, the deficit would be $21,127; the third year, $10,125; and after the fourth year, the operation will finally make a return on investment of $877. The NFT system will be paid for in just under 4 years. After that, the $11,002 becomes profit that can go toward any upgrades the student employees want to make.

Standard Operating Procedures (SOP)

SOPs are an important part of any production facility. These documents should be displayed at work stations and readily available to all workers. This standardizes the entire process, ensuring quality control, food safety, and worker safety (Brechner & Both, 2013). With Penn State’s tech-savvy student body, the best way to create SOPs would be in video form. Record a volunteer performing each task, with clear explanations and identifying each important step. Then use file sharing services to share these video SOPs with all employees. For example, a harvest SOP will begin with hand washing, and sanitizing tools. A brief explanation for why each step is taken, like ensuring food safety, should be included. A demonstration of how the head of lettuce is grabbed and clipped at the base, how they are packed into the boxes, and how to properly weigh, label, and record the harvest. These SOPs should be developed for seeding, transplanting, cleaning the NFT system, refilling the fertilizer tanks, and scouting for pests.

Fertilizer

A Modified Sonneveld's solution is an industry standard salt mix widely used for lettuce production. This solution includes all macronutrients N, P, K, Ca, Mg, S, and micronutrients, B, Fe, Mn, Zn, Mo, Cu, as is necessary when designing a hydroponic nutrient solution, as this will be the only source of nutrition. Background salts in the water may need to be considered when mixing custom nutrient solutions.

Lighting

Supplemental lighting is necessary for year-round production in Pennsylvania. They should be evenly distributed throughout the growing area. A total of 15 mol/m2/day is recommended for lettuce (Brechner & Both, 2013). Sensors to detect sunlight, as well as historical records of amounts of sunlight received during each time of year can regulate when lights are necessary.

Production schedule

Production of lettuce in a hydroponic system, from seeding to harvest, takes approximately 6-8 weeks. This time scale will differ from summer to winter, even with supplemental lighting. As some dining halls are open year-round, to truly supply a significant portion of campus dining's lettuce, year-round greenhouse production is necessary. My proposal includes use of existing greenhouses on Penn State campus.

In order to have a continuous harvest each week, staggered seeding and transplanting is recommended. Seeding to transplant size takes 1-3 weeks. Once the seedlings are transplanted into the system, let them grow on for 4 weeks before the heads are harvest size.

Seeding

Seeding into flats of rockwool will be done each week. Ebb and flood benches are a popular and efficient solution for seeded flats. These benches sub-irrigate the flats on an automatic timer, usually twice per day for 10-15 minutes. Plain water or a nutrient solution can be used. A reservoir holds that water when the benches are empty. All reservoirs should be opaque and covered as much as possible, to inhibit algae growth. Irrigation tubing and a small pump, connected to the timer, will supply the water. The system should be checked daily to catch failures. A germination room is not necessary for lettuce, and is very energy intensive. Pelleted seed is recommended as it is easier to handle and will germinate better (Brechner & Both, 2013).

Figure 3 Lettuce seedlings growing in rockwool cubes at a PSU greenhouse. (Photo credit Dr. Robert Berghage, PSU)

Transplanting

Seedlings can be transplanted at 11-14 days from seeding. At transplant the rockwool cubes can be separated and placed into the individual holes in the NFT troughs, making sure the young roots are in contact with the nutrient solution film.

Harvest

Harvest occurs 4-5 weeks after transplanting. In consideration of the dining hall's needs, harvesting without the root ball is the best option. Each head can be cut with a sharp knife or pair of trimmers, or snapped by hand. Heads should be placed in cardboard or plastic boxes with a food-safe plastic liner. Lettuce should be refrigerated as soon as possible at 40F to remove greenhouse heat.

Pest Management

A few common pests are common in greenhouses across the country, and a robust integrated pest management (IPM) plan should be in place to prevent and control pest populations from cross the economic injury level. The most common insect pests of lettuce are aphids, thrips, and whiteflies. The first step of an IPM program is scouting and monitoring, which can be done by hand, or by the use of traps or sticky cards. Correct identification of the pest is crucial to choosing control methods. The use of beneficial insects as a biological control agent is common in commercial greenhouses. Companies that sell biocontrols will include a management plan for the grower. For example, *E. formosa*, a parasitoid wasp, will attack and kill whitefly larvae and adults. Many horticultural soaps and oils are rated for greenhouse use, and will have lower reentry intervals for workers than harsher pesticides (Resh, 2013).

Botrytis, Fusarium and *Pythium* are all examples of common pathogens that may cause widespread damage to a greenhouse crop. Sanitation and prevention are the keys here, as well as culling infected plants as soon as they are detected. A 10% bleach solution can be used to clean all equipment as well as trays or beds (Resh, 2013).

Legal requirements for food safety

The Food Safety Modernization Act (FSMA) of 2011 is a set of regulatory standards set forth by Congress to control the spread of human pathogens on fresh produce. Foodborne illnesses sicken 48 million Americans each year, and kill 3,000 (*Food Safety Modernization Act (FSMA)*, 2020). Many of these cases occur from human pathogens present on fresh produce, that is not cooked and therefore does not go through a "kill step" to reduce pathogens. Hydroponics facilities are considered a "farm" under this act, and unless they obtain an exemption status, must follow the rules of the FSMA. This operation will receive a "qualified exemption" from the regulations of the FSMA as the produce will be sold to a qualified end-user, campus dining, that is within the same state as the farm. This legislation provides an updated guide on how to best prevent contamination of the food supply, and it would be wise to follow the regulations as closely as possible even though not legally required; for example, the act includes a written food safety plan that evaluates hazard analysis and preventative controls, which should be updated every 3 years (*Food Safety Modernization Act (FSMA)*, 2020).

Chapter 4 Discussion

This system can comfortably supply all of the fresh lettuce used at Redifer each semester. There are five student dining commons on campus, so to to supply every dining hall on campus, additional construction off-site would be necessary; approximately five times as large as discussed in this proposal, assuming that all dining halls use a similar poundage of lettuce per week. Labor requirements would also be higher. This is a major project that the University is unlikely to undertake.

The variety selection would be tailored to fit what the dining halls desire for food service. Since we are replacing their whole supply, a mix of three varieties of varying textures and color will best serve the PSU dining halls. Johnny's Seed is a reliable seed supplier already used by the University for many greenhouse projects. Offerings include varieties of pelleted seed especially suited for greenhouse and hydroponic production. Given the close relationship between grower and customer, communication with the customer over time could hone which varieties they prefer, and production could be altered accordingly. The quick turnaround of lettuce provides a lot of flexibility for trying out varieties.

The budget calculations include an hourly wage for workers to provide labor for the system. Given the level of routine labor the system would need, it could not rely on volunteers to keep it going. Several employees, likely to be students, will be hired to care daily for the lettuce. This gives opportunities for employment and to learn about food production, a main objective of a university (Despommier, 2011). Two trained students would be sufficient to carry out the daily tasks of monitoring fertilizer levels in the irrigation water, refill stock tanks, and scouting for pests. Larger crews would be arranged for the harvest days.

Almost everyone loves to participate in the “eat local” movement, as they feel good about supporting the local economy and reducing the environmental impact of their meals. This project will allow Penn State students, faculty, and visitors to engage in eating locally. The dining hall could even advertise where their salad greens come from to entice or educate customers.

Chapter 5 Conclusions

Penn State’s University Park campus hosts over 40,000 students and faculty, serving many of them in the five dining halls that offer high-quality and fresh produce every day. This proposal lays out the framework for how existing greenhouse space and student workforce could be utilized to produce a continuous supply of fresh lettuce to Redifer Dining Commons. This enterprise would create jobs, foster a learning environment, and allow diners to participate in and feel good about eating local. It would also lower Penn State’s carbon footprint by reducing the food miles of some of the produce served on campus. The proposed operation would use an NFT system to grow lettuce year-round, using supplemental lighting to aid in wintertime. An area for further research would be a direct comparison of lettuce productivity in an NFT and DWC system. The budget analysis found that the system could become profitable during the fourth year in production, after which it can generate revenue for upgrades. Using an existing relationship between the Student Farm and Redifer Dining Commons puts Penn State in a position to successfully implement this type of operation.

Appendix A

Additional Budget Calculations

ANALYSIS	Variable Costs ($)	Fixed Costs ($)	Total Costs ($)	Return over Variable Costs ($)	Return on Investment ($)
Per Head	0.48	0.38	0.86	0.24	-0.14
Per Square Foot	9.17	7.29	65.86	18.71	-10.46
Per House	112,719.89	89,602.52	202,322.41	57,473.71	-32,128.81
Acre (43,560 sq. ft./acre)	399,583.22	317,633.93	717,217.15	203,739.79	-113,894.14

Analysis summary for the first year.

ANALYSIS	Variable Costs ($)	Fixed Costs ($)	Total Costs ($)	Return over Variable Costs ($)	Return on Investment ($)
Per Head	0.48	0.20	0.67	0.24	0.05
Per Square Foot	9.17	3.78	51.82	18.71	3.58
Per House	112,719.89	46,471.64	159,191.53	57,473.71	11,002.07
Acre (43,560 sq. ft./acre)	399,583.22	164,738.33	564,321.55	203,739.79	39,001.46

Analysis summary for following years.

										Return on Investment:	-32,129

HYDROPONIC GREENHOUSE LETTUCE ENTERPRISE BUDGET
BASED ON QUONSET STYLE HOUSE
INDIVIDUAL BAY DIMENSIONS ARE 24' X 128' = 3072 sq. ft.
64 square inches per plant

HOUSE CONFIGURATION

		NUMBER OF BAYS		BAY WIDTH (ft)		BAY LENGTH (ft)					TOTAL AREA
		4	x	24	x	128					12,288

RECEIPTS[1]

% Space Utilized	Crop Harvest per Turn	Ave. wt. is 5 oz. / head	Packout	Marketable Heads per Harvest		No. Turns per Year[2]	Marketable Heads per Year[3]		Price[4]	Unit	TOTAL RETURN / YEAR
90%	24,883	Heads	95%	23,638	Heads/Harvest	10	236,380	Heads	0.72	/head	170,194

	ITEM	Description				Quantity per year	Unit		Price ($) / Unit		Total Cost per Year
VARIABLE COSTS[5]		**Variable Cost Auto-Adjust[6]:**									
Production Supplies											
	Beneficial Insects	(650 lacewing larvae/package; 1000 insects/900 sq. ft)				22	packages		36.00	/package	792
	Fertilizer										
		Blended Mix				2,000	pounds		0.90	/pound	1,800
		$CaNO_3$				2,000	pounds		0.25	/pound	500
		Additions	Iron Chelate or $MgSO_4$			27	pounds		7.00	/pound	189
	Fungicide/Pesticide[6]					27	gallons		60.00	/gallon	1,620
	Horticubes	1" x 1" x 1.25"	5520/case			46	cases		65.00	/case	2,990
	Sanitizer					9	gallons		35.00	/gallon	315
	Seed	5% overseeding	5,000 pelleted seeds/package			53	packages		80.00	/package	4,240
	Sticky Traps[7]	3 x 5" trap	100/package			2	packages		30.00	/package	60
	Total Production Supplies cost										**12,506**
Production Labor											
	Delivering to Market	0.14	min/head	10.6	hrs / wk	551.6	hrs / year		8.00	/hour	4,412
	Marketing	0.035	min/head	2.7	hrs / wk	137.9	hrs / year		10.00	/hour	1,379
	Seed / Transplant / Harvest / Package	1.5	min/head	113.6	hrs / wk	5,909.5	hrs / year		8.50	/hour	50,231
	Production Management	0.123	min/head	9.3	hrs / wk	484.6	hrs / year		8.50	/hour	4,119
	Maintenance	0.018	min/head	1.4	hrs / wk	70.9	hrs / year		8.50	/hour	603
	Total Production Labor		**Weekly Hrs**	137.6	**Annual Hrs**	7,154.4					**60,744**
Packaging Costs											
	Labels	Used on crispers		1,000/roll		0	rolls		30	/roll	0
	Crispers	1/2 crop in crispers		720/case		0	cases		0	/case	0
	Liners	1/2 crop bulk packed		500/roll		12	rolls		80	/roll	960
	Boxes	1/2 crop in crispers		12 crispers/box		0	boxes		1	/box	0
		1/2 crop bulk packed		20 heads/box		5,910	boxes		1	/box	5,910
	Total Packaging Costs										**6,870**
Utilities											
	Fuel Choice (choose one)[8]										
		Fuel Oil				16,361	gallons		3.7	/gallon	0
		Liquid Propane				26,181	gallons		1.8	/gallon	0
		Natural Gas				2,181	1000 cu. ft.		10	/1000 cu. ft.	21,810
	Electricity (general - non fans)					2,001	kilowatt-hr		0.08	/kilowatt-hr	160
	Electricity (fans and pads)					40,001	kilowatt-hr		0.08	/kilowatt-hr	3,200
	Electricity (fanjets/Horizontal Air Fans)					8,001	kilowatt-hr		0.08	/kilowatt-hr	640
	Electricity (lights)					27,000	kilowatt-hr		0.08	/kilowatt-hr	2,160
	Water and Sewer					400,001	gallons		0.0017	/gallon	680
	Telephone					12	months		50	/month	600
	Cell Phone					12	months		40	/month	480
	Total Utilities Costs										**29,730**
Miscellaneous Costs											
	Advertising, Mailings, Flyers					1	campaigns		200	/campaign	200
	Continuing Education					1	meetings		75	/meeting	75
	Internet Service					12	months		20	/month	240
	Laboratory Fees										
		Leachate Analysis				12	tests		20	/test	240
		Tissue Analysis				12	tests		20	/test	240
		Nutrient Solution Analysis				12	tests		20	/test	240
	Office Supplies					12	months		25	/month	300
	Postage					12	months		15	/month	180
	Marketing Materials & Promotions					1	promos		300	/promo	300
	Record Keeping					12	months		50	/month	600
	Software					3	programs		50	/program	150
	Subscriptions					3	subscriptions		35	/subscription	105
	Marketing & Trade Shows					0	trade show		500	/show	0
	Total Miscellaneous Costs										**2,870**
Professional Services											
	Accountant					5	hours		0	/hour	0
	Lawyer					4	hours		0	/hour	0
	Total Professional Services										**0**
TOTAL VARIABLE COSTS											**112,720**

FIXED COSTS[9]								
Greenhouse Structure								
	Concrete-Material and Labor		10% of floor is 4" concrete	1228.8	sq. ft.	0	/sq. ft.	0
	Frame, Poly, Ends, Door			4	houses	0	/house	0
	Energy/Shade Curtains			11059.2	sq. ft.	0	/sq. ft.	0
	Ground Cover			11059.2	sq. ft.	0	/sq. ft.	0
	Permits			4	permits	0	/permit	0
	Site Preparation			4	houses	0	/house	0
	House Construction	(cost for house construction and installation of components)		600	hours	0	/hour	0
	Total Greenhouse Structure Costs							**0**
	Total Annual Greenhouse Stucture Costs (Annual costs of owning the greenhouse includes depreciation and/or principal payments, interest, repairs, taxes, and insurance)			20%	Annual Fixed Costs[10]			**0**
Greenhouse Environmental Control Equipment								
	Back-up Generator and Transfer Switch			4	bays	0	/bays	0
	Cooling System (fan, vent, & pad)			4	systems	0	/system	0
	Fanjets, 30" 1hp / Horizontal Air Fans			4	fanjets / HAF	0	/fanjet / HAF	0
	Electrical Panel with Computer Relays			4	panels	0	/panel	0
	Computer for Environmental Control			1	computers	0	/computer	0
	Miscellaneous Building Supplies			4	bays	0	/bays	0
	Heating System (reflects utility choice from above)							
		Fuel Oil	200,000 BTU Heaters	4	heaters	0	/heater	0
		Liquid Propane	200,000 BTU Heaters	4	heaters	0	/heater	0
		Tank Lease		12288	sq. ft.	0	/sq. ft.	0
		Natural Gas	200,000 BTU Heaters	4	heaters	0	/heater	0
	Poly Inflation Kit			4	kits	0	/kit	0
	Low Voltage Wiring Package			4	packages	0	/package	0
	Protective Equipment (PPE)			4	sets	0	/set	0
	Grow Lights[13]							
		None						
		Metal Halide	W Lights (with Wiring)	80	Lights	460	/light	0
		Sodium	W Lights (with Wiring)	80	Lights	520	/light	0
		Custom	300 W Lights (with Wiring)	50	Lights	350	/light	17,500
	Annual Hours of Light Usage			1800				
	Total Greenhouse Environmental Control Equipment Costs							**17,500**
	Total Annual Equipment Costs (Annual costs of owning the equipment includes depreciation and/or principal payments, interest, repairs, taxes, and insurance)			0%	Annual Fixed Costs[11]			**0**
Growing & Delivery								
	Back Pack Sprayer			0	sprayers	100	/sprayer	0
	Carbon Dioxide Generator			0	generators	480	/generator	0
	Cooler			4	bays	0	/bay	0
	Delivery Van with A/C			0	vans	6000	/van	0
	Fertilizer Mixing Pump			0	bays	30	/bay	0
	Meters and Sensors	EC		1	meters	160	/meter	160
		pH		1	sensors	50	/sensor	50
		Thermometer		1	thermometers	25	/thermometer	25
	Monitor	Humidity		1	sensors	120	/sensor	120
		CO_2		1	sensors	500	/sensor	500
	NFT System			16588.8	linear feet	2	/linear foot	33,178
	NFT Channel Support System			9953.28	square feet	1	/square foot	9,953
	Scale			1	scales	100	/scale	100
	Total Other Equipment							**44,086**
	Total Annual Growing & Delivery Costs (Annual costs of owning the greenhouse includes depreciation and/or principal payments, interest, repairs, taxes, and insurance)			0%	Annual Fixed Costs[11]			**0**
Miscellaneous								
	Land Rent[12]			12288	acre	2.28	/acre	28,017
	Total Miscellaneous Costs							**28,017**

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ACADEMIC VITA
Lauren Brandenburg

Education
Bachelor of Science in Plant Sciences with Agroecology Option
Graduation: December 2020
The Pennsylvania State University, University Park, PA
College of Agricultural Sciences
Schreyer Honors College
Minor in Chinese Language

Work Experience
The Walt Disney Company — Orlando, FL
Plant Science Intern — June 2019 – January 2020

- Greenhouse operations
  - Maintain 4 greenhouses of EPCOT's "Living With The Land" attraction, including transplanting, pruning, trellising, nutrition, pest and disease management, irrigation, and harvesting
  - Worked with over 150 food crops
  - Learned diverse skills by working with entomologists, plant pathologists, and horticulturalists
- Guest interactions
  - Led over 100 75-minute tours of up to 20 guests, educating and answering questions about all aspects of plant care
  - Interact with guests weekly at the tour desk, selling tours and merchandise

Redifer Dining Commons — University Park, PA
Student Employee — January 2017 – January 2019
Culinary Apprentice — January 2019 – present

- Maintain food safety by measuring food temperatures; cleaning and sanitizing food prep areas
- Develop teamwork with full-time staff and students in a working kitchen

Related Coursework
Horticulture 496, Independent Study

- responsible for caring for poinsettias from cuttings to salable size in the Penn State greenhouses for commercial sale
- responsibilities included measuring and mixing fertilizer for fertigation, cleaning and monitoring plants, helping out at the sale

Plant Propagation, Plant Breeding, Plant Pathology, Floral Crop Production Management

- learned to propagate herbaceous, semi-woody, and woody materials
- identify various common plant pathogens
- basic understanding of genetics and linkage analysis

Relevant Experience
Root Crop Lab

Research Assistant

- Completed laser ablation tomography on root cross-sections; earned laser certification for a Class 4 laser
- Devised test protocol for testing phosphate in leachate samples

Student Farm Club Hydroponics Project

- Set up hydroponic systems and maintain proper pH, CEC, and nutrient content
- Grow basil, lettuce, and tomato from seed to harvest and sell to dining hall on campus

Skills

Hydroponics system management, including NFT, deep water float, aeroponics; pest scouting, Microsoft Word, PowerPoint, Excel, beginner-intermediate Mandarin, Pennsylvania Class C Driver's License

Student Involvement

Student Farm Club, *member*	Spring 2018 - present
PSU KPMD, *dance coordinator*	Spring 2017 - present
Eclipse Indoor Winter Guard, *performer*	Fall 2018