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Methods

Vertical-Horizontal Regulated Soilless Farming via Advanced Hydroponics for Domestic Food Production in Doha, Qatar

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Abstract

Qatar, with a population of 2.17 million, currently has poor cultivated lands and agricultural potential for self-sufficiency. The main problem is the infertile soil and harsh environment, which can be very common in Middle-Eastern Gulf regions. A country with only 1.6 % of arable land and could barely produce its own food would need to spend to import food to meet the demands of the population. An estimated amount of 11 billion USD has been spent on imported food in the year 2014 alone. A developing country like Qatar, which country is basically a desert, would need to come-up with a solution that would allow them to produce their own fresh food, even with an infertile soil. This project proposes to utilize a large-scale vertical-horizontal hydroponic soilless farming technology and aims to briefly present the technology of soilless farming and how it can be utilized for large-scale food production in Doha, Qatar.

The Ministry of Environment of Qatar recently created the *National Food Security Programme* to address the food-shortage in Qatar. One of the main aspects of the program is to utilize various hydroponic systems to grow crops for food-production. Several ideas for the project has been made, but none of them utilizes both vertical and horizontal orientation of planting.

Keywords

hydroponics, soilless farming, vertical-horizontal growing, large-scale

Introduction

Soilless farming is a method whereby plants can be grown without the use and presence of soil. Using this technology, growers are able to produce crops that are not naturally grown in the place (Mason 2014, Mason 1988). Qatar occupies a land area of 160 km^2 and mostly consists of low, barren plains, covered mostly by sand. Technically speaking, Qatar is a desert. Qatar mainly has a dry, *subtropical desert* climate with very low rainfall of 75 mm per annum and intensely hot and humid summers. It has daily temperatures of 41.1 °C and easily exceeding 44.4 °C, reaching 51.1 °C during the peak summer temperature. Only 1.6 % of Qatar's land is arable. Furthermore, this fraction of arable land, due to the harsh conditions, could only grow selected crops (Wyatt 2014). Table 9.

Table 1.
NEW YORK FANS Custom Direct Gas Fired Material Handling Radial Fans Set

Wheel Diameters	.1 m – 2.54 m
Air Volumes	236 m^3/s
CO2 Supply	Yes
Microfilters	30/30 High Efficiency V-bank Configuration
Static Pressures	12454.1 Pa
Horsepower Req.	2,000 HP (1,492,000 J/s)
Temperatures	537.80 ° C
Maximum Eff.	70%

Table 2.
Windmaster® 715mm Tornado Turbine Industrial Roof Ventilator

Air extraction capacity	11,491 m^3/h per unit
Blades	46
Throat	950 mm
Ventilator Head Width	980 mm
Ventilator Head Height	580 mm
Total Height	1,020 mm

Table 3.
AIN KING 30” Quiet Oscillating Industrial Fans

Speed	3-Speed
Oscillation	90°
Min. CFM	1.62 m^3/s
Max. CFM	3.51 m^3/s
RPM	530 (Min) – 1,010 (Max)

Table 4.
Windmaster® VR180 Industrial Evaporative Cooler Set (Aluminum)

Air Output	18,000 m3/h
Temperature Regulator	LCD
Electric Motor	1.1 kW
Water Capacity	40,000 ml
Base Width	1,100 mm
Filters	100 mm HiTech CELdek pads

Table 5.
CONDAIR ME Industrial Evaporative Humidifier

Air Speed	4.5 m/s
Water Connection Press.	2 – 10 bar
Water Temperature	5 – 45 °C

Table 6.
LED Lighting System ILLUMITEX Quantum Horticulture Plant Research LED Lighting System

LED Spectra	Abeo™ FA
Beam Control	Ultra-precision
Channels	450 nm, 660 nm, 730 nm
LED Count	3 LEDs per foot
Dimming	0 – 100 % per LED channel

Table 7.
NFT Channels System - GRAZE GREEN Fodderking 24-24 Custom Vertical-Horizontal Hybrid NFT System

1.6256 m x 0.2286 m Wide x 1.524 m Long UV stabilized, Food-grade PVC Growing Channels
16 Channels (176 holes) per Level by 4 Levels High
Overall footprint of assembled system is 7.3 m Long x 1.2 m Wide x 1.8 m Tall
3 Soaking buckets with 6 mesh liner
9.3 m^2 of growing area

Table 8.
HydroTowers – GROWHARDY I-Stack Commercial Vertical Grow System

6 Levels, 24 Plants/ Tower
6 Planting pots/ 6 Support Plates
24 Grow Pots

Table 9.
Climate Data for Qatar

	Average Low °C	**Average High °C**
January	12.8	25
Febuary	15.5	26.1
March	17.2	26.7
April	22.2	37.2
May	24.4	46.7
June	28.9	51.1
July	28.9	51.1
August	31.1	51.7
September	24.4	46.1
October	22.8	42.2
Novermber	19.4	35
December	16.7	27.2

The main difference between soil and soilless farming is basically the way the plants take in the nutrients. Conventional farming would require fertilized soil and make the plants, especially their roots, work hard in order to acquire the necessary nutrients. Furthermore, plants on soil rely on nitrogen fixation by diazotrophs to be efficiently nourished (Wikipedia

2015, Puri et al. 2015, Dixon and Kahn 2004). As a result, plants grow slower and in many cases, do not get appropriate amounts of nutrition and die. Plants in soil are also at risk of contracting diseases due to the open environment. In contrast, plants in soilless farms work much, much less and could focus on growth. Nutrients are supplied directly to the plants in liquid-form and their condition, needs and biology are closely monitored all throughout their life; from seeds to their mature form, when they are ready for harvest. The environment where soilless farming is conducted is tightly controlled and regulated wherein the essentials for a plant to successfully grow are amply provided; light, water, nutrition, temperature etc. (Jones 2014c, Jones 2014a, Mason 1988). Therefore, soilless farming has a better yield potential, shorter harvest cycle and can be conducted basically in any place, regardless of what the environmental conditions are. Soilless farming usually takes place in either a Greenhouse, a modified warehouse or even inside an office building, basically a place where the environment can be regulated (Mason 1988). The basic setup requires a few essential things: plant seeds, nutrient-enriched water, light and growing systems. A few technical tweaks such as introducing a cloning system, computerized environment-condition regulators and a simple water desalination system can maximize yield, cut costing and raise growth potential significantly. Although soilless farming heavily relies on water to function, it interestingly uses almost 90% less water when compared to conventional soil-farming; water in the system is recycled until the crops are ready for harvest, instead of it wasted in water run-offs (Jones 2014b, Baptista 2014).

Soilless farms also do not need high maintenance to operate. Labors such as digging, watering, fertilizing, pest and weed control, protection and manual plant care are eliminated, making the workplace safer and more favorable for employees. A farm that produces 50 ton/month of crops could be easily managed by 2-3 employees only. This vastly reduces costs for manpower and labor, therefore resulting in a higher gain and lower expenditure. Depending on the workflow setup, crops can be supplied to markets daily, which meets the demands of the population (Benton 2014). Countries that were previously not self-sustainable may start producing their own crops, right in their own country. In-demand seasonal fruits can be produced any time; even climate-sensitive produce such as strawberries can be grown at any point of time. Quality of food may be easily controlled to meet the demands of the population. As a result of the controlled growing environment, pathogens would not be able to easily penetrate the farm. If in case it does, the infected plant can be easily isolated and treated to prevent an outbreak in the farm (Jones 2014a, Mason 2014, Solutions 2013). This makes sure that crop quality is highly maintained and that consumers receive only the best. Using soilless farming techniques, planting can take place horizontally or vertically, making use of every space. Yields of produce are much higher due to the maximized use of space and calculated nutrition provided. Countries such as Qatar which is rapidly developing, has a steady and increasing demand of produce and spends a huge fortune on imported foods, can take a huge advantage of this program and be assured that food is steadily supplied, all year-round. Fruits, herbs and vegetables are within the reach of the Qatari people.

Setup and workflow

Techniques such as succession planting and continuous harvest will be utilized to achieve indefinite crop production. For this workflow, seeding will be done every **2 days** for *Lactuca* , while as cloning can be done with *Occimum*, *Petroselinum*, *Mentha* and *Fragraria* every **7 days**. After 30 successful cycles, harvesting for Lactuca will take place every 2 days; while harvesting for *Occimum*, *Petroselinum*, *Mentha* can take place every 3 days. Harvesting for *Fragraria* will take place every 2 days.

Site

Soilless planting can take place in any environment; indoors or outdoors. Indoors, however, are much more preferable as it will give the opportunities of total control of the environment. For this project, a **1,000 – 1,500 m^2** of space is recommended as an initial large-scale soilless farm. It is preferred that the infrastructure be a concrete warehouse, or office building, as opposed to a greenhouse. The climate in Qatar can go to both extremes, therefore, a well-insulated building will be necessary to achieve and maintain full-control over the conditions.

Cultivars

Five types of plant cultivars will be selected for planting; *Lactuca*, *Ocimum*, *Petroselinum*, *Fragraria* and *Mentha*.

Grow-house

The grow-house must be modified carefully to provide us with the necessary controls over the growing environment. The atmosphere of the grow room must be purified and free of pathogens while keeping thetemperature at optimum levels. Next, humidity must be controlled since excess moisture in the environment would encourage mildew and other diseases. Then, plants need light to photosynthesize, however, theamount of light provided must be calculated/regulated to optimum levels. Lastly, the project solely relies onthe growing system where plants are grown in, so the most suitable system will provide the best yields. These can be achieved by the following installations:

1. **Ventilation requirements:** Ventilation allows the opportunity to control the overall temperature of the environment. A proper exchange of air must be present in order to maintain a steady temperature, however, it is also necessary that the ventilation is micro-filtered, to prevent any particulates to breach the controlled environment of the growhouse. The grow-house area occupies about 1,500 m^2, therefore, using the cubic feet per minute (CFM) requirement calculation to compensate for the 25 % efficiency drop, 2,564,500 CFM (1210.30 m^3/s) will be required. (Tables 1, 2, 3, 4)

2. **Humidifier/Dehumidifier:** Humidity levels are important in preventing wilting/ drying-out, sporadic outbreaks of diseases and maintaining the temperature. Industrial-grade humidifiers will be used inorder to fully-control the atmospheric humidity of the grow-house. (Table 5)
3. **Lighting requirements:** Since this project is a proposal for plant research as well as agricultural research. A lighting system with variable and wide control capability will be needed. A system that willenable the researcher and growers to adjust the light spectra according to requirements. The lighting systems will be attached to the growing systems. (Table 6)
4. **Growing Systems:** The growing systems are where the plants will be planted along with the required nutrients. The systems vary according to the type of plant. NFT Channels, oriented in both vertical and horizontal arrangement, will be utilized to maximize space efficiency. HydroTowers, a purely vertical type of soilless farming will be used for small fruit-bearing plants. (Tables 7, 8)
5. **Nutrient Formulation:** Nutrient solutions will be prepared according to manufacturer's instructions. Properties of the water used to dilute the nutrients will have the following general properties: TDS willrange between 0 – 200, pH will range at 5.5 – 6.0 and EC of >10. Nutrient solution temperatures must always be maintained between 20 – 23 °C. Variables of the solution properties will be changed according to the requirement of individual plant species.

Propagation

Nursery

- Seeds will be prepared and selected carefully. Seeds with deformities, abnormal size and obvious damage will be removed.
- A germination tray that can hold 200 - 500 Rockwool cubes is sterilized using **0.001 % Sodium Hypochlorite** for **5 minutes.**
- Rockwool cubes will be set on the tray and soaked with **25 % conc**. prepared nutrient solution for **2 minutes**.
- Careful measurement of pH of the germination system must be taken using the pH meter. Optimum pH will be **5.5 – 6.0** with an Electric Conductivity (EC) of **15 - 20 S/m** using an EC meter.
- For seeded plants (*Lactuca* cultivars), 2-3 seeds will then be placed into each hole in the Rockwool cubes.
- For cloned seedlings, see section on cloning below.
- Transparent tray cover will be attached to the tray to maintain humidity.
- Ambient temperatures must be maintained at **35 – 38 °C**. mant

- Lights at **450 nm** at **25 – 30 %** dimming will be placed **0.127 - 0.203 m** above the tray continuously for about **6 days** or until seeds start germinating.
- Once true set of leaves have emerged, (**7 days, 20 days, 28 days**, **16 days**, *Lactuca*, *Ocimum*, *Petroselinum* and *Mentha* respectively) lighting is decreased to **18 hours** each day at **660 nm, 0 % dimming**, for their respective germination days until they are transplant-ready. On the 4th day, nutrient solution concentration will be increased to **75%**.
- For *Fragraria* cultivars germinated root stocks will be purchased. For seed starting, seed packet will be placed inside a sealed and airtight container, which will then be placed inside the freezer at **-2 – 0 °C** for **21 – 28 days**. Afterwards, the container will be thawed at room temperature for **4 - 6 hours** or until it has reached **23 – 24 °C**, to avoid condensing on the seeds.
- Transplant date for *Lactuca* will be **20 days** after germination. Transplant date for *Ocimum* will be **25 days** after germination. Transplant date for *Petroselinum* will be **21 days** after germination. Transplant date for *Mentha* will be **26 days** after germination. Transplant date for *Fragraria* (if grown from seeds) will be **30 days** after germination.
- Records and observations will be noted down.

Maturity

- All growing systems must be thoroughly sterilized with **0.001% Sodium Hypochlorite** before initial use to avoid contamination.
- For *Lactuca* and *Ocimum* individual seedlings will be placed inside each well of the channels of the **24-24 Modified Vertical-Horizontal Hybrid NFT System.**
- For *Mentha*, *Petroselinum* and *Fragaria*, seedlings will be placed in the **GROWHARDY I-Stack Commercial Vertical Grow System.**
- Lighting will be set to 740 nm, 0% dimming for maximum photosynthesis.
- Lighting will be provided for **15 hours** and an alternate of darkness for **9 hours** each day.
- Days for growing will be **30 -35 days** for *Lactuca* at **23 – 26 °C**, pH range of **6.2 – 6.8**, Nutrient EC of **23 – 26.**
- Days for growing will be **40 – 45 days** for *Ocimum* and *Petroselinum*;
- Days for growing will be **30 - 35 days** for *Mentha* at **20 – 24 °C**, pH range of **6.5 – 7.0**, Nutrient EC of **20 – 25**.
- Days for growing will be **65 – 75 days** for *Fragraria* at **15 – 20 °C**, pH range of **5.5** – **6.8**, Nutrient EC of **18 – 24**. For the first **28 – 35 days**, flowers will be pinched to allow growth concentration on the leaves and their biomass. Afterwards, flowers will be allowed to grow until fruiting.

Cloning of *Ocimum*, *Fragaria* and *Mentha*

- Materials and equipment will be sterilized with **70 % EtOH**.
- A healthy and mature plant will be selected and its stem will be cut at a **45°** angle below 2 leaf nodes.
- The cutlet will be dipped into a rooting solution, cut side down, for about 1 inch from the cut and carefully placed directly in a new and unused **75% conc**. nutrient-soaked rockwool cube.
- Germination tray will be covered with dome and will be lighted with **450 nm at 0 %** dimming
- After **4 – 5 days**, lighting will be increased to **660 nm** at **0%** dimming.
- Once the roots have bounded on the Rockwool cubes, at about the 7th day, the seedling will be transplanted into their respective systems.
- Plants will be grown in their respective systems for their respective transplant-harvest length of days.

Harvesting

- For *Lactuca* cultivars, the whole plant will be extracted from the system and will be immediately ready for consumption.
- For *Ocimum*, *Petroselinum*, *Mentha* harvesting method will be done by cutting only **70 %** of the plant and allowing them to regrow for the next **7 days**. *Mentha* will be harvested every 4 days. For *Ocimum*, the whole plant may be harvested, provided that cloning had taken place and will replace the harvested plant and be ready for harvest in the next 7 days.
- *Fragraria* fruits may be harvested every **2 days** and **100 – 200 grams** of fruit will be collected each harvest.

Discussion

Farming using cultivated land proves to be very difficult in arid environments such as in Qatar. Good-quality and fertile soil, along with optimum growing environments are needed for the plantlife to thrive (Mason 2014). Therefore, it is obvious that conventional farming is not very viable in countries such as Qatar. This is reflected in the country's GDP, which is estimated to reach 203.2 billion USD in 2014 (GDP 2016, Data 2015). Soilless farming, specifically hydroponics, not only bypasses, but it overcomes these problems. Obviously implied by its name, the method does not require soil at any point of production at all.

Nutrients are directly delivered to the plants via water, which is often coined as hydroponics. However, there are many types of soilless farming such as aeroponics, which uses vaporized nutrients, aquaponics, which uses fishes and other marine organisms, but hydroponics, using nutrient-enriched water, is the simplest and easiest to commercialize of them all (Jones 2014c, Resh 2013a). Hydroponics is not that new, but it was only recently studied in a scientific and evident-based method, especially passive methods such as the Kratky Method (Kratky B. 2004). The ancient *Babylonians* used a very similar system for the *Hanging Gardens of Babylon*, whereby each steps or landing of the garden structure are trickled with carried water using a chain-pull system. The *Aztecs* had also used Soilless farming when they were driven to settle at *Lake Tenochtitlan*, where they took advantage of the lake and planted on the water alone using floating rafts (Resh 2014). The main principle of soilless farming is that it takes the nutrients from another media than soil, which in this case is water. Plants who take nutrients at this pure form are evidently healthier and physically cleaner, due to the absence of soil (Roberto 2003a). Plants that are planted on the soil are exposed to almost every environmental hazard and contamination; from simple dusts, to animal fecal matter and to weather extremities, especially *frost* and *heat wave*, which is common in Qatar during the summers and could devastate the entire crops (Ismail 2015). Diseases usch as molds, mildew, fungi growth, as well as pests, are also very common in soil-planted plants due to their exposure to the environment; due to an open environment, one infected plant that is several hundred meters away could easily transmit and infect the surrounding crops and could lead to a domino effect until the entire field is infected (Richards 1998).

A controlled-environment soilless farm eliminates all these problems. The environment where the plants are grown are strictly controlled and regulated. The temperature, light-exposure, light spectrum and *wavelength*, plant biology, *gas concentration*, nutrient concentration and other essential factors that affect the quality of the plant are closely monitored by personnel with good technical and scientific knowledge. Plants would not waste energy in root tissue production because nutrients in pure form will be provided to the plants instead of the plant stressing to search for the nutrients. Due to this, plants develop whiter, cleaner and finer roots that are visually pleasing. This makes it possible for plants to focus on upward growth, be planted closer together, eliminating nutrient competition and maximizing the use of space. Furthermore, the problem of contamination is also eliminated. The environment of a soilless farm is aseptically-maintained, meaning personnel working directly with plants are trained in aseptic techniques to avoid introduction of pathogens. As a result, growers could grow healthy plants regardless of the season, climate and weather in an almost indefinite amount of cycles which would provide food all-year round (Mason 1988, Mason 2014, Merrill 2011, Jones 2014b). Subsequent cycle would be cheaper, as only seeds and the nutrient source need to be affected by cost. Seeds can either be harvested from flowering plants, ordered from certified retailers or plants that have exemplary traits could be easily *cloned* by an employed *biotechnologist* and make production infinite and maximize production potential in a shorter amount of time. Tissue culture can also be done for slow-staring crops such as strawberries (Miller et al. 1992) Moreover, because of the controlled environment, pests and other contamination have very little chances of contact with the plant. The plants are supplied with the exact and calculated amount of nutrition that it needs, along with the exact amount of light and gas exposure. Hydroponics utilizes water formulated with elemental nutrients (*Macro and Micro)* that the plants need to grow (Resh 2013b). Despite the fact that this system requires amounts of water for the plants, it actually uses significantly lesser amount of water compared to conventional farming. The amount of water used in the system only accounts to 5-7% of total water volume compared to a regular farm. This is because the enclosed-system recycles the water used, preventing run-off, until the crop is ready for harvest. This makes soilless farming very ideal for places where water is expensive, such as in Qatar (Ismail 2015).

Today, the advancement of soilless farming is backed by countless scientific research. Not only does it provide food in a cheaper and guaranteed way, but it also revolutionizes agriculture and aides scientist conducting various research. Countries that previously do not have the capabilities to grow their own produce can now easily be an importer and supplier of fresh and premium quality food making them self-sustaining. Food quality is easily controlled and tailored according to the demand. Previously seasonal produce, such as strawberries, can now be grown in a hydroponic farm, anytime, anywhere (Miller et al. 1992, Merrill 2011). Furthermore, soilless farms, being an agricultural and scientific innovation, could be an attraction for tourists due to its high-tech nature and appeasing image; soilless farms are environmental-friendly and with a few tweaks in the system, soilless farms could be self-sustainable itself by using solar panels to produce the needed electricity and could significantly reduce *greenhouse gases*, thus making the places such as Qatar greener (Hydroponeast 2013).

In the near future, a very large scale and well-equipped soilless farm could reduce overall carbon dioxide levels of the environment, which reduce global warming and most importantly could even produce as much as 56 million kW/h of energy per farm, through the use of *biogas digesters* and by using solar panels to capture solar energy. Scientists, especially Biotechnologists use soilless farming to grow genetically-modified plants that produce pharmaceutical products, allowing a faster and more accurate results in medical research (Asao 2012) The National Aeronautics and Space Administration (NASA) have even started a program to introduce the Soilless Farming technology in space to sustain astronauts in space indefinitely. Initial trials have been launched and had given promising and successful results (Jones 2014b, Roberto 2003b).

Advantages of soilless farming

Food production using hydroponics has several notable advantages; it overcomes environmental inadequacy of infertile lands such as in Qatar. Lands that were previously unused for any productive means can now be used for food production. Once set-up has commenced operation, production of produce is infinite and subsequent costs are very minimal. Operation and production are systematic, accurate and could be planned with a very high level of accuracy. Uses less water than conventional agriculture and recycles the water until the end of production; only 10% of total water used compared to conventional farming because the system prevents water run-off, which is a common occurrence in soil-planting. This means, 90 % of total fresh water used is saved. In this way, fresh water is greatly conserved in countries like Qatar, where water is very scarce and expensive (Ismail 2015Baptista 2014, Baptista 2014). Soilless farming only uses mineral-enriched water, chemical-rich, hardly biodegradable compounds, which are used in soil farms are eliminated. This positively impacts the environment and reduces overall land pollution. in this way, chemical deposits on both land and water are vastly reduced (Dawson 2011, Jones 2014c, Mason 1988).

Plants won't need to waste energy developing huge roots to search for nutrients, because nutrients are supplied to the plants in pure and unhindered medium. Plants would have smaller roots, therefore plants could be planted closer together, guaranteeing higher yields in less space. Plants could concentrate on floral production, growing fruits or vegetables, instead of roots. Therefore, plants grow evidently 50% faster and bigger. It can be set-up almost anytime and everywhere, in a greenhouse, warehouse, inside a building, or even in outer space. Any nutrient deficiency, disease or problem could be easily traced and corrected, preventing huge amounts of loss for the grower. Integrated Pest Management could be employed, controlling any possible threats from pests if ever a containment breached occurs. Environment is strictly controlled to imitate optimum growing conditions and maximum growth potential. Control over environment provides the opportunity to provide optimum growing environment, leading to better quality and higher yields. Produce are not affected by climate change, sudden weather change and environmental hazards. Seasonal produce can be grown all-year round, meaning there will be no shortage of selected products, even produce like berries and lettuce, which are not commonly found in countries like Qatar. Crops such as lettuce, strawberries and herbs are grown above ground level at an ideal height which allows better working conditions, faster and better crop cultivation and harvesting with lower labor costs and possible injuries to the worker. Growing environment is sterile and workers practice aseptic techniques, therefore no contamination is present. There would be no need of for fertilizers, pesticides, weedicides and other harsh chemicals for plants to grow and survive. Plants grown have a high degree of uniformity. All plants would be visually identical. Evidently results in a cleaner, fresher, healthier, tastier produce which has more nutrients due to the intake of pure nutrients and absence of pests and parasites (Dawson 2011, Solutions 2013).

Disadvantages of soilless farming

Initial start-up is slightly more expensive than conventional farming and requires technical expertise and science-oriented employees. However, subsequent production cost is 90 % cheaper and cost-effective compared to conventional farming (Benton 2014, Jones 2014c, Jones 2014b). Also, delicate operation and constant monitoring is required to be done by trained personnel for optimal results (Solutions 2013, Roberto 2003b, Roberto 2003a).

Nutrient Film Technique (NFT) Channels System - GRAZE GREEN Fodderking 24-24 Custom Vertical-Horizontal Hybrid NFT System

An innovative method in hydroponics occurred in the 70s when the Nutrient Film Technique (NFT) was introduced. The method of NFT soilless planting utilizes an enclosed, long and narrow channel where plants are grown in bare roots. A shallow stream or "*film*" of nutrients flows through the channels continuously. The nutrients are recycled via a drain that leads back to the reservoir and pumped backed into the channels by a pump. The plant roots grow into a dense mat or growing cube (rockwool) while the foliage sits on top (Green 2015, Mason 2014).

The basic parts of the NFT system is made up of a channel, where the plant sits on top and thin films of nutrients are pump through the channel, a pipe that drains the nutrients back into the reservoir, a reservoir where the nutrient solutions are stored and a pump. To maximize the utilization of space for plant growing, a system that can accommodate the conventional (horizontal) orientation of NFT systems with an addition of *tiers* for vertical growing will be used. The system may be pre-ordered and custom-built, or can be constructed. Additional modifications to the system for a fully controlled environment, such as the LED grow lights attached above the foliage, measurement devices for pH and EC of the nutrients in the reservoir and a reservoir and environment thermometer, will be added. A basic outline below shows the concept of a Hybrid NFT Channels System Fig. 1.

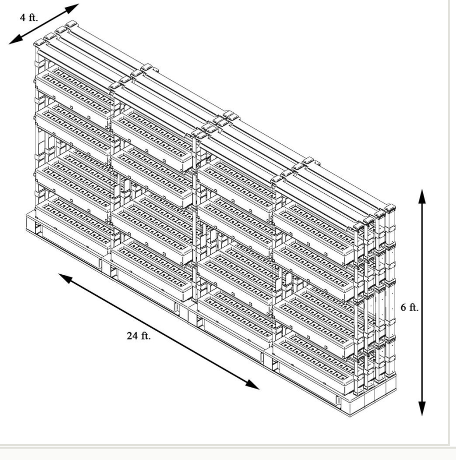

Figure 1.

24-24 Custom Vertical-Horizontal Hybrid NFT System - A concept of the proposed growing system which occupies as little as **9.2 m^2**, but could yield as much as **176** plants.

Large - Scale Food Production

By using the modified NFT system oriented for vertical growing, it is possible to upscale the amounts of yields while only using a very small area of space. The proposed system,

24-24 Custom Vertical-Horizontal Hybrid NFT System, only takes up **100 m^2** of area, but produces as much as per harvest. Therefore, a **1,500 m^2** (**~16,145 ft^2**) growing area could hold around **160 units** of the growing system. This theoretically results in almost **28, 336** actively growing crops, in only a single level of floor, and depending on the setup, may be the amount of crops per harvest as well, whereas a conventional farm with the same amount of area could only produce **284** heads of crops (World 2010). Therefore, soilless farming produces 100 times more yield. *Lactuca* and *Ocimum* cultivars are the most recommended crops to be grown in this type of system. The efficient use of space by the modified system will be very useful and effective. The same principle can be applied to *Mentha*, *Petroselinum* and *Fragraria* cultivars, by growing them using the **GROWHARDY I-Stack Commercial Vertical Grow System.** Fig. 2. Table 9.

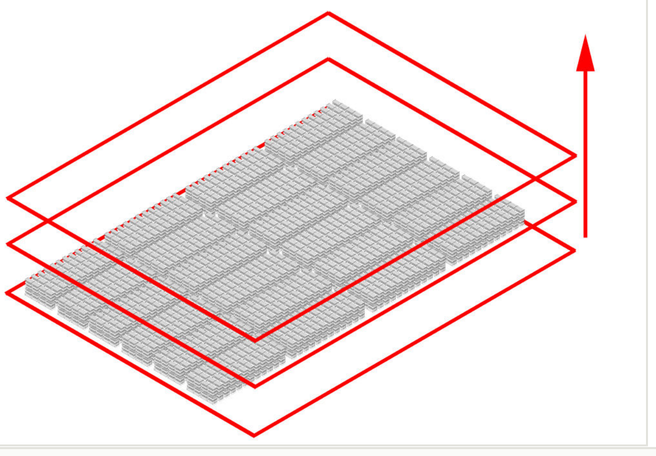

Figure 2.

Concept of upscaling the production of crops for large-scale food production. The red box indicates 1 floor. By upscaling upwards, the same amount of land area occupied by a single growhouse will enable an exponential increase in yields.

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