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Tomorrow's Agriculture "NFT Hydroponics" – Grow within Your Budget



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Stephanie Mohammed

Tomorrow's Agriculture

“NFT Hydroponics”-Grow within Your Budget

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Preface

As a hydroponic farmer at the age of 25, hydroponics was intriguing to me. It appeared as a new era in food production. Trees no longer had to be cut down, men no longer needed to spend countless of hours in the boiling sun, soil-borne diseases were not a problem, the use of pesticides were no longer a major priority, and weather disturbances posed no more threat.

This was the best environment for a better tomorrow. There were many ups and downs, many crop losses at first, and many unanswered questions. However, I had no knowledge of this practice, so everything for me was a test run. But once I eliminated a problem, I was happy because now I was becoming closer to the perfect production system.

Hydroponics is not as difficult and costly as advertised. It is actually a very simple process which requires all fields of expertise. Agriculturalist, farmers, scientist, and engineers are the main people required to run an efficient system.

Hydroponics is the most efficient way of production for a sustainable market in the future. It can address numerous of the countless challenges we face on a daily basis in food production. It is suitable for all varieties and classes of fruits and vegetables as hydroponics is categorized in many different aspects. It is the most adaptable system for a fast paced, ever-growing world.

People who venture into hydroponics have realized its benefits and potential for both small- and large-scale practices.

My advice to all those interested in this practice is to conduct proper research at first and after start off with a small and simple system that is manageable by only one person. It is good to get advice, but be careful as many people and companies are just trying to market the materials and equipment required. It is however much simpler than that. A hydroponic system can be set up with zero dollars to the use of millions of dollars. It all depends on you as the individual and your design. In this book, I will introduce you to some of the simplest forms to the most sophisticated forms.

Acknowledgement

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Director of Iere Group International
for the funding of the hydroponic system highlighted.

Abstract

Hydroponics is an effective agriculture practice used for growing countless of plants, fruits, and vegetables. It can be easily adapted to suit any environment regardless of land availability which has made this practice so popular. The advantages presented with this form of growing which consist of a soilless environment compensate for the disadvantages existing with the use of soil agriculture such as soil-borne plant diseases, the use of pesticides, and overall the unpredictable weather disturbances.

In this monograph we highlight the importance of effective growing with the use of hydroponics with particular interest focused on the nutrient film technique. We have also provided a simple guide to the setup and operation of a practical protocol system within your budget designed by the author for a tropical climate. We have also revealed how to turn a simple system into a business that can help generate an income by providing an effective business plan.

Overall this monograph highlights the importance of the nutrient film technique for the production of premium, healthy, fresh, and tasty vegetables at their maximum potential required for human consumption.

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Chapter 1

Introduction



1.1 What Is Hydroponics?

Hydroponics is referred to as the art of growing plants without the use of soil. The Greek words, hydro and ponos meaning water and working respectively gives a clear definition of the term as water working [1]. This culture is believed to have been in existence since the eighteen century and maybe even prior to that [2].

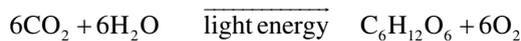
Hydroponics is a form of soilless agriculture that is dependent on an aerated water-enriched nutrient solution, which is essential for the optimal growth of plants. A good water supply is required with a low ppm and salt content of pH 5.8–6.2 [3].

The science of growing plants efficiently is ensuring that plants have the essential nutrients available under the optimal conditions. In order to understand plant growth then we need to understand certain terms.

1.2 Common Scientific Terms

Major terms required to help understand and appreciate the science of growing hydroponically are listed below.

Photosynthesis is the form in which plants synthesize organic compounds from inorganic raw materials with the use of light from the sun [4]. It is the conversion of light energy to chemical energy and storing in bonds of sugar. The light band is 400 nm – 700 nm in the spectrum range [5, 6].



Why Is this Important? Photosynthesis is the **KEY** to good growth and high yields as carbon dioxide and water are converted to carbohydrates and oxygen by plants.

Osmosis is the movement of water molecules from an area/place of high concentration of the water molecules to an area/place of lower concentration of the water molecules, across a semi-permeable membrane. That is from a dilute solution to a strong solution [7].

Why Is This Important? The manner in which roots take nourishment is via osmosis [8]. Osmosis is vital for plant life as it is the means by which nutrient rich water is taken through plant roots and distributed throughout the plant accordingly where it is required for the process of carbon assimilation or photosynthesis.

The pH is a measure of the acidity or alkalinity of a substance. It simply measures the hydrogen ion activity in the solution. To measure the pH a logarithmic scale of 0–14 is used [9].

Soil pH is an indicative measurement of the chemical properties of soil.

0–6 is acidic

7 is neutral

8–14 is alkaline

Why Is This Important? In hydroponics we measure the pH of the nutrient solution to obtain a measurement of its relative concentration of positive hydrogen ions, as plants feed by an exchange of ions. In this manner we will know what nutrient the plant/crop requires.

Note: Plants grow best at pH 5.5–6.5

Electrical Conductivity (E.C) is a measure of the salinity of water, i.e. a measure of the electrical conductivity of a solution [10]. It measures the dissolved salts in a solution on a scale that reflects the nutrients present in the solution. Electrical conductivity is measured in milli Siemens per cm (mS/cm) [11].

Why Is this Important? The EC value gives an indication of the nutrients present in the solution.

1.3 Importance of Nutrient Solution

Nutrient Solution is the most important aspect of growing hydroponically. It is the natural fuel for the plants as it determines the growth of each cell.

The nutrient solution must contain the mineral elements as seen in Table 1.1 which consist of: macro elements such as Nitrogen, Phosphorous, Potassium, Calcium, Magnesium and Sulphur; trace elements such as Iron, Manganese, Boron, Copper, Zinc and Molybdenum and micro elements of Sodium, Chlorine and Aluminum.

Table 1.1 Showing the benefits of minerals to plants

Mineral	Benefits to Plant
Carbon	All cells are made up of carbon
Oxygen	Required for producing cellulose
Nitrogen	Essential for proteins and is present in the chlorophyll and protoplasm
Phosphorous	Required for all living cells and is present in seeds and fruits
Calcium	Helps build cell walls and neutralize organic acids
Magnesium	Assist in the formation of chlorophyll
Sulphur	Present in certain proteins and required oils
Trace elements	Act as catalytic agents [11]

Table 1.2 Showing various mediums used in hydroponics

Medium	Feature
Rockwool	This is a non-degradable medium. It needs to be soaked in pH water before to be pH balanced.
Perlite	When this is exposed to high heat it becomes very light. It has an excellent pH but doesn't retain water very well.
Coconut fiber	These are from the husk of coconut. It retains water well and allows for oxygen to pass through freely.
Vermiculite	This is a silicate material that expands when exposed to heat. Very good at retaining water.
Sand	It has rock like particles, just smaller and does not drain very easily.

The nutrient solution can be bought directly at agriculture shops as pre-packaged or can be purchased independently of each required element and mixed accordingly. Most of the time the mineral elements are pre-packaged as fertilizer salts such as Potassium Nitrate, Calcium Nitrate, Ammonium Sulphate, Potassium Chloride, Potassium Sulphate, Magnesium Chloride, Magnesium Sulphate, Ferrous Sulphate, Zinc Sulphate, Iron Chelate and Magnesium Chelate just to name a few [12, 13].

1.4 Mechanical Support Medium

These nutrients flow through plant roots sustained by a form of mechanical support of inert medium. In the selection of a suitable medium, it all depends on a medium that will complement your hydroponic system. Depending on the form of hydroponic, its cost, location and system design, then a suitable medium can be chosen. It must also have the right size of particles, be clean and non-reactive so as to allow for the proper absorption of nutrients and oxygen [14].

The best forms of medium can be either of an inorganic substance such as gravel, perlite or rock wool or it can be an organic substance such as coconut fiber, peat moss or pine bark [15]. The features of these are listed below in Table 1.2.

1.5 Classification of Hydroponics

There are many forms of hydroponics such as the nutrient film technique (NFT), drip system, aeroponics, Ebb Flow, water culture and wick system. The list continues as different designs emerge and are renamed. Each system is selective to climate, location, outcome desired, crop type and the cost willing to be invested.

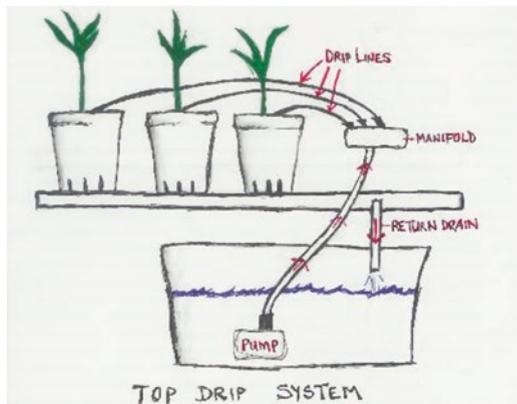
1.5.1 Drip System

In this system as shown in Figure the nutrient solution is pumped from the reservoir through drip lines as spaghetti to the plant roots. The solution is sprayed at intervals set by a timer and returned to the reservoir where it re-circulates. The advantages of this system is that you have total control of the nutrients and how much is fed through your system. The “nutrient drips” are directed exactly at the roots of the plants which reduces the loss of nutrients drastically. This system has been used for growing commercial tomatoes and peppers [19, 20, 21]. Fig. 1.1.

1.5.2 Water Culture

The nutrient solution can be held in small containers for single plants or larger troughs for numerous amounts. This form of hydroponics is the simplest. The plants are suspended into the nutrient solution for optimum oxygen to be allowed to pass through.

Fig. 1.1 Showing drip system © <http://www.hydroponics-simplified.com/hydroponic-drip-system.html>



1.5.3 Aeroponics

This system is considered to be the most technical among all the other hydroponic systems. In aeroponics the plant roots are suspended in the air and obtain their nutrients by an aerosol mist. A significant advantage of this system is the aeration of the plant roots and they use little no growing medium [15]. It has been successful in growing of herbaceous and woody species [22]. Fig. 1.2.

1.5.4 Wick System

This system uses capillary action to feed plants via a synthetic fiber such as nylon. It is best suited for indoors and single plant growth [23]. Fig. 1.3.

Fig. 1.2 Showing aeroponics © <https://www.buydutchseeds.com/blog/the-difference-between-hydroponics-and-aeroponics.html>

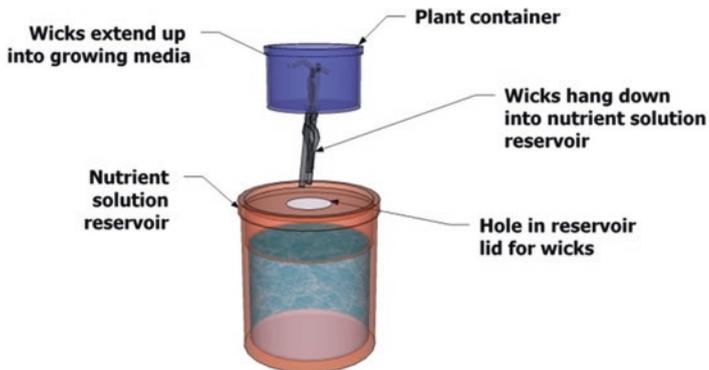
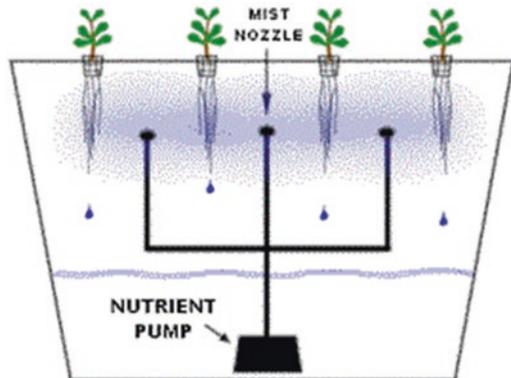


Fig. 1.3 Showing wick system © http://www.homehydrosystems.com/hydroponic-systems/wick-system_systems.html

1.5.5 Nutrient Film Technique (NFT)

In this system the plant roots are exposed and suspended in channels called gullies where a thin film of nutrient solution passes through thus keeping the roots moist and not logged. The required minerals are mixed accordingly in a primary reservoir from which it then flows through the system continuously feeding the plants at a rate of 1 liter per minute. The system can be adjusted with automation for aeration [24]. Fig. 1.4.

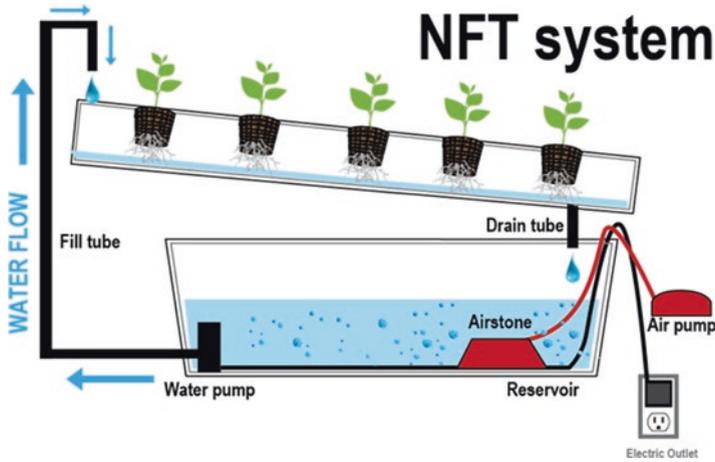


Fig. 1.4 Showing NFT system © <http://howtogrowmarijuana.com/nft-nutrient-film-technique/>

Chapter 2

Introduction to Nutrient Film Technique



The nutrient film technique is considered the most widely used system in hydroponics. The main theory involved in the NFT is the principle by which nutrient solutions in the form of a thin film is fed through the system and re-circulated for crop production. The system is widely accommodated for a variety of crop production and is ideal for short term crops such as lettuce, leafy crops and herbal vegetables.

The larger NFT systems are adaptive for more long term crop production such as cucumbers and tomatoes [24, 25]. This makes hydroponics economically attractive and with such outstanding advantages it is ideal for protection of degradation of natural resources which makes the culture efficient to countries.

2.1 Advantages and Disadvantages of Hydroponics

In any form of agriculture, there are always positive and negative aspects to growing. The margin between these is what determines the most suitable design and growing technique in order to achieve the maximum output production.

The overall advantages of hydroponics are:

- No need for soil contaminated with diseases – Soil has various associated characteristics depending on its location. Some environments are more polluted than others and this may be expressed in the soil in the form of chemical, microbial or physical contaminants. This in can result in the texture of the soil changing, the ability for it to retain nutrients are affected and chemical reactions among both wanted and unwanted chemicals can drastically affect what is feed to plants.
- Labor for field management is reduced or eliminated – In hydroponics there is less manual work as now there is no need for preparation of land such as plowing, digging holes or even banking. The construction of the system is the maximum amount of work that will ever occur.

- Economically feasible system with high yields – The output is far much greater than the input.
- Better control of nutrients and lower concentration of nutrients required as there are no losses of nutrients from leaching- When growing in the ground, nutrients are loss easily. However, in hydroponics, there is TOTAL control of the nutrients being fed to the system.
- Use of disease treated seeds – Since there is total control in hydroponics and no soil is being used, the reduction of diseases is drastically cut down. So by using disease treated seeds, the production of healthy plants is increased greatly.
- Water conservation – Water is being recycled.
- Constant statistics - As market prices fluctuates continuously due to various factors such as flooding, pest and disease and proper portions of nutrients the market price of selling your produce becomes more controlled.
- Eliminates environmental problems such as excessive cold and heat and wind and rain.
- Increases yields, size, quality and taste of products grown, color and shelf life- Healthier plants are produced as there is total control of the system.
- Boost the insect/disease resistant of the plants.
- Eliminates water quality and soil contamination (major sources of microbial contamination).
- Less space required – More plants are now grown in less space
- Less growing time required.
- Labor and garden maintenance is reduced – In hydroponics labor is greatly reduced as the skills required are more technical. There is no need for weeding or molding.
- Nutrients are recyclable- Nutrients are no longer lost as they are circulated through the pipes back to the reservoir and again through the pipes.
- Transplanting shock is reduced for seedlings – Plants can be grown from seedling stage in the hydroponic system. As they grow, adjustments can be made to the nutrient solution so there is no sudden shock in the plant.
- No crop rotation necessary- It is now a soilless environment and you are no longer dependent on nutrients from the soil. The nutrient solution is now mixed and added directly.
- Less impact on the environment (less pesticides and insecticides)- The use of pesticide is reduced and this makes the environment happy.
- Allow customers to see where and how their foods are grown – Hydroponics is such a beautiful art form of growing plants as it is clean and flawless. People would be delighted to see their food grown in such a majestic environment.
- Shelf life of produce is much longer – The use of a wide range of chemicals can affect the ability of plants shelf life. Weather disturbances also decrease the shelf life of plants as they are more susceptible to damages.
- GREENWAY OF LIFE (reduce, reuse, recycle) e.g. Water, nutrients.

2.1.1 Disadvantages

There are few disadvantages associated with hydroponics such as:

- Cost – The cost of systems can be very cheap but also extremely expensive. However, it all depends on the level of production wished to achieve, the location, the design, the seasonal changes and most of all the cost willing to invest.
- Trained personnel – The knowledge of chemistry and agriculture is very important in hydroponics. The preparation, and mixing of nutrients must be accurate, along with the analyzing of the pH and EC content.
- Rapid spread of a disease once it enters the system- Since the nutrients are always flowing and circulated, once a disease enters, it will be distributed quickly to all other plants.
- Initial cost setup can be high if not consulted properly – There are many companies willing to market their products. Since hydroponics involves the use of technology for growing, it can become very expensive if proper consultation is not given
- Pump failure can lead to a loss of crops if there is no backup system – If there are no backup pumps or generators, then this can lead to serious loss in production. The system must be monitored to avoid electrical failures as electricity is very important for the circulation of nutrients throughout a system.
- Clogging of system because of immense plant roots [15, 16, 17, 18].

Overall the advantages of hydroponics outweigh the disadvantages. Hydroponics has been constantly changing to adapt to the needs of those investing.

The elimination of soil in this form of growing has brought countless of benefits by the reducing cost and time associated with all the disadvantages from soil. It has grown from a single man practice to a commercial business.

2.2 Variety of Crops That Can Be Grown Hydroponically

A variety of crops can be grown hydroponically. However, plants have different roots and so they must be fostered to a production system that will ensure proper oxygen is available to them. Some of the crops include: herbs such as basil, chive, celery, rosemary, sage, oregano, mint and lavender; vegetables such as cabbage, cucumber, eggplant, lettuce, peas, potatoes, cauliflower, cabbage and asparagus; fruits such as tomatoes, watermelon, blue berries, straw berries, black berries and grapes. Below also highlights some of the major vegetables grown with hydroponics and the type of systems recommended. Table 2.1.

Table 2.1 Showing crops grown hydroponically and the best suited system

Crop	Type of System
Vegetables	
Lettuce, Patchoi, cabbage	NFT- easy to manage leafy vegetables
Tomatoes, sweet pepper	Drip system – These plants grow tall and troughs may not be able to hold them because of the roots
Celery	Ebb and flow – They have shallow roots and respond well to this system
Radishes	Water culture – They are best suited for this
Cucumbers	Drip system irrigation
Fruits	
Strawberries, blue berries	NFT – They require special conditions such as humidity
Water melon	NFT – Ebb and flow
Herbs	
Chive, Celery	NFT

2.3 Practice of NFT Worldwide

Hydroponics is practiced worldwide and used for the growth of countless of plants and vegetables. This culture has been implemented for both home gardening and commercial production. The size and design can be adapted to suit the needs of the investors.

In urban countries hydroponic systems can be intensive and expensive as compared to the rural areas where the operation and maintenance cost are more reduced. In simplified hydroponics, it is easy for untrained personnel to be successful as compared to the more advanced practices. However, the production is greater in the advanced systems.

Various vegetables are grown such as tomatoes in Egypt [26], lettuce and chive in Trinidad [27], Blueberry in Taiwan [28] and multiple crops in Greater Gaborone Botswana [29].

In the mainland of China, hydroponics has been introduced to maintain a good production environment [30]. It has also become increasingly popular in the United States, Canada, Western Europe and Japan where the people are highly conservative and protective of their environment [31].

Countries such as Pakistan where there are great challenges to increasing food production while maintaining the ecosystem stability and rehabilitation of the environment have implemented the use of hydroponics as the most ideal solution for overcoming their problem [24]. In the Gulf Corporation countries where water is a limited resource, hydroponics has been used for the successful growth of vegetables [32].

Overall there has been growing awareness on the environment and ecosystem in terms of the agriculture industry. Hydroponics has become a source of food security regardless of climatic changes.

Regardless of the size of operation, hydroponics is beneficial to those invested in it as the outcomes outweigh the regular farming production.

Chapter 3

Designing of NFT Hydroponic System



In the designing of a proper system for commercial production or just home gardening, it is advised that at first a proper analysis be conducted as seen in Fig. 3.1.

Education Before venturing into an NFT system, it is best to read as many books and articles that explain the system thoroughly. This way you are open to new ideas and designs for your perfect system. Visiting other hydroponic systems and speaking to experienced personnel in the field will also be beneficial.

Cost Analysis When you have obtained your design, the next step is to look at the price ranges at various stores to know who your supplier will be. Put together a material listing, prices and supplier.

Project Planner The next step is to plan how you are going to build your system and the time frame. Remember “Time is Money”. The best way to do is to have a project tracker as seen in Appendix Table A.1, so that way your system is completed in the best time frame.

Set up The set-up is easy after all the required materials and equipment are obtained for your design. Depending on the size of your system you can hire trained professionals to fabricate your design. Small systems for home gardening can usually be built by you along with friends and family members.

Trial and Error Now that your system is set up, you need to have a test run of it. However, you need to re-grow over and over until you can obtain consistency especially if it is for commercial production. In the trial and error stage you analyze all the necessary parameters for proper growth such as pH, EC, temperature, oxygen content, nutrient uptake and water use. You also have to look at the pest and diseases invading and that may potentially affect your system. All these can be recorded on templates as shown in the Appendix Table A.2 and A.3.

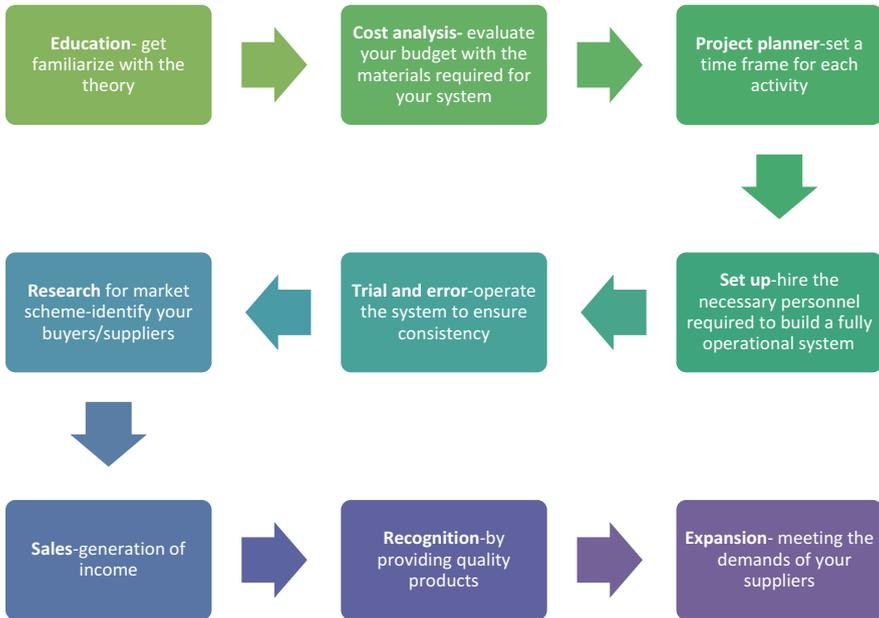


Fig. 3.1 Showing Chain reaction for creating a profitable hydroponic system

Research for Market Scheme After trial and error, you have to plan a market scheme for your produce if you are going to make money from it. In doing this you need to obtain the current market price at that time for the selective crop and then you can adjust. However, if you are going to create business from it then you need to create a business plan which can be seen later on in this book.

Sales This will depend on the quantity, quality, location and various other factors for your produce. It is the point where you generate an income.

Recognition this factors depends on your consistency and the ratings of your produce by your buyers. It is how you brand yourself and what you have to offer by providing quality.

Expansion This is when you can take your business to the next level. After trial and error, consistency, recognition you can then expand your business so as to meet the demands of your suppliers.

Chapter 4

Nutrient Film Technique Greenhouse Set-up



4.1 Hydroponic (NFT) Greenhouse Set up for Small-Scale Production

1. Hydroponic System setup – In order to have a hydroponic system, you must first have a piece of area allocated for your system. This area can be soil or soilless. In this case we used an open piece of abandon land. The land was cleared properly to ensure that there were no other forms of plants growing. This is important as having other unnecessary plants will lower the carbon dioxide and bring insects or pest that will affect the crops to be grown hydroponically. Fig. 4.1.
2. Ensure proper drainage and securing of the land properly so it not prone to flooding or corrosion. Proper drainage is extremely important as the accumulation of stagnant water can cause unwanted insects which can invade crops in the hydroponic system. It can also cause the growth of algae which consumes a lot of carbon dioxide required by the crops in the system.
3. Have a design for your hydroponic greenhouse system. There are various types of greenhouse designs such as A frame, conventional post and rafter, gothic arch, hoop house, cold frame, high and low tunnel, and countless others. However, it all depends on the location and the amount of money willing to be invested. Some hydroponic systems are out in the open with no greenhouse covering, some have a netting only and many others are remained open. However, in this design we used an A frame design. The location of your system will determine the materials used to build your frame. In this case there were houses and tress surrounding the system and therefore iron pipes were used to construct the frame. Fig. 4.2.
4. Add on greenhouse plastic (uv treated). This is the main feature and can be glass, polyvinylchloride (PVC) or plastic. This selective covering must be able to transport visible light from the spectrum required by the plant for photosynthesis to occur. If you are on a low budget you can leave it open.

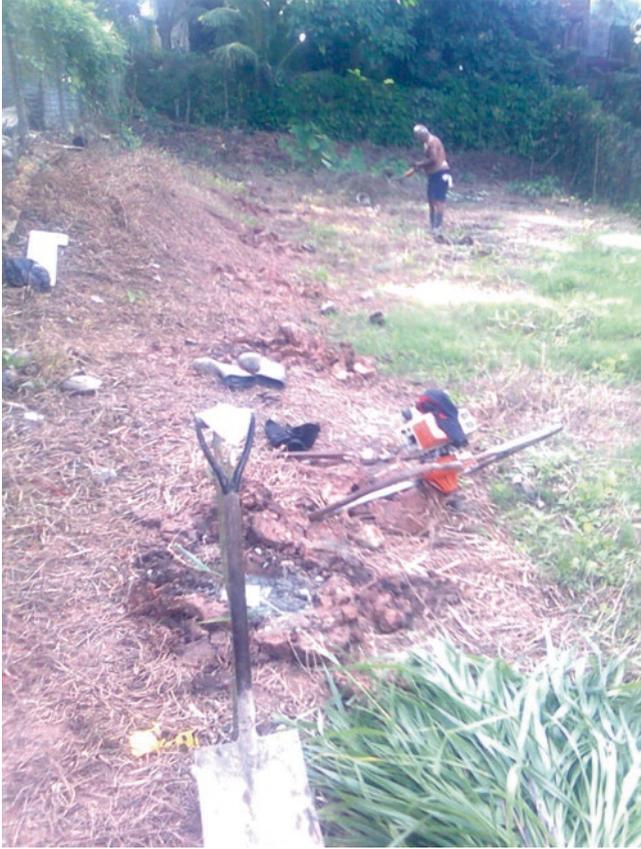


Fig. 4.1 Showing cleared land allocated for hydroponic system

Construction of an A-frame greenhouse



Fig. 4.2 Showing A-frame greenhouse

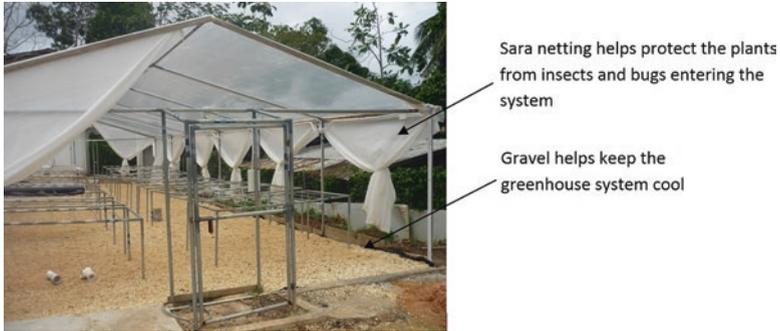


Fig. 4.3 Showing Sara netting and UV treated plastic covering



Fig. 4.4 Showing Racks to support PVC

5. Add insect netting (sara netting). This is very important as it controls the amount of pest entering and exiting your system. It also reduced the amount of insecticides being used.
6. The ground is also coated with gravel to help control the temperature of the inside of the greenhouse. Fig. 4.3.
7. Place racks to support your hydroponic system. In this project we are using the NFT system. Racks must be designed at an angle so as to allow the nutrient solution to flow continuously through the system. The angle used in this system was 1:40. Fig. 4.4.
8. Addition of pvc guttering. This can be at any height from above ground level. However, the elevation is at which the pvc are to be is very important as it will determine the flow rate of the nutrient solution. It is also important to use flat pvc rather than round pvc to ensure equal distribution of the solution to the plant. The length of the channels can go from 30' to 35', Above 35' there



Fig. 4.5 Showing pvc guttering for setting crops

Reservoir lining



Fig. 4.6 Showing reservoir lining

depressed rate increases. The width of the channels can be between 4" and 6" as the plant tends to develop. Fig. 4.5.

9. Ensure the reservoir is set up with a pump. The reservoir can be lined with reservoir lining. Our reservoir was able to hold a capacity of 400 gallons of nutrient solution. There was also a float to control the water level from a tank. Fig. 4.6 and 4.7.
10. Ensure system is completely chlorinated (guttering and reservoir) before the addition of nutrients. This is a very crucial step as it kills all unwanted bacteria and pest that can potentially infiltrate the system and cause damage to plants.



Fig. 4.7 Showing nutrient solution

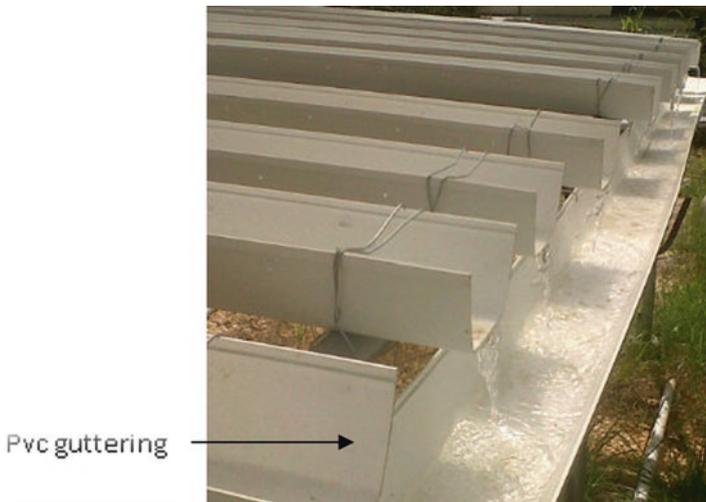


Fig. 4.8 Showing test run of nutrient solution through system

11. After proper chlorination of the system, the nutrient solution can then be added to recirculate throughout the system. In our system we added one nutrient at a time by dissolving it in a bucket of water and then discarding into the reservoir.
12. The EC and pH should then be tested to ensure the appropriate levels are attained. These levels are crucial to the plants survival as each plant works best at certain levels. In this system we tested for a pH of 5.5–6.5. Fig. 4.8.



Fig. 4.9 Showing the setting of seedlings

13. Set seedlings aside to grow before placing them in the system. Seedlings can be grown in a variety of growing mediums such as outlined earlier on. Seedlings can also be bought from the local seedling or agriculture shops as well. The medium we used was promix as it is cheap and airy to allow water to pass through. Fig. 4.9.
14. Place seedlings in a growing medium inside net pots. Net pots can be brought at the local agriculture shops. They have good quality and a mesh to allow for the roots to pass through to grow. (Note: net pots are to be washed out and chlorinated, preferably $\frac{1}{2}$ cup bleach to 5 gallons of water)
15. Ensure that the net pots are suitable for the depth and size of pvc guttering to be used. Place net pots with the growing medium and plant in the slots made in the pvc guttering.
16. Stagger seedlings in the system so all don't grow up the same time. Use the nutrient mix as given later on and have it recirculated throughout the system. This solution must be monitored twice daily for the correct pH and EC as stated earlier on. Use record sheets as given in the appendix to monitor the growth of each crop and their required conditions. Fig. 4.10, 4.11 and 4.12.
17. Monitor the growth of roots to ensure they are healthy. Healthy roots are very important as they are responsible for the uptake of water and nutrients as required by the plant. Fig. 4.13.
18. When the crops are fully grown they can then be harvested. The color, size and weight should be recorded for future reference. This way you can then compare with other productions to make the necessary adjustments for higher and more quality yields. Fig. 4.14.

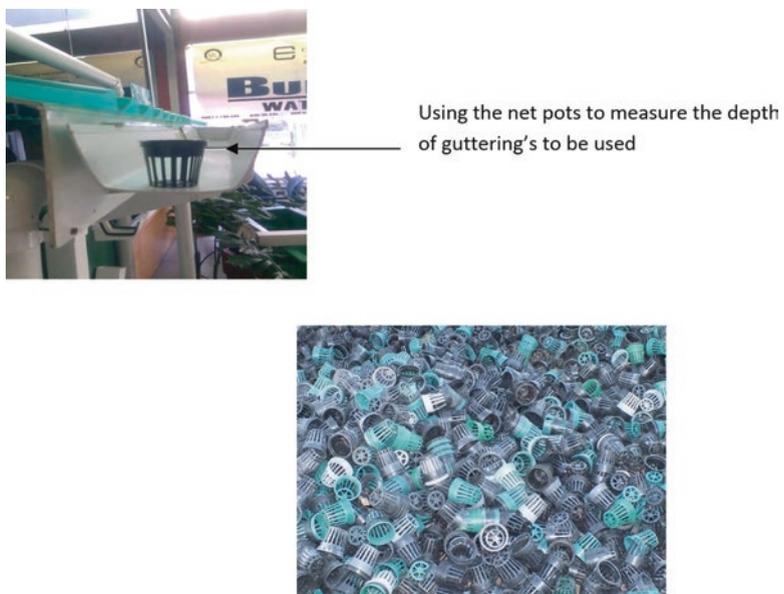


Fig. 4.10 Showing net pot size in PVC



Fig. 4.11 Showing seedlings stage set in the system



Fig. 4.12 Showing crops staged in system



Good root growth

Fig. 4.13 Showing healthy roots



Fig. 4.14 Showing lettuce production

4.2 Example of Cultivation System in Trinidad

In designing a hydroponic system, it is not mandatory to have it covered. Some systems can be open NFT systems as seen in Fig. 4.15 by the owner Mr. Tickaram Harripersad (Figs. 4.16, 4.17 and 4.18).



Fig. 4.15 Showing open NFT hydroponics for seedling stage



Fig. 4.16 Showing intermediate stage for lettuce growth



Fig. 4.17 Showing fully grown lettuce



Fig. 4.18 Showing transportation of lettuce

Chapter 5

Formula for Nutrient Film Technique



5.1 A Hydroponic Formula for Good Results

5.1.1 Composition (Micro, Macro and Trace Elements)

To be dissolved in 400 gallons of water (dissolve completely one product before adding the next).

Hydopal – 3 lbs.

Calcium Nitrate ($\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$) – 2.5 lbs.

Magnesium Sulphate ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) – 1.5 lbs.

Iron Chelate (Fe-EDTA) – 250 g

Kasanic – 1 bottle

Mineral Elements

MACRO – nitrogen, phosphorous, potassium, calcium, magnesium, sulphur

TRACE – iron, manganese, boron, copper, zinc, molybdenum

MICRO – sodium, chlorine, aluminum

Volume - 400 gallons

Flow rate - 1 liter per minute

Changes in time - every cycle

Aeration will vary from system to system. However, it is best to have oxygen pump in the solution to keep well aerated. System should also be closed off for two hours early morning and two hours late afternoon. Fig. 5.1

pH - 5.5 – 6.5

Transpiration is also a very important parameter and is the amount of water loss which can be calculated by measuring the initial volume of nutrient solution and



Fig. 5.1 Showing reservoir with hydroponic formula

subtracting the final volume of nutrient solution. Water is lost throughout the plants and also evaporated throughout the daytime and night time.

Conversions to Note It does not matter whether pounds or grams are used. The most important conversions used in this system were:

- 1 lb. → 453.5924 g
- 1.5lbs → 680.3886 g
- 2lbs → 907.1847 g
- 3lbs → 1360.7771 g
- 2.5lbs → 1133.9809 g
- 400 gallons = 1.5 m³

Chapter 6

Climatic Conditions for Crop Production



6.1 Best Conditions for the Leafy Vegetable Plant Growth

The success of vegetable growth depends on well balanced parameters in relation to the climate. Some vegetables thrive better in the rainy season as compared to the dry. Some of the best conditions recommended for healthy plant growth consist of:

Air Temperature - 24 °C Day/ 19 °C Day (75F/65F)

H₂O Temperature – no higher than 25 °C, cool at 26 °C, heat at 24 °C

Relative Humidity – minimum 50 and no higher than 70%

CO₂ – 1500 ppm if light is available, ambient

Flow rate – 1 liter per minute of nutrient solution

pH – 5.5-6.5



Chapter 7

Management Practices



7.1 Problems Encountered in Growing Hydroponic Lettuce, Chive and Celery

A major problem that occurs in hydroponics is the unwanted growth of algae. This occurs because the conditions of this agriculture practice are optimal for algae growth, however if untreated it can pose serious damages to the other plants in the system because of the rise in competition for nutrients [33].

Another major concern in hydroponics is the consistency of the pH. This determines the lack in nutrients that can drastically affect the growth of plants as outlined earlier on. When this happens, physical appearances in the plants such as brown spots in lettuce, chive and celery becomes visible. There are also other appearances when insects or worms infest the plants. Fig. 7.1

One of the most outstanding visible appearances on the lettuce or celery is *Cecospora* as seen in Table. These are circular to oval brown spots about 1 cm in diameter with white to yellow centers. They spread very quickly from the oldest leaves to emerging ones thus making the crops unfit for consumption. Fig. 7.2.

In any form of agriculture, it is good to practice always walking through and looking at your plants daily. This way you can clearly observe any changes that occur, and through proper records as stated earlier on, preventative methods can be implemented to adjust the parameters such as temperature, humidity, pH, EC and oxygen content.

However, no matter what the problem, there are various solutions to overcome these as can be seen in Table 7.1 below.

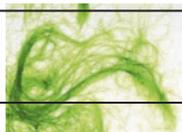


Fig. 7.1 Showing unwanted algae growth in NFT system



Fig. 7.2 Showing Cercospora infestation on lettuce

Table 7.1 Showing problems encountered in NFT system and the solutions recommended

Item	Problem	Solution
	1 Cercospora (brown spots on leaf)	Cu based Fungicide, bellis
	2 Jagged edges	Bacha
	3 Algae growth	Bleach or 10% hydrogen peroxide or wash with water
	4 EC, Ph less	Add more hydrolal and calcium nitrate
	5 EC, Ph more	Add more water

Preventative measures recommended for the operation of the nutrient film system outlined from trial and error consist of:

1. Nutrient solution was cut off every night and every morning for increasing the O₂ and CO₂ flow
2. Reservoir was cleaned thoroughly on a monthly basis with the addition of new nutrients
3. Vegetables were sprayed with fungicide once per week only at afternoons, (use a smaller quantity of fungicide to water than the required amount).
4. Open guttering was sprayed to wash out algae, (note that the outlet pipe into the reservoir should be removed so polluted water does not re-enter the reservoir).

Chapter 8

Developing a Business Plan



8.1 Using Hydroponics to Bring an Income: First Develop a Business Plan

If you plan on selling your produce, then it is best that you develop a strategic plan that will ensure you meet all the goals that you wish to achieve. A business plan can be searched for on the internet via various search engines.

Below is a list of the following things you should consider when developing your business plan. It also highlights an example of a business plan.

8.2 Business Concept

In developing a successful income from any form of agriculture whether it is for small or large-scale production, it is best to have a highlighted business concept. This way a person knows exactly the outcome they wish to obtain from their input.

8.3 Input = Output

A business concept gives a clear and concise definition of the overall aim, vision, goals and objectives and sources of advantage that will guide you along the path you wish to go.

Example The objective of the system highlighted on page was to develop a prototype hydroponic system that would be used later on for the establishment of a state of the art growing farm so as to maximize production and market potential by

eliminating the disadvantages of soil medium and weather disturbances through the use of a semi-controlled environment.

8.4 Aim

The aim identifies what you want to do.

Example To establish the true potential of vegetable growth by generating premium, healthy, fresh and tasty vegetables required for consumption.

8.5 Vision

This is anticipation for future developments. It expresses the dreams you envision for years to come as a result of your present status.

Example To be recognized as leaders in hydroponics.

8.6 Goals and Objectives

This states clearly what you want to achieve and how you plan on achieving it. It is actions to be taken and the results expected.

Example To be a priority sector that would address the urgent challenge of food price inflation and to contribute to the achievement of food sufficiency.

- To reduce the price margins between the producers and consumers.
- To sustain competitiveness by becoming resilient, adaptive, green technological in focus and market driven.

8.7 Advantages

Source of advantage highlights what makes you suitable and qualified to produce the results you wish to have. It can also show any gaps that needs filling to make you more equip to achieving your goals and objectives.

Example: In this project, my source of advantage consisted of the following:

1. Consultancy from highly experienced engineers (Agriculture Shops, Ministry of Agriculture), all versatile in greenhouse.

2. Certificates –1). Identification and Management of Common Pest and Disease in Crop Plants.2). Growing Vegetables using a Sharp Sand based Hydroponics System.
3. Experience- Trial and error for several months
4. Education- BSc Physics and Chemistry to help in the understanding of plant development and the necessary procedures required for consistency
5. Solid Greenhouse in Progression Supplying- Local Supermarkets

8.8 Financial Analysis

This is the most crucial part of any business plan. In order to have a successful business then you must be able to evaluate and keep track of your expenditure. You must be able to differentiate from the amount you are spending as compared to the amount that needs to be spent. If you are to have a successful agricultural business, then you must be able to make a profit.

Example From the system outlined on page _ a cost analysis was performed as seen in Table -. Money was spent on seedlings, chemicals, packaging material, salaries, electricity, vehicle, insurance and miscellaneous items. Table 8.1

A graph was produced to show a pictorial view of expenditure as seen in Fig. 8.1 -. As seen in the graph the cost of the packaging materials and use of transportation was extremely high. In order to increase your profits then, these would be the first two to cut down on.

Table 8.1 Showing cost analysis for a small NFT hydroponic system

Cost analysis			
Cost center	Annual cost	Percent of Total	Cumulative percent
Seedlings	\$2880.00	5.58%	5.58%
Chemicals	\$6000.00	11.63%	17.22%
Packaging materials	\$15,900.00	30.83%	48.04%
Salaries	\$3600.00	6.98%	55.02%
Electricity	\$1200.00	2.33%	57.35%
Vehicle	\$12,000.00	23.26%	80.61%
Insurance	\$5000.00	9.69%	90.31%
Miscellaneous	\$5000.00	9.69%	100.00%
	\$0.00		0.00%
	\$0.00	0.00%	0.00%
Total	\$51,580.00	100.00%	

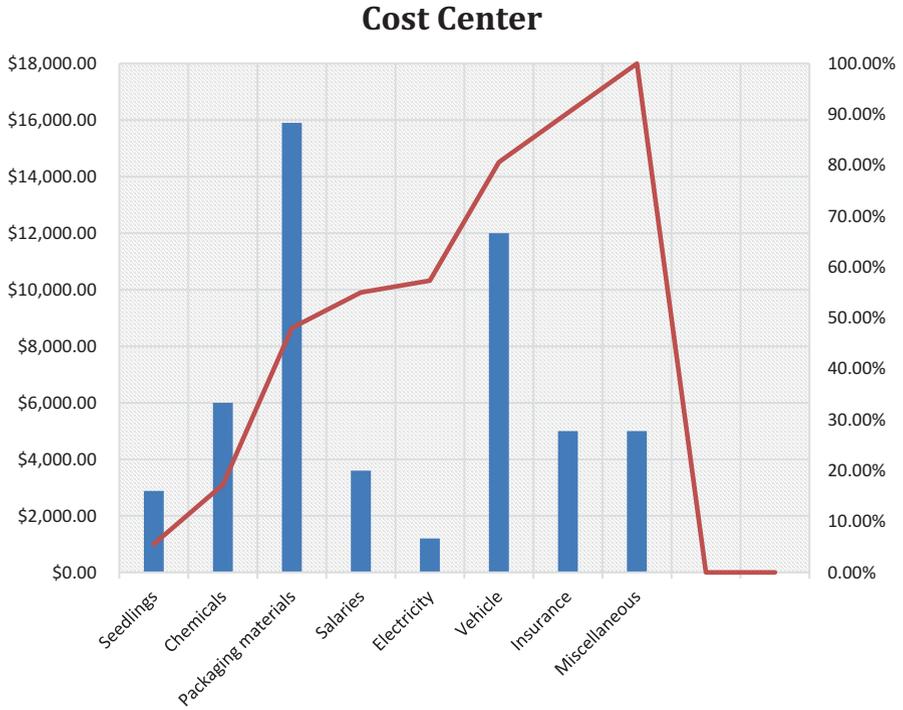


Fig. 8.1 Showing cost analysis graph

Chapter 9

Conclusion



Hydroponics is the most ideal system recommended for many growers because of the awareness placed on the environment and ecosystem. It is a form of soilless agriculture that presents great advantages when compared to other agricultural practices. In the designing of a functional system, hydroponics is fully adapted to suit the needs and outcomes as required by those investing in it. Proper background education is needed alongside an effective project planner, highlighting the aim, vision, goals, objectives and sources of advantage that will bring about successful production.

Once theory is fully understood, then can one venture into the practical aspect of this art of growing. Only through trial and error can one fully understand and appreciate the science of growing without soil.

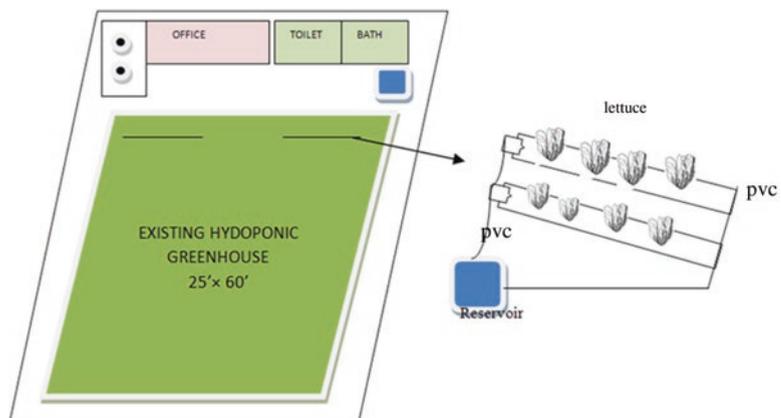
In understanding this concept, one will learn to appreciate that nutrients are responsible for the proper growth of plants and vegetables. A list of specific macro and micro elements when combined under the appropriate conditions are what brings about a successful production.

Many persons venture into making hydroponics as a business. Whether it is for small or large scale production, it is best advised that you ensure consistency is obtained from production. Once this is attained, a business profile can then be drafted to explore a proper cost analysis spectrum of all the expenditure and profits made.

Summary of Nutrient Film Technique

Structure of greenhouse frame – A frame Model
Type of selective covering – UV treated plastic or Open air
Type of insect netting – Sara netting
Angle of PVC guttering – 1:40
Length of PVC guttering – 30'
Depth of reservoir – 400 gallons
Quantity of lettuce – 2,000 heads of ice-berg
Volume - 400 gallons
Flow rate - 1 liter per minute
Changes in time - every cycle
pH - 5.5 – 6.5
Air Temperature - 24°C Day/ 19 °C Day (75F/65F)
H₂O Temperature – no higher than 25°C, cool at 26°C, heat at 24°C
Relative Humidity – minimum 50 and no higher than 70%
CO₂ – 1500ppm if light is available, ambient

Layout of Small Hydroponic Greenhouse



References

1. Duren L (2001) Home garden hydroponics. Duren Company, Middleton, p 1
2. Benton J. J. Jr (1982) Hydroponics: history and use in plant nutrition studies. *J Plant Nutr* 5(8):1003–1030
3. Stone M (2004). How to hydroponics- a beginners and intermediates in dept Guide to hydroponics
4. Hall DO, Rao KK (1999) Photosynthesis, 6th edn. Cambridge University Press Chapter 1
5. Bell GE (2011) Turfgrass physiology and ecology, advanced management principles. Cambridge University Press, Cambridge, p 78
6. Clayton KR (1980) Photosynthesis: physical mechanisms and chemical patterns. Cambridge University Press, Cambridge, pp 3–54
7. Bhattacharya S (2008) Science in action 8. Pearsons Education, p 35
8. Burkett CW, Stevens LF, Hill HD (1904) Agriculture for beginners, Rev. edn. Medprintor, p 38
9. Logsdon S, Clay D, Moore D, Tseyaye (2008) Soil science step-by-step field analysis. Soil Science Society of America, Madison, p 147
10. Peverill KI, Sparrow LA, Reuter DJ (1999) Soil analysis: an interpretation manual. CSIRO Publishing, Melbourne, p 129
11. Alexander T (2000) The best of the growing edge: popular hydroponics and gardening for small commercial growers and hobbyists. New Moon Publishing Inc, Corvallis, pp 39–60
12. Resh HM (2004) Hydroponic food production: a definitive guidebook for the advanced home gardener and the commercial hydroponic grower, 6th edn. New Concepts Press Inc, Boca Raton, pp 63–64
13. McCaskill J. (1998). Plant nutrient facts for hydroponics and how to make your own fully formulated plant nutrient
14. Alexander T, Parker D (2002) The best of the growing edge. New Moon Publishing Inc, Corvallis, p 3
15. Benton J, J Jr (2005) Hydroponics: a practical guide for soilless growers, 2nd edn. CRC Press, pp 1–28
16. Olympios CM. (1999). Overview of soilless culture: advantages, constraints and perspectives for its use in Mediterranean countries. *Cashiers options Mediterranean's*. 31. pp 307–324
17. Trip T (2014) Hydroponics advantages and disadvantages: pros and cons of having a hydroponic garden. Speedy Publishing LLC
18. Perez LE (2008) Hydroponics for the home. Inter-American Institute for Cooperation Agriculture (IICA), p 15

19. Roberto K (2003) How to hydroponics, 4th edn. Future garden Inc, p 22
20. Tripp T (2014) Hydroponics systems: how to build a hydroponic system for your garden. Speedy Publishing LLC
21. Yeats P (2012) The hydroponics garden: growing without soil. Healing Self and Spirit Ltd, p 21
22. Zobel RW, Tredici PD, Torrey JG (1976) Method for growing plants aeroponically. *Plant Physiol* 57(3):344–346
23. Harris D (1992) Hydroponics: the complete guide to gardening without soil. New Holland Publishing, London, p 16
24. Sheikh BA (2006) Hydroponic: key to sustain agriculture in water stressed and urban environment. *Pak J Agric Agric Eng Vet Sci* 22:53–57
25. Burrage SW (2006) Nutrient film technique in protected cultivation. *Acta Hort* 1992(323):23–38
26. Zayed AM, Abou-Hadid AF, Behairy EL, Beltagy EL (1989) The use of nutrient film technique for the commercial production of greenhouse tomatoes in Egypt. *Egypt J Hortic (Egypt)*
27. Mohammed S, Sookoo R (2016) Nutrient film for commercial production. *Agric Sci Res J* 6(11):269–274
28. Peckenpaugh D (2004) Hydroponic solutions volume 1 hydroponic growing tips. New Moon Publishing Inc, Corvallis, p 72
29. Hovorka AJ (2005) The (Re) production of gendered positionality in Botswana's Commercial Urban Agriculture Sector. *Ann Assoc Am Geogr* 95(2):294–313
30. Jiang WJ, Yu HJ (2006) Twenty years development of soilless culture in mainland China. In: XXVII International Horticultural Congress-IHC 2006: Global Horticulture: diversity and harmony, an Introduction to IHC, vol 759, pp 1811–1186
31. Jensen MH (1997) Hydroponic worldwide. *Acta Hort* 481:719–730
32. Ajmi AA, Salin AA, Kadim I, Othman Y (2009) Yield and water use efficiently of barley fodder produced under hydroponic system in GCC countries using tertiary treated sewage effluents. *J Phytology* 1:5
33. Coosemans J (1995) Control of algae in hydroponic systems. *Acta Hort* 382:263–268

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