Farooq A Khan*, Sumati Narayan, Faheem U Khan, Zaffar M Dar, M Amir, Mouinuddin and Astha

Hydroponic vegetables: A sustainable food production system and profitable venture under climate change

Humans require food, water, and living space in order to survive. These do not exist in endless abundance, making humans dependent upon the optimization of land area. Considering that world population is increasing and will reach about 9 billion by 2050, it is evident that food security is one of the pivotal themes of the new millennium & reasonably, the most urgent challenge for the agricultural sector. Food productivity of the current system of cultivation as well as water harvesting are the major concerns. Also, there is a progressive drop of fertile soil surface and quality water due to present trend of global climate change/ uncertainty, environmental pollution and urbanization phenomena, which greatly complicates the context. Infestation by the pathogens under traditional growing system further limits the potential crop production. Thus, farming has to become more productive as well as protective with some advance growing technique, especially under changing climatic situation and areas difficult to cultivate must be adopted. Hydroponics, particularly in the form of vertical farming is a wonderful option that provide the opportunity to grow anywhere with least use of land and water, and without any fear of insect, pest, diseases and other natural calamities. Also, due to the changing global economic scenario, getting jobs in public sector is arduous and private entrepreneurship is a lucrative option. Vegetables are important cash crops that hold the potential of improving both income and nutrition of farmers, and rising demand for vegetables require growing vegetable crops in all possible places and ways.

What is hydroponics?

Hydroponics is the cultivation of plants without using soil. In this system of cultivation, vegetables are planted in inert growing media such as gravel, vermiculite, rockwool, peat moss, saw dust, coir dust, coconut fibre, etc. to provide mechanical support and supplied with nutrient-rich solutions, oxygen, and water. This system fosters rapid growth, stronger yields, and superior quality. The primary advantage of using hydroponics to grow plants is that it allows for a much quicker growth rate. The term hydroponics ('hydro' - water and 'ponos' - labour) was coined by Professor William Gericke in the early 1930s that describes the growing of plants with their roots suspended in water containing mineral nutrients. Researchers at Purdue University developed the nutriculture system in 1940. During 1960s and 70s, commercial hydroponics farms were developed in Arizona, Abu Dhabi, Belgium, California, Denmark, Germany, Holland, Iran, Italy, Japan, Russian Federation and other countries. A basic hydroponic system looks as shown in figure.

Hydroponic system of crop production is known to be more efficient in crop water use and produces 3-10 times food in the same amount of space. Further, no chemical weed or pest control products are needed when operating a hydroponic system and thus are more environment friendly than traditional agriculture. Since it does not require natural precipitation or fertile land, it

Basic hydroponic system

presents people with an alternative to traditional farming. Since, about 3.5% of the worldwide area cultivated under tunnels and greenhouses for vegetables production adopts the soilless agriculture techniques based on hydroponic solution. This significant diffusion at the field scale undoubtedly highlights the presence of many advantages of this production approach in addition to the more efficient use of the nutritional resources including water. Also, there are a variety of examples where hydroponic solution can be efficiently used for bio-fortification programs with iodine (I), selenium (Se), silicon (Si), and calcium (Ca) as well as to improve fruits and vegetables' quality and its shelf life according to the market and consumer needs.

Components of a hydroponic system

How does a hydroponic system work?

Plants sustain themselves by process of photosynthesis. Plants capture sunlight with chlorophyll (a green pigment present in their leaves). They use the light's energy to split water molecules they have absorbed via their root system. The hydrogen molecules combine with carbon dioxide to produce carbohydrates, which plants use to nourish themselves. Oxygen is then released into the atmosphere, a crucial factor in preserving our planet's habitability. Plants do not need soil to photosynthesize. They need the soil to supply them with water and nutrients. When nutrients are dissolved in water they can be applied directly to the plant's root system by flooding, misting, or immersion. Hydroponic innovations have proven that direct exposure to nutrient-filled water can be a more effective and versatile method of growth than traditional irrigation.

Hydroponic systems can be either active or passive. Active means that nutrient solutions will be moved, usually by a pump. Passive relies on a wick or the anchor of the growing media. Hydroponic systems are also characterized as recovery or non-recovery. Recovery means the nutrient solution will be reused into the system while as, with non-recovery, the nutrient solution is applied to the growing media, and vanishes.

Components of a hydroponic system

To maintain a flourishing hydroponic system, one needs to become acquainted with a few components that make hydroponics run efficiently as shown in figure.

Hydroponic plants are often grown in inert media that support the plant's weight and anchor its root structure. Growing media is the substitute for soil; however, it does not provide any independent nutrition to the plant. Instead, this porous media retains moisture and nutrients from the nutrient solution which it then delivers to the plant. Many growing media are also *p*H-neutral, so they will not upset the balance of the nutrient solution. There are several types of growing media such as gravel, vermiculite, rockwool, peat moss, saw dust, coir dust, coconut fibre, etc. and the specific plant and hydroponic system will dictate which media best suits your endeavour. Plants that are submerged in water can quickly drown if the water is not sufficiently aerated. Air stones disperse tiny bubbles of dissolved oxygen throughout your nutrient solution reservoir. These bubbles also help evenly distribute the dissolved nutrients in the solution. Air stones do not generate oxygen on their own. They need to be attached to an external air pump. Net pots are mesh planters that hold hydroponic plants. The latticed material allows roots to grow out of the sides and bottom of the pot, giving greater exposure to oxygen and nutrients. Net pots also provide superior drainage compared to traditional clay or plastic pots.

Types of hydroponics

There are 6 main types of hydroponic system. In fact, the plant roots need three things, water/moisture, nutrients, and oxygen. So, viz. what differs in the 6 methods is the way the systems delivers these three important things to plant roots. Of course, there are lots of variations with different types but they all belong to these 6 core types of Hydroponic systems:

Wick system: Wick system exploits the capillary action of water to draw up water and nutrients from a reservoir to the plants. This is a passive form of hydroponics, meaning the system works without the need for any motors, pumps, or moving parts.

Water culture: Deep Water Culture is one of the most simple and efficient hydroponics technique, where the plant grows in a net pot filled in a small quantity of clay pebbles; the roots develop immersed in a water based mineral solution are constantly oxygenated by an air pump.

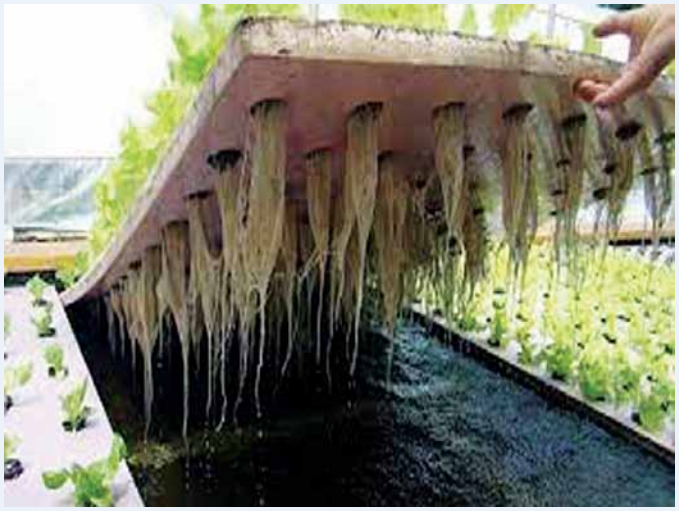
Ebb and Flow: Ebb and Flow, or Flood and Drain is a system that involves the periodic flooding and draining of the nutrient solutions. Basically, there are two phases of its operation. Flood is when the water and nutrients flow through the growing areas, flowing over the plants' roots. The drain is when the water drains back to the reservoir. These two actions take turn continuously and hence their name.

Drip system: In drip system hydroponics, the water-based nutrient solution is delivered to the root system of plants using drip irrigation. This type of low-flow irrigation is very water-efficient, avoiding waste due to evaporation by providing moisture via slow drip at the base of the plants rather than mimicking rainfall from above.

NFT system: The nutrient film technique (NFT)

Different types of hydroponic system

Wick System



Water Culture

Ebb and Flow system

Drip System

NFT System

Aeroponic System

Table 2. Requirements and setup cost to start NFT hydroponic farming in a 5000 square feet area

Hydroponic farming one time setup cost	
Polyhouse shelter	₹ 600000
Pipes (4 inches)	₹ 700000
Pipes (2 inches)	₹ 12000
Pipe connectors	₹ 120000
Stand platform for 40 stands (hold 32 pipes each)	₹ 100000
Tank (20000 L)	₹ 55000
Plastic tanks - 2 (1000 L)	₹ 15000
Plastic tank (5000 L)	₹ 22000
Water pump (1-HP)- 4 pumps	₹ 30000
Water pump (0.5-HP)- 2 pumps	₹ 10000
Net cups- 20000 plus	₹ 100000
Water cooler	₹ 60000
RO system	₹ 50000
*p*H meter	₹ 1200
TDS meter	₹ 2000
Labour cost	₹ 10000
Total one time cost	₹ 1887200 to 2000000
Hydroponic farming per cycle cost: Considering, the hydroponic farming system gives yield every month, following is per cycle or per month cost in hydroponic farming of lettuce	
Electricity	₹ 15000
Seeds	₹ 20000
Fertilizers	₹ 20000
Labour	₹ 10000
Maintenance	₹ 5000
Packing and transportation	₹ 10000
Total per cycle cost	₹**80000/-**
Hydroponic farming profit: On a 5000 square feet area, the following are the outcomes in one-time yield of crops like lettuce	
Total production	3200 kg
Waste	1000 kg
Total left	2200 kg
Value in market	200 ₹/kg
Value of yield	₹440000
Profit margin	
Profit margin = Total earning per cycle - per cycle investment	
Profit margin= 4,40,000 - 80,000 = 3,60,000 INR/cycle	
The margin of profit per cycle or per month	₹360000
Total margin of profit per year (per cycle × 12)	₹**4320000**

is a hydroponic technique in which the plants stand in a shallow stream of water containing all the dissolved nutrients necessary for plant growth. This water flow is circulated through growth tanks containing the roots of the plants. The plants absorb the nutrients through the roots, and because the stream is shallow and the roots are also suspended in the air, the roots can also absorb oxygen.

Aeroponic system: Aeroponic systems are a specialized version of hydroponics where the roots of the plant extend only in air and the roots are directly sprayed with a nutrient water mix (the recipe). The primary difference is the availability of oxygen to the roots. In hydroponics, one has to be sure to supply oxygenated water. Standing water gets depleted of oxygen over

time. In aeroponics, oxygen is surrounding the roots at all times. Surplus oxygen accelerates nutrient absorption at the root surface.

Vegetable crops suitable for hydroponic cultivation

A large number of plants and crops or vegetables can be grown by hydroponics system. Selecting vegetable crops for hydroponics is the most important phase in hydroponic vegetable farming. All your success depends on what you select in the plants and how you plan the farming is the key role. In fact, you can grow any plants in hydroponics, but many plants will flourish in the water based environments, while many will burdensome and could not bring similar produces, as in the actual soil counterparts. Therefore it's recommended you select one best suited for hydroponics farming.

Table 1. Vegetable crops suitable for hydroponics system

Leafy vegetables	Lettuce, Spinach, Kale, Chives, Coriander, Pakchoi, Baby leaves, Microgreens, Celery, Swiss chard, Atriplex
Other than leafy vegetables	Tomato, Capsicum, Chilli, Brinjal, Cucumber, Turnip, Cabbage, Cauliflower, Onion, Melons, Radish

Growing lettuce using NFT hydroponics

NFT systems grow almost any kind of vegetable, but lettuce (Lactuca sativa) is the easiest vegetable to grow hydroponically, so it's a great place to start. The nutrient film technique (NFT) was developed during the late 1960's by Dr Allan Cooper at the Glasshouse Crops Research Institute in the U.K. This system allows a thin film of hydroponic growing solution to flow steadily over the plant roots. A principal advantage of this system in comparison with others is that a greatly reduced volume of nutrient solution is required. This system also provides highly oxygenated roots, ease of setup and takedown.

Green leafy vegetables can be easily grown in soilless media because of their short life span and tender nature. These leafy vegetables are rich in antioxidants, fibre, vitamins, minerals and substances that help to protect from various diseases. Lettuce (*Lactuca sativa*) is most common among leafy vegetables that can be easily grown in hydroponic system and commercially it is mostly grown using the nutrient film technique (NFT) system. Growing of these leafy vegetables through hydroponic technique has several advantages compared to soil, like faster and uniform development of plants, higher average yield and balanced development, free from soil-borne diseases, eliminating use of harmful chemicals and superior quality of produce. This technique is gaining popularity in India, also various institutes and private firms are conducting experiments and trainings for efficient management of hydroponic systems.

Life cycle of hydroponic lettuce is very short compared to traditionally grown lettuce. Hydroponic lettuce can be harvested after 35 to 40 days of production. Lettuce can be successfully grown in NFT system and more than 10 crops

NFT system of hydroponics at SKUAST-K

per year can be grown efficiently in this system. Growing of lettuce in recirculating hydroponic system at spacing of 50 plants/m^2 significantly increased yield and yield components. It has been found that there is significant difference in productivity and nitrate content of lettuce in both soilless (floating system and substrate culture) and soil culture, however, other traits like leaf area, dry weight and ascorbic acid content remain unaffected.

Is Hydroponic farming profitable in India?

Hydroponic farming has experienced a boom in the recent past. It has been getting a lot of attention in the press and its awareness is spreading widely. Hydroponic farms are mainly built indoor or in greenhouses. Both of the alternatives have proved to be good for commercial use. They have been utilized in numerous ways for farm operations. Hydroponic farms have proved to be productive facilities that generate enough revenue. The revenue raised from hydroponic farms is enough to pay the overhead expenses and provide decent wages for farmworkers.

CONCLUSION

The frame of hydroponics has increased dramatically in a short period of time. Hydroponic culture is possibly the most intensive method of crop production in today's agriculture industry mainly used in developed and developing countries for food production in limited space. It is highly productive, profitable, conserves water, is protective for adverse environment and can be done in limited land and space. After getting the sufficient training, it may be most beneficial venture for an entrepreneur.

For further interaction, please write to:
Farooq A Khan (Professor-Plant Physiology), Division of Basic Sciences and Humanities, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, Jammu & Kashmir. *Corresponding author email: drkhanfa1966@gmail.com