Next Generation Food Growing Routes

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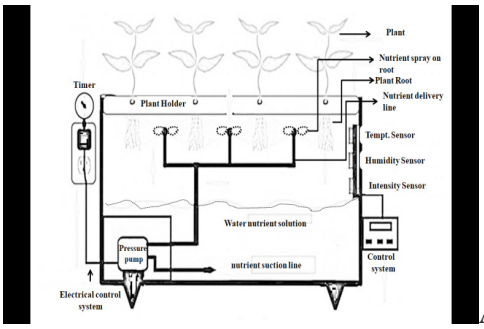
Introduction

Agriculture has been conceptualized way back to human civilization in the discovery of food, cloth, and shelter. Farming was an art in the earlier stage of growing crops by observing nature; later science advancement contributed to tremendous cultivation developments. Indian Vedic religion believes that natural five elements could be the major cause for life on earth soil, water, air, fire, and sky. Such concepts empirically witnessed biological plant growth on soil, seawater, and air near heightened waterfalls/rocks or dense forests. This affirms that there shall be life existing in the remaining two places on the moon and sun.

Traditionally, food was grown openly on soil come across quality and quantity productfaces numerous challenges mainly irrigation, fertilisers and pesticide use, and yield apart from effects of climate change, particularly global warming, and drought. In this context, it was discovered alternative methods of certain quality food produced adequately under modified environment/microclimates.

There are three methods of modified climate food cultivation Greenhouse, Hydroponics and Aerophonics. The titles Hydroponic and Aeroponics originate from the Greek and Latin words Hydro and Aero, which signify water and air, respectively, while Ponic signifies labor. In both systems, the artificial supporting framework is provided by the plant, which develops in the controlled conditions even without soil.Whilst,the name “greenhouse” is derived from the greenish colour of the glass or other transparent materials often used to build such structures in early genesis period.

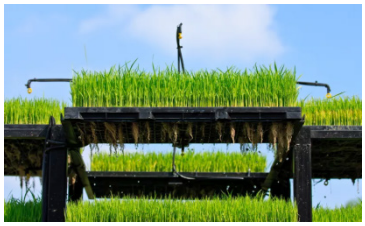
Mostly aeroponics or hydroponic cultivation is practiced in greenhouses, thus it’s important to note that the success of these cultivation depends on factors like water quality, maintaining proper nutrient balance, EC, and pH levels, apart from environmental conditions (lighting, temperature, humidity).

1. 

Aerophonics

Aeroponics is the science of growing plants without the need of soil or a substrate culture. In instances where a plant is supported artificially and grows in the air without the need for soil or substrate, as seen in Figures 1 and 2 (Osvald*et al.,*2011).

Figure 1. Aeroponics plant growing system with computer controlled techniques.



Basically, it is an air-water culture cultivation system, the roots of the plant are hung inside a sealed container under darkness and openly exposed in the air to get water nutrient-rich spray through atomizers.

Figure 2. Aeroponics rice growing system.

The upper portion of the plant leaves and crown extend above the wet zone. The artificially created structure divides the plant's root from its canopy. In order to maintain hypergrowth under controlled circumstances, the system makes use of the nutrient-enriched spray in the air with the assistance of pressure nozzles or foggers..

Atomisation of aerophonic systems:

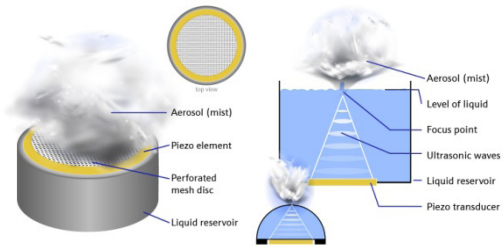
The nutrient and water for aerophonics system is supplied through spraying solution in fine droplets size or mist form. The absorption of the nutrient are mainly depends on size of droplets, frequency of root exposure and interval time are the essential factors for successful plant cultivation.

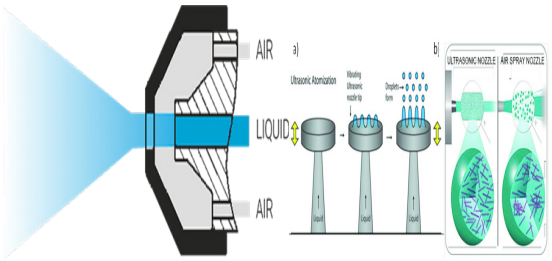
Ultrasonic Atomization Fogger

- ✓ It is small metallic covered device which comprises a plastic shell, built-in AC/DC adapter, and a small piezoelectric ultrasonic transducer.
- ✓ The piezoelectric ultrasonic transducer is the core component which generates the high-energy vibrations at frequencies from 0.5 to 3.0 MHz.
- ✓ This atomization fogger is placed in the centre of the container under one to four inches of liquid solution, these ultrasonic wave sprays as thick fog, 5-25 µm, like clouds shown in figure a & b.

Pressure air atomisation nozzles

- ➢ The air-atomization nozzles are operated by providing the air with high-pressure 550kPa, through the air-compressed container.
- ➢ The compacted air delivers energy to break down the larger liquid particles into very fine particles, 10 to 100 microns.
- ➢ The liquid is distributed through the orifice into the atomization nozzle, where high-pressure air stream produces the shearing force to break up the large liquid molecules.
- ➢ Their exposure causes the larger droplets to break up into a fine mist spray.





Nutritional solutions used for hydroponic system.

Table 3 Nutrients solution needs for a potato aeroponic module of 400 L(Tunio, *et al.*, 2020).

Nutrient	$meqL^{-1}$	gL^{-1}	$g400L^{-1}$	Nutrient	$meqL^{-1}$	gL^{-1}	$g400L^{-1}$
K Nitrate	5.4	0.54	216	Mg Sulfate	1.000	0.24	96
NH4 *Nitrate	4.4	0.35	140	Fetrilon-combi	0.034	0.009	4.8
Ca triple superphosphate	2.6	0.28	112	ironobelate ((6%	0.050	0.012	3.6

*When tuberization is initiated, the concentration should be reduced by half after 2-mo of transplantation.

A nutrient solution's ideal pH and EC values are 6.5 to 6.8 and 1.5 and 2.5 dS m-1, respectively. However, the nutrient solution of aeroponics should be changed every 4-week intervals to maintain the correct pH and EC.

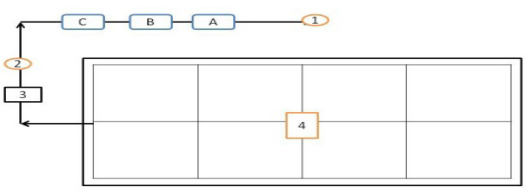
Advantages of aeroponics system

1. It has the potential to cultivate plants in large quantities and tree saplings
2. It is an indoor horticulture practice.
3. It is the best to suitable for the soil is not suitable for plant growth.
4. The system reduces the labour cost.
5. The nutrient solution could be recycled easily for reuse.
6. Consumes less water usage (98%) &fertilizer usage (60%), pesticide and herbicides usage by 100%
7. Maximize plant yield by 45% to 75% than either hydroponics or geoponics system.
8. The system allows for vertical farming.
9. The possibilities of multiple harvests of a single perennial crop
10. The mature plant could be removed easily at any time without disturbing plant.
11. The diseases could not expand quickly because of clean root material free from soil.
12. The plant receives 100% of the available carbon dioxide and oxygen.
13. It is environmentally friendly and economically efficient plant growing system.

Disadvantages of aeroponics system

1. It is expensive for long scale production
2. The plant grower must need a specific level of proficiency to operate the system.
3. Needs trainedpersonals for maintenance of plant growth.
4. It requiresconcentrated nutrients supply.
5. There is no any solid culture to absorb the excess nutrients.
6. The system design material is expensive.
7. Knowledge of how plants grow and of the principles of nutrition is important.

1. **Hydroponics**



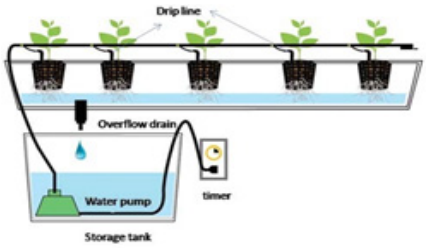
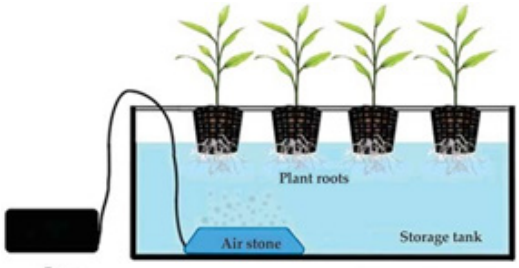
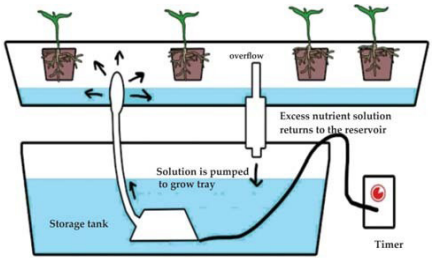
Hydroponics is a technique that uses mineral nutrient solutions based on water to grow plants without the need for soil. The roots of the plants are either exposed to the nutritious liquid (Floating type) or mechanically supported by an inert medium such as perlite, gravel and polycarbonate boardssubstrates. Supplemental lighting in the form of various LED diodes or their combination is common practice to increase the nutritional content (vitamin C, anthocyanins, and total phenols) of leafy vegetables. The most common hydroponic system for growing leafy vegetables, like lettuce, radicchio, arugula, dill, spinach, and basil, is the floating hydroponic system. In this system, plants are grown on an aerated nutrient solution in tanks 20 to 25 cm with plant supporting Styrofoam containers or boards. This system has a shorter production cycle and faster growth density.

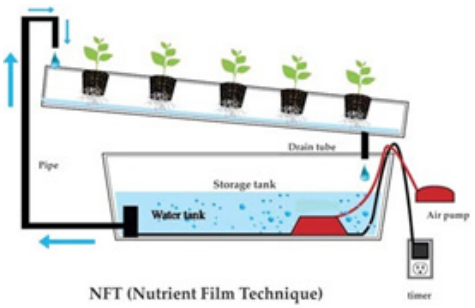
Figure 4. Graphical scheme of floating hydroponics cultivation. 1—water; A, B, C—tanks for concentrated nutrient solutions and; 2—tank for standard nutrient solution; 3—pump; 4—basin with polystyrene containers or boards, left-Hydrophonics.

Types of Hydrophonic structures and their operation

This system,using solely water as a substrate, has been classified accordingtorecyclingandreuseofnutrientsolutionandsupportingmedia, they are DripSystem, Deep Water Culture, Ebb-and-flow, Nutrient Film Technique and Wicking Systemare detailed in below table.1.

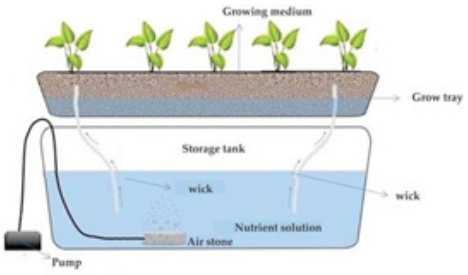
Fig.1. Diagram of various structures of hydroponic system (ref)

Hydrophonic Type	Its Details
 Drip system	✓ In *drip system* technique, a pump delivers a slow feed of the solution to the base of each plant individually based on a timer, and the remaining solution will be either return to the reservoir. ✓ It is widely usedmethod by home and commercialgrowers.
 Deep water culture	In the *Deep Water Culture* method, nutrient-rich oxygenated water is the medium wherein plant roots are suspended in about .6-18inch until harvest ✓ DWC systems hold a large volume of water slowing any .swings
 Ebb & Flow System	✓ *Ebb-and-flow* certainly resembling Nutrition Film Technic, but the crop roots are temporarily flood, ebb, with solution every few hours before returning, flow, to the reservoir. ✓ Thisisfirstcommercialhydroponicsystem. ✓ They are low maintenance and produce high yields unlike NFT, whereas pump failure become catastrophic.



NFT (Nutrient Film Technique)

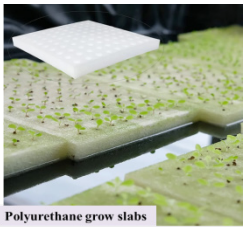
- ✓ **Nutrient Film Technique(N-FT)** wasdevelopedinthe-mid1960sinEnglandbyDr. AlenCoopertoovercometheshort-cutsofebb&flowsystem.
- ✓ The water or a nutrient solution circulates by water pump through-out the growth tray and drains by gravity.
- ✓ By closing the loop and recycling the water, an NFT hydroponics system uses only 10% the amount of water used in conventional farming methods.



Wick System

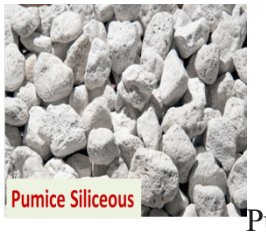
- ✓ A *wicking system* is a technique by which solution is delivered to a tray through the wicks and then to the roots via the plant's capillary action.
- ✓ This is simplest hydroponic sys-tem requiringnoelectricity,pump-andaerators.

Hydroponic system supporting material properties (ref)

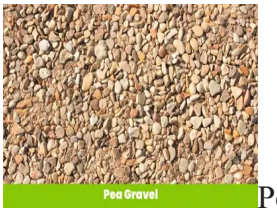


Polyurethane grow slab has a 75% to 80% air space and 15% wa-.ter-holding capacity

Perlite Siliceous, sterile, sponge-like, very light, freedraining, no cation-buffer or exchange capacity, good germination medium when mixed with vermiculite; dust can cause respiratory irritation



Pumice Siliceous ma-terial of volcanic origin, inert, has higher water-holding capacity than sand, high air-filled porosity



Pea gravel and metal chip Particle size ranges from 5 to 15 mm in diameter; free draining; low water-holding capacity; high weight density, which may be an advantage or disadvantage; may require thorough water leach-ing and sterilization before use

Scoria Porous, volcanic rock, fine grades used in germination mixes, lighter and tends to hold more water than sand

Expanded clay Sterile, inert, range in pebble size of 1 to 18 mm, free drain, physical structure can allow for accumulation of water and nutrient elements, reusable if sterilized, commonly used in pot hydroponic systems

Nutritional solutions used for hydroponic system.

The first hydroponics nutritional solutions were made using two formulations in 1950 by Hoagland and Arnon, and second formula was modified Hoagland nutrient solution. In 1960 Steiner was developed one formula for most of plants grown based on ion balance maintenance. Further, Cooper (1988) developed the Nutrient Film Technique (NFT) formula. Later various improvements were developed and general use solution formula was given below table 1.

Table1. Basic Nutrient Formula for General Use (Jones, 2014).

Reagent	Formula	Grams
	Bag A	
Calcium nitrate	$Ca(NO_3)_2 \cdot 4H_2O$	2000
	Bag B	
Potassium nitrate	KNO_3	2275
Magnesium sulfate	$MgSO_4 \cdot 7H_2O$	1757
Potassium phosphate	$MnSO_4$[a]	878
(Ironchelate(EDTA	H_3BO_3	132
Manganese sulfate	$MnSO_4$	24.5
Boric acid	H_3BO_3	6.0
Coppersulfate	$CuSO_4 \cdot 5H_2O$	2.0
Zinc sulfate	$ZnSO_4 \cdot 5H_2O$	1.5
Ammonium molybdate	$NH_4)_6Mo_7O_{24} \cdot 4H_2O)$	0.35

Touse: to 10 L of water, add 1 level teaspoon of bag A, stir until dissolved, and then add 1 level teaspoon of bag B and stir to dissolve. [a]Assumed formula.

A pH meter or test papers are necessary because pH is very important. Although proprietary materials are available, baking soda is used to raise pH and citric acid is used to lower pH. Typically, a pH of 5.8 to 6.2 is desired.

Advantages

1. Crops can be grown on non-suitable soils or where the soil is contaminated with disease.
2. Labor for tilling, cultivating, fumigating, watering, and other traditional practices is largely eliminated.
3. Maximum yields are possible, making the system economically feasible in high-density and expensive

land areas.

4. It reduces pollution of land and water streams because valuable chemicals are not lost.
5. Soil-borne plant diseases are more readily eradicated in closed systems.
6. More complete control of the environment is generally a feature of the system (i.e., root environment, timely nutrient feeding, or irrigation), and in greenhouse-type operations, the light, temperature, humidity, and composition of the air can be manipulated.
7. For low soluble salt concentrations in the water supply in closed system and open system for concentrated water over 500 ppmwith care is given to frequent leachingof the growing medium to reduce the salt accumulations.
8. A hydroponic system can be clean, lightweight, and mechanized.

Disadvantages

1. The original construction cost per acre is great.
2. Trained personnel must direct the growing operation.
3. Knowledge of how plants grow and of the principles of nutrition is important.
4. Introduced soil-borne diseases and nematodes may be spread quickly to all beds on the same nutrient tank of a closed system.
5. Most available plant varieties adapted to controlled growing conditions will require research and development.
6. The reaction of the plant to good or poor nutrition is unbelievably fast.

2. **Green House**

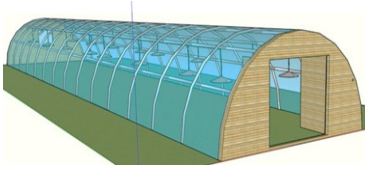
Greenhouse cultivation is one of the finest kind of protected agricultural evolved, where microclimate factors such as temperature, humidity, light and ventilation of air can be tuned according to crops optimal level. This framed structure is constructed on leveled, dam proof field using GI pipes/MS angle support and covered by glass, rigid panned and flexible materials. Under this condition, preferably, high value, commercial, medicinal and market driven agricultural crops are protected against intense heat, bright sunlight, strong winds, hailstones and cold waves. The green house benefits greatly from east and south sunlight and can be left open on these two sides; however, to protect from winds, it should be shaded on the north and west sides.

Types of greenhouses suitable for the different regions are:

1. Tunnel type (cold climate green house)
2. Quonset (semicircular/subtropical green house)
3. Gabble type (slopping roof)
4. Tropical region green house
    a. Ridges and furrows green house
    b. Ground to ground or free-standing green house

The maintenance of favorable environment inside the greenhouse, it is important to control the temperature in conjugation with relative humidity, heat and carbon dioxide gas is controlled through

Greenhouse Ventilation Systems:



Ventilation of greenhouse is defined as circulation of outside fresh air to reduce inside high temperature or replenishing carbon dioxide supply and for moderating the relative humidity in the greenhouse by virtue of natural ventilation system or forced ventilations. This ventilation is possible to control green house temperature level below 40^{O}C. if the temperature level crosses over and above 40^{o}C, then cooling systems of green house are applicable such as fan and pad cooling system and fog cooling systems.

Greenhouse Cooling Systems:

In area were relative humidity is less such as tropical regions, the Pad fan cooling system works with evaporation principle. Evaporative cooling pads with a water circulation system are situated on one side of the greenhouse, while exhaust fans installed on the opposite side draw hot air from within the greenhouse. This allows outside air to pass through the cooling pads, where it vaporizes the water, thus lowering the temperature inside the greenhouse.

In addition, fog systems utilize high-pressure nozzles to create fine water droplets, which aid in cooling the greenhouse.Cooling effectiveness of fog systems depends on ambient air having a relative humidity of less than 90 percent. Injected air tiny water droplets of fog remain suspended until they are evaporated. Fan and pad cooling system principle is applied in fog systems for cooling and humidifying.

Greenhouse Heating Systems:

The effective heating of commercial greenhouses is a significant challenge. There are various heating systems that can be used in greenhouses, and they are typically categorized as either central or local. In a central system, the boiler is situated in a separate building outside the greenhouse, and the heat is delivered to the greenhouses via a distribution system. On the other hand, in a local system, the heat is directly released into the greenhouse space because the furnace and combustion process are located within the greenhouse itself.

Advantages of green-house:

3. The yield may go up to 10-12 times higher than that of outdoor cultivation depending upon the type of greenhouse, type of crop, environmental control facilities.
4. Reliability of crop increases under greenhouse cultivation.
5. Ideally suited for vegetables and flower crops.
6. Year round production of floricultural crops and off season production of vegetable & fruit crops
7. Disease-free and genetically superior transplants can be produced continuously.
8. Efficient utilization of chemicals, pesticides to control pest and diseases due to precision farming.
9. Water requirement of crops very limited and easy to control.
10. Production of quality produce free of blemishes.
11. Most useful in monitoring and controlling the instability of various ecological system.
12. Modern techniques of Hydroponic (Soil less culture),Aeroponics and Nutrient film techniques are possible only under greenhouse cultivation.

Disadvantages

1. High initial costs for building and equipping a greenhouse can be expensive.

2. High maintenance cost for require regular maintenance and monitoring of green house.
3. More energy consumption in regions with extreme climates for maintaining optimal temperature, humidity, and lighting conditions in a greenhouse
4. Greenhouses can have a substantial carbon footprint, mainly due to energy consumption.
5. Greenhouses may require significant labor during peak seasons for planting, harvesting, and maintenance.
6. The finite space within a greenhouse may restrict crop rotation, which is a common practice to prevent soil depletion and disease build-up

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