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The Greenhouse of Tomorrow: Exploring Hydroponic Technologies

Kavya C. Nironi, Seema S. Doddamani, Praveen S. and Anjali C. Nironi

ICAR- Indian Grassland and Fodder Research Institute, SRRS, Dharwad

*Corresponding Author: kavyanironi30@gmail.com

Hydroponics is a technique of growing plants in nutrient solutions (water containing fertilizers) with or without the use of an inert medium (sand, gravel, vermiculite, rock wool, perlite, peat moss, coir or sawdust) to provide mechanical support (Sharma *et al*., 2018). It is also called as Controlled Environment Agriculture (CEA). The earliest published work on growing terrestrial plants without soil was found in the book 'Sylva Sylvarum' by Francis Bacon in the year 1627. The term 'hydroponics' is derived from two Greek words i.e. "Hydro" and "Ponos" means water and labour respectively. The first modern use of hydroponics was done by W.F. Gericke from the University of California during the 1930's. In India, Hydroponics was introduced in year 1946 by an English scientist, W.J. Shalto Duglas.

Why to grow crops hydroponically?

At present, only 80 per cent of the Earth's arable land suitable for farming. Roughly about 15 per cent of this land has been rendered unusable for farming due to poor management and vulnerable climate. However, soils do pose serious limitations for plant growth too, at times. Presence of disease-causing organisms and nematodes, unsuitable soil reactions like salinity and alkalinity, unfavourable soil compaction, poor drainage, degradation due to erosion *etc*., are some of causes for non-suitability of land for cultivation. In addition, conventional crop growing in soil (Open Field Agriculture) is somewhat difficult as it involves large space, labour intensive and large volume of water. Besides, it is also facing various challenges such as urbanization, natural disaster, climate change, indiscriminate use of chemicals and pesticides which is depleting the land fertility. That ultimately leads to the less food production. To get rid of these issues, there is an utmost need for adoption of alternative technology in agriculture that can contribute towards water saving and have a positive impact on food production and availability.

Table 1: Difference between traditional and hydroponic cultivation

Traditional cultivation	Hydroponic cultivation
Traditional cultivation requires soil	Hydroponic cultivation doesn't require soil
A lot of water is absorbed by the soil	Water can be recycled
We can avoid the use of power	Power is necessary to continuously supply the nutrients
Requires larger area	Requires very little area
Great need for pesticides and fertilizers	Less quantity of pesticides and fertilizers needed
More labour requirement to conduct inter-cultural operations	Less labour requirement since this system is automated
Low investment cost	High investment cost

How does hydroponic work?

Hydroponic systems work by allowing minute control over environmental conditions like temperature and pH balance and maximized exposure to nutrients and water. Hydroponics operates under a very simple principle: provide plants exactly what they need when they need it. Hydroponics administers nutrient solutions tailored to the needs of the particular plant being grown. They allow you to control exactly how much light the plants receive and for how long. pH levels can be monitored and adjusted. In a highly customized and controlled environment, plant growth accelerates (Hector, 2005).

Components of hydroponic system: Greenhouse structure, growing systems like grow bag, dutch bucket, pots, NFT channels, trough (benches) *etc*., Environmental control like cooling, heating and ventilation systems, Drip irrigation and fertigation machine/system, Plant nutrients, Growing media- Coco peat, Perlite, Rice hull, Vermiculite, Rock wool etc.

Nutrient solution

A nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions from soluble salts of essential elements for higher plants. Plants require 17 essential elements for vegetative and reproductive development. The first three are carbon, hydrogen and oxygen (Taken from air, non-fertilizer). Other 14 are (Taken from soil in ionic form- A chemical bond formed between two ions with opposite charges) includes: Macro nutrients and Microelements

Table 2: Sources of nutrient elements

Source	Element	Characteristics
Potassium nitrate (KNO_3)	N, K	Very soluble salt
Potassium phosphate monobasic (KH_2PO_4)	P, K	Corrects phosphorus deficiency
Magnesium sulfate ($MgSO_4$)	S, Mg	Cheap, highly soluble, pure salt
Iron chelates	Fe Cit	Best sources of iron
Boric acid (H_3BO_3)	B	Best source of boron
Calcium nitrate ($Ca(NO_3)_2$)	N, Ca	Very soluble salt

Hoagland's solution is used as most common nutrient solutions for hydroponic systems. It is a hydroponic nutrient solution that was developed by Hoagland and Snyder in 1933, modified by Hoagland and Arnon in 1938, and revised by Arnon in 1950. It is one of the most popular solution compositions for growing plants.

It provides every essential nutrient required by green plants and is appropriate for supporting growth of a large variety of plant species. This solution imitates the nutrient rich soil solution. ***Cooper's* 1988** and ***Imai's* 1987 nutrient solutions** were also used for growing leafy vegetables, tomatoes and cucumber.

Growing medium: This can be variety of materials, including coconut fiber, coco peat, gravel, perlite, rice hull, vermiculite, Rock wool *etc.* Even air can be a growing medium.

Table 3. Optimum range of EC and pH for hydroponic crops

Crops	EC ($dS^{-1}\,m^{-1}$)	pH
Cucumber	1.7 to 2.0	5.0 to 5.5
Egg plant	2.5 to 3.5	6.0
Tomato	2.0 to 4.0	6.0 to 6.5
Capsicum	0.8 to 1.8	5.5 to 6.0
Chilli	1.0 to 2.5	6.0 to 6.5
Broccoli	2.8 to 3.5	6.0 to 6.8
Cabbage	2.5 to 3.0	6.5 to 7.0
Bean	2.0 to 4.0	6.0
Lettuce	1.2 to 1.8	6.0 to 7.0
Spinach	1.8 to 2.3	6.0 to 7.0
Pak Choi	1.5 to 2.0	7.0

Types of hydroponic systems

1. **Nutrient film technique:** In this system, water or a nutrient solution circulates throughout the entire system; and enters the growth tray via a water pump without a time control. The system is slightly slanted so that nutrient solution runs through roots and down back into a reservoir. Plants are placed in channel or tube with roots dangling in a hydroponic solution. Although, roots are susceptible to fungal infection because they are constantly immersed in water or nutrient. In this system, many leafy green can easily be grown and commercially most widely used for lettuce production.
2. **Deep water culture method:** This system is an active system with moving parts. In deep water culture, roots of plants are suspended in nutrient rich water and air is provided directly to the roots by an air stone. Hydroponics buckets system is classical example of this system.
3. **EBB and flow method:** This is first commercial hydroponic system which works on the principle of flood and drain. Nutrient solution and water from reservoir flooded through a water pump to grow bed until it reaches a certain level and stay there for certain period of time so that it provide nutrients and moisture to plants.
4. **Drip method:** The drip hydroponic system is widely used method among both home and commercial growers. Plants are usually placed in moderately absorbent growing medium so that the nutrient solution drips slowly. Different types

of vegetables (Tomato, chilli etc.) can be grown systematically by this method with more conservation of water.

5. **Aeroponics:** Aeroponic systems are high end technology/ high tech type method of hydroponic growing. Like the N.F.T system the growing medium is primarily air. In this method, the roots are hanged in air and are misted with nutrient solution. The misting of roots is usually done every few minutes. The roots will dry out rapidly if the misting cycles are interrupted. This method is suitable for potato, tomato and leafy vegetables like lettuce, spinach, etc.
6. **Wick method:** Wick method is described as passive system with no moving parts. This is simplest hydroponic system requiring no electricity, pump and aerators (Shrestha and Dunn, 2013). Plants are placed in an absorbent medium like coco coir, vermiculite, perlite with a nylon wick running from plant roots into a reservoir of nutrient solution. Water or nutrient solution supplied to plants through capillary action. This system works well for small plants, herbs and spice and doesn't work effectively that needs lot of water.

Table 4. List of crops that can be grown on commercial level using soilless culture

Types of crops	Name of the crops
Cereals	Rice, Corn
Fruits	Strawberry
Vegetables	Tomato, Chilli, Brinjal, Green bean, Beet, Winged bean, Bell pepper, Cabbage, Cauliflower, Cucumber, Melons, Onion
Leafy vegetables	Lettuce, Spinach, Celery, Atriplex
Condiments	Coriander leaves, Methi, Persley, Mint
Flowers/Ornamental crops	Marigold, Roses, Carnations, Chrysanthemum
Medicinal crops	Indian Aloe, Coleus
Fodder crops	Sorghum, Alfa alfa, Barley, Bermuda grass

Various species of plants grown under soilless hydroponic system

Crops such as vegetables, spices, flower and ornamentals, medicinal plants, fodders and up to some extent cereals can be raised through soil less hydroponic technique and is mentioned in Table 4.

Pros/advantages of hydroponics

1. Crops can be grown where no suitable soil for crop cultivation exists or where the soil is contaminated with some diseases.
2. Labour for different intercultural operations like tilling, cultivating, fumigating, watering and other practices are largely eliminated.
3. Maximum yield can be obtained thus making the system economically feasible in high-density and expensive land areas.
4. This method can efficiently use water and nutrients. Therefore, it can lead to a reduction in pollution of land and streams because there is minimum chance of loss of the valuable chemicals.
5. Soil-borne plant diseases can be eradicated very efficiently by adopting this system.
6. More complete control of the environment is possible by using the system (i.e. timely nutrient feeding, irrigation and root environment) and different greenhouse type operations, the light, temperature, humidity and composition of the air can be manipulated very easily.
7. Water which is carrying high soluble salts can be used if done with extreme care. If the soluble salt concentrations in the water supply are over 500 ppm, an open system of hydroponics can be used if thorough care is given to frequent leaching of the growth media in order to reduce the salt accumulations.
8. Hydroponically grown crops are easier to harvest than conventional cultivation practices.
9. Hydroponically grown crops are more palatable and better for consumption.
10. Plant grown in hydroponic system can be protected from UV radiations just like they are within a protected structure.

11. Plants grown through this system develop a very good and vigorous root system and it makes the plant risk free from contaminants and different diseases and pest attack.
12. Production of 'off-season' vegetable is possible when market prices are highest.
13. With vertical hydroponic gardening, space management can also be done.
14. Possibility of obtaining more products in less time than using traditional agriculture
15. Produces residues free foods since there is no use of pesticides
16. Hydroponically grown crops are easier to harvest than conventional cultivation practices and are superior in taste, quality, appearance and uniformity. Hence, better for consumption.

Cons/disadvantages of hydroponics

1. Initial cost is relatively high compared to traditional cultivation
2. Proper training or knowhow is an important prerequisite before starting up cultivation of any vegetable crop hydroponically. Knowledge of how plants grow and nutrition principle is very important.
3. Not all crops can be grown by using hydroponic method
4. The mediums require some sort of container to grow the plants
5. Constant supply of water is required for successful crop growth
6. The nutrients have to be mixed in water and then applied to the plants every time
7. Some water borne diseases can spread rapidly in recirculating system
8. Limited production in comparison to field conditions
9. Technical skill is required to maintain the equipment's
10. Hydroponic gardens are influenced by power cut
11. If a disease appears, all plants in the container will be affected
12. If the hydroponic system fails, it can leads to rapid plant death and losses
13. The growers must have knowledge of climate control inside the structure.

Conclusions

Hydroponic culture is possibly the most intensive, cost effective and promising method of crop production in today's agriculture industry and a hopeful strategy for growing different crops in view of climate change. Any nation can increase their food productivity by focusing on such new and innovative system. This system, if used in a wise manner, can lead to the self-sustainability. In a country like India, where urban concrete conglomerate is growing day-by-day, there is no option but to adopt soil-less culture to improve the yield and quality of the produce so that we can ensure food and nutritional security of our country. Progress has been rapid and results obtained in various countries have proved that, this technology is thoroughly practical and has very definite advantages over conventional methods of crop production. Besides, this kind of ground-breaking tool can also be explored or even adoptable to produce quality seeds of especially low volume and high value crops like vegetable, flower and medicinal crops.

References

Hector, M., 2005, Hydroponics home-based vegetable production system manual, IICA, Georgetown, Guyana.

Sharma, N., Acharya, S., Kumar, K., Singh, N. and Chaurasia, O. P., 2018, Hydroponics as an advanced technique for vegetable production: An overview. *J. Soil Water Conserv.*, **17**(4): 364-371.

Shrestha, A. and Dunn, B., 2013, Hydroponics. Oklahoma Cooperative Extension Services HLA-6442.

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