Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 05, Issue: 01 (JAN-FEB, 2025)
Available online at http://www.agriarticles.com

Growing Green: The Role of Hydroponics in Sustainable Vegetable Production

(*Ankita Thakur)
Department of Seed Science and Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India
*Corresponding Author's email: ankitathakur1998@gmail.com

Hydroponics is an advanced soilless cultivation system that utilizes nutrient-enriched water solutions and inert substrates to support plant growth, addressing critical agricultural challenges. This method eliminates soil-borne diseases and enables precise control of environmental conditions, enhancing productivity and resource efficiency. Furthermore, hydroponics is well-suited for urban and resource-constrained areas, contributing to sustainable food production. Despite these benefits, the adoption of hydroponics faces barriers such as high initial investment costs, the need for technical expertise, reliance on uninterrupted power supply, and the requirement for meticulous monitoring of environmental parameters like pH, nutrient balance, and light intensity. Hydroponics offers a transformative approach to modern agriculture, promoting sustainability and food security in the face of global challenges such as climate change and resource scarcity. This paper explores the key concepts, classifications, benefits, limitations, and future prospects of hydroponics, emphasizing its role as a sustainable and innovative approach to modern agriculture.

Keywords: Hydroponics, Sustainable agriculture, Soilless cultivation, Vertical farming

Introduction

Due to the urbanization, industrialization, and population growth, the amount of arable land is decreasing daily. So, the challenge of producing more food as the world's population keeps on expanding led to the introduction of new, modern technology in order to ensure sustainability. The traditional method of growing crops is facing significant challenges of depleting soil fertility due to natural disasters, urbanization, climate change, and excessive chemical and pesticide use (Kumar *et al.*, 2022). One of the major issues with growing plants in soil is soil-borne diseases.

The novel method of hydroponics has been devised to address these issues. Hydroponics is a method of growing plants in nutrient solutions with or without the use of an inert medium to establish mechanical support (Sharma *et al.*, 2018). Thus, it is evident that in hydroponic plants do not require soil and receive their nutrients from a fertilizer solution that is introduced to the water. Professor William Gericke first coined the term 'hydroponics' in 1937 to refer to the practice of growing plants with their roots suspended in water that contains mineral nutrients. The term 'hydroponics' literally translates to 'water work' and is derived from the Greek term "hydro", which means water, and "ponos", which means work. It has several advantages over traditional growing techniques, such as faster growth, more yield, ease of handling, and a lesser need for fertilizer (Barbosa *et al.*, 2015).

Underlining theory in hydroponics

Plants can grow as long as they have access to essential nutrients, light, water, carbon dioxide (CO_2), and oxygen (O_2) in their root zone, plants can grow without soil. As a result, in hydroponic systems, inert growth media such as pumice or perlite support plant roots, while nutrient-rich solutions containing essential macro- and micronutrients promote plant growth (El-Kazzaz & El-Kazzaz, 2017).

Requirements of hydroponics

1. Media: In hydroponics, media the term "medium" refers to a substance that is used to sustain plants and replace soil. The growth medium is crucial for delivering water and dissolved nutrients into contact with the roots of the plants and for helping to anchor them so they do not topple over. The majorly used growing media are: 1. Rockwool, 2. Hydro corn, 3. Coco fiber or coco peat, 4. Perlite, 5. Vermiculite, 6. Oasis cubes, 7. Floral froth, 8. Poly froth protection, 9. Rice hulls.
2. Nutrient solutions: The nutrient solution is a crucial part of hydroponic systems and must be properly prepared and regularly checked to meet the unique needs of farmed crops as well as to maintain optimal nutrient levels and pH balance (Domingues *et al.*, 2012). Understanding the makeup of nutrient solutions is crucial for hydroponic vegetable production, which places a focus on essential macronutrients like nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients like iron, calcium (Ca), and magnesium (Mg) needed for strong plant growth and development.
3. Conditions: Ideal temperature, air, supporting materials, water, mineral nutrient and light are ideal conditions for running a hydroponic system.

Types of Circulating system in Hydroponics

Hydroponic systems can be categorized into two primary groups: 1. A closed system; 2. An open system.

a) Closed system: In a closed hydroponic system, the entire nutrient solution utilized for plant growth and delivered to the roots is routinely retrieved and replenished. The nutritional solution is recycled by this method, which often grows plants in a liquid medium or with solid substrates. Water and nutrients are strictly monitored throughout recycling.

b) Open system: An open hydroponic system has direct contact between the root system and the nutrient solution, which is not recyclable or recirculated. This configuration removes the possibility of plant system infection because the fertilizer solution is changed frequently.

Types of Hydroponics system

1. Nutrient film technique: This technique circulates the nutritional solution throughout the system by continuously pumping it through channels. The plants are held in place by these canals, which allow the nutrient solution to flow through and allow the plants to come into contact with it (Domingues *et al*., 2012).
2. Deep water culture (DWC) and deep flow technology (DFT): Another name for it is the floating raft system. In DFT, as opposed to the nutrient film technique, the water remains motionless with a raft floating on the surface rather than being circulated throughout the system. This floating raft serves as the plants stand. Air compressors and air stones are to be suspended into the reservoir for aeration purposes (Chidiac, 2017).
3. Root dipping method: This technique involves submerging the roots of plants in supporting pots in a nutritional solution (Mariyappillai *et al*., 2020).
4. Floating technique: This technique causes the nutritional solution to remain still while maintaining a thin, opaque raft on top. The plants are positioned on the raft, floating on the nutrient solution and only partially contacting it (Mariyappillai *et al*., 2020).
5. Capillary action method: Using this technique, plants are kept in pots with slightly sized holes at the bottom and extremely porous growing material. The nutrition solution is kept in a shallow container using this configuration. Through capillary action, the nutrient solution reaches the plants (Sengupta *et al*., 2012).

Table 1: Various crops that can be grown in hydroponics (Kumar *et al*., 2024)

Crop Type	Name of the crops
Cereals	Rice, Maize
Fruits	Strawberry
Vegetables	Brinjal, Tomato, Brinjal, Tomato, Chilli, Green Bean, Campos Granados, Winged Bean, Bell Pepper, Cabbage, Cauliflower, Cucumber, Melons, Radish and Onion
Leafy vegetables	Lettuce, Kang Kong
Condiments	Mint, Parsley, Oregano and Sweet Basil
Flower or ornamental crops	Rose, Marigold, Chrysanthemum, Carnations
Medicinal crops	Indian aloe, Coleus

Advantages of Hydroponics

1. When nutrients are given directly to the roots, plants grow faster and form smaller root systems, allowing for denser planting (Kumar *et al*., 2021).
2. It is more appropriate, especially in regions with a shortage of arable land.
3. It provides much greater crop growth and output than soil-based farming because it carefully regulates water, nutrients, and environmental variables (Kannan *et al*., 2022).
4. Hydroponically grown vegetables typically last longer and contain more nutrients, which minimizes waste and rotting.
5. Hydroponic farms are not impacted by the changing of the seasons, and crops can be grown year-round in regulated environments.
6. Hydroponic culture automates agricultural operations by reducing labor, reducing the need for pesticides, simplifying maintenance, and increasing productivity.
7. By employing recycled water in hydroponic culture, which reduces the requirement for freshwater, the significance of water resource conservation is further highlighted.
8. Since this production method doesn't require any soil, the soil's structural and textural qualities as well as its nutrient status are totally unnecessary and can also be grown on wastelands.
9. It is feasible to identify the signs of nutrient shortages in their very early stages, take the necessary steps, and supplement the plant to prevent the symptoms.
10. Weed infestation is minimal or nonexistent as a result of improved management, weed-free seeds, and weed-free culture in the hydroponics system.

Disadvantages of Hydroponics

1. Effective high competence and superior knowledge of hydroponics science and technology are necessary for system establishment and maintenance.
2. High investment is required for this technology application, whether on a small or commercial scale (Sardare, 2013).
3. Light intensity has a significant impact on the plants because it is a necessary element for their growth.
4. Limiting the flow of air will harm the roots and ultimately harm the plant.
5. Due to a lack of public awareness of hydroponics and its benefits, the market for the items may be diminished.
6. When it comes to hydroponics, the biggest challenge is the availability of electricity, which can seriously harm the crop even if it is disrupted a short time (Silva *et al*., 2021).
7. Since the hydroponics culture uses a shared fertilizer solution, waterborne infections among the plants spread quickly.
8. Several parameters, including pH, EC, and balanced nutrient levels of the solution must be maintained for optimal plant growth under hydroponics system.

9. A number of variables, including temperature, light intensity, humidity, and CO_2 concentration, should be monitored frequently in order to optimize hydroponic production in greenhouse settings.

Future trends of hydroponics

Hydroponics has emerged as a viable strategy to mitigate the impacts of climate change, which are increasingly pronounced due to alterations in global climatic patterns. The rapid growth of the global population and urbanization have intensified pressure on arable land, thereby expediting the adoption of soilless agricultural systems (Singh *et al.*, 2017). The production of fresh, nutrient-rich crops with extended post-harvest longevity offers substantial benefits for addressing global food security challenges. Moreover, hydroponic systems are recognized for their ability to achieve high crop yields within spatially constrained environments, positioning them as a critical approach to alleviating global hunger.

The importance of hydroponic technologies is anticipated to increase, particularly in extraterrestrial applications. Soilless cultivation methods provide a feasible alternative for the production of plants, including fruits, vegetables, and herbs, in interplanetary habitats where soil is unavailable and logistically infeasible to transport via space missions (Barman *et al.*, 2016).

Advancements in automation and sensor technologies are enhancing the efficiency of hydroponic systems by enabling real-time monitoring, precise environmental control, and optimized nutrient delivery. Furthermore, the integration of renewable energy sources into hydroponic operations improves sustainability by reducing reliance on conventional energy resources. Current research is also focused on the development of stacked hydroponic systems, which aim to enhance the scalability and productivity of soilless agriculture, particularly in urban environments characterized by limited spatial availability.

Conclusion

Hydroponics represents a transformative approach to modern agriculture, addressing critical challenges such as dwindling arable land, soil degradation, and the increasing global demand for food. By enabling plants to grow in nutrient-rich water solutions without the need for soil, this method offers sustainable, efficient, and innovative solutions for food production. The advantages of hydroponics such as faster growth, higher yields, and water conservation make it a promising alternative to traditional farming, especially in regions with limited resources or urban settings.

However, the technology comes with its own set of challenges, including high initial investment costs, dependency on technical expertise, and the need for meticulous environmental control. Despite these limitations, the integration of hydroponics with advanced technologies such as IoT and vertical farming is paving the way for a more sustainable agricultural future.

As the world faces the pressing issues of climate change, population growth, and resource scarcity, hydroponics has the potential to revolutionize agriculture by promoting sustainable practices and ensuring food security for future generations.

References

1. Kumar, K., Kamini, K., Tsewang, T., Tiwari, V.K., Avantika, Sahay, D., Mishra, A., Verma, A. and Acharya, S. (2022). Hydroponic Technique: A New approach for Crop Production at Trans Himalayan High-altitude Cold Desert Regions of India. *International Journal of Plant & Soil Science*. **34**(15): 43-52.
2. Sharma, N., Acharya, S., Kumar, K., Singh, N. and Chaurasia, O.P. (2018). Hydroponics as an advanced technique for vegetable production: An overview. *Journal of Soil and Water Conservation*, **17**(4): 364-371.
3. Barbosa, G.L., Gadelha, F.D.A., Kublik, N., Proctor, A., Reichelm, L., Weissinger, E., Wohlleb, G.M. and Halden, R.U. (2015). Comparison of land, water, and energy

requirements of lettuce grown using hydroponic vs. conventional agricultural methods. *International Journal of Environmental Research and Public Health*, **12**(6): 6879-6891.

4. El-Kazzaz, K.A. and El-Kazzaz, A.A. (2017). Soilless agriculture a new and advanced method for agriculture development: an introduction. *Agricultural Research Technology: Open Access Journal*, **3**(2): 63-72.
5. Domingues, D.S., Takahashi, H.W., Camara, C.A.P. and Nixdorf, S.L. (2012). Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production. *Computers and Electronics in Agriculture*, **84**: 53-61.
6. Chidiac, J. R. (2017). Shallow aggregate ebb-and-flow system for greenhouse lettuce production. M.Sc. thesis. University of Arkansas. 47 pp.
7. Mariyappillai, A., Arumugam, G. and Raghavendran, V.B. (2020). The Techniques of Hydroponic System. *Acta Scientific Agriculture*, **4**(7): 79-84.
8. Sengupta, A. and Banerjee, H. (2012). Soil-less culture in modern agriculture. *World Journal of Science and Technology*, **2**(7): 103-108.
9. Kumar, S., Vani, D. and Reddy, M. (2024). Hydroponics - The future of farming. *AIP Conference Proceedings*, **2971**(1): 040050.
10. Kumar, S., Singh, M., Yadav, K. K. and Singh, P. K. (2021). Opportunities and constraints in hydroponic crop production systems: A review. *Environment Conservation Journal*, **22**(3): 401-408.
11. Kannan, M., Elavarasan, G., Balamurugan, A., Dhanusiya, B., and Freedon, D. (2022). Hydroponic farming–A state of art for the future agriculture. *Materials Today: Proceedings*, **68**(6): 2163-2166.
12. Sardare, M.D. and Admane, S.V.A. (2013). A Review on plant without soil hydroponics. *International journal of research in engineering and technology* **2**(3): 299-304.
13. Silva, M., Huther, C.M., Ramos, B.B., Araujo, P. G., Hamacher, L. and Pereira, C.R. (2021). A global overview of hydroponics: nutrient film technique. *Revista Engenharia na Agricultura*, **29**: 138-145.
14. Singh, K., Gupta, G., and Ghangal, R. (2017). Soilless cultivation, its various types and applications in agricultural and pharmaceutical sector. *World Journal of Pharmaceutical Research*, **6**(7): 722-739.
15. Barman, N. C., Hasan, M. M., Islam, M. R., and Banu, N. A. (2016). A review on present status and future prospective of hydroponics technique. *Plant Environment Development*, **5**(2): 1-7.