

# Roles and challenges of hydroponics, aeroponics, and aquaponics in improving vegetable production: A review

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Farmers do not use chemicals and other pesticides to control pests while growing vegetables. Therefore, the main problem of vegetable production in the current situation is the misuse of drugs and pesticides, as well as the increasing cost of food production and decreasing profits. To solve this problem, farmers have used many advanced food processing methods. Hydroponics is a useful concept with many advantages; It reduces diseases and pests by allowing plants to grow in a shorter time than normal growth. Hydroponics can save 70% to 90% of water in the production of leaves and other vegetables. Another method is aeroponics, which is widely used in

agriculture around the world today. The plant is cultivated under all conditions in the growth chamber by applying a small mist of nutrient solution to the soil. The other method is aquaponics. This is a food production technology that combines today's traditional hydroponics and aquaculture to form a closed-loop system that re-circulates all water and nutrients through symbiosis and develops terrestrial plants and aquatic life. Aquaponics is a sustainable food production method that combines traditional aquaculture (growing fish in a tank) and hydroponics (growing plants in water) in a symbiotic environment. Many studies of commercial-scale hydroponic, aeroponic, and aquaponics production confirmed the ability of new technology to perform positive functions within sustainable food protection and production.

**Key Words:** *Aeroponics; Aquaponics; Hydroponics*

## INTRODUCTION

Hydroponics is a method for developing plant life in nutrient solutions (water containing fertilizers) without the usage of a soil medium but the method use sand, vermiculite, rock wool, peat moss, or sawdust to offer mechanical assistance. Liquid hydroponic structures don't have any special assisting medium for the plant roots [1]. Hydroponics is a way of developing plants in nutrient solutions (water containing fertilizers) with the use of an inert medium (sand, gravel, vermiculite, rock wool, peat moss, coir or sawdust) to offer a mechanically useful resource. Due to the higher control over nutrients, hydroponically grown plant normally has a much better yield than comparable plants grown in soil. In hydroponics, the nutrients are dissolved in water and the solution goes into the plant roots, which uptake the water with minerals. Most people's previous use hydroponic research has targeted leafy vegetables, peppers, and tomato fruit. Furthermore, hydroponics is not dependent on season of growing vegetables [2].

Aeroponics is the cutting-edge method of modern agriculture for growing plants. The majority of farmers have not used it yet. Because it uses resources that researchers can use for experimental research, it is greatly preferred. Different studies came to the conclusion that it is suitable for use in agriculture as a modern method of cultivating plants without the need for soil. Water supply pump failure, nutrient distribution line clogging, and atomization nozzle clogging are all vulnerabilities of an aeroponic system that necessitate specialized skill and attention in order to avoid harm and system failure. Additionally, employing a combination of well-thought-out agricultural practices may be an effective method for avoiding or dealing with the aforementioned problems [3]. Each small and large-scale farmer can benefit from incorporating this technique into the agriculture system which increasing productivity, taking extraordinary steps forward, and lowering costs.

An aquaponic system is an effective, innovative, and sustainable way to produce vegetable crop. It is revolutionizing agriculture in the face of drought, soil fertility losses, and climate change. Aquaponics, as an advanced aquaculture-agriculture implement, is predicted to improve food protection in growing all places. As the era progresses, there may be very limited statistics at the system in Africa. It also maps the existing spatial adoption of the era in sub-Saharan Africa and highlights the system's contribution to enhancing food safety in the continent. Egypt and South Africa are nations in which aquaponics is rising and being accompanied by faster rate and contributing to food protection. Although aquaponics systems typically have higher start-up costs today, their ability to be economically feasible when carried out with local substances could be very high [4].

## LITERATURE REVIEW

### Hydroponics growing

A plant receives its food source through the use of turning CO<sub>2</sub>, and water (or hydrogen) into carbohydrates *via* photosynthesis. Hydroponics is a method of growing vegetable without soil, so the plants must obtain their mineral from nutrient solutions added to the water. In many cases, a growing medium is used for beneficial aid and provide a useful resource in moisture and nutrient retention in hydroponics growing.

The method of growing plants without soil is known as hydroponics. At the moment, a lot of farmers are growing a lot of plants, especially vegetables that are grown this way. The Greek words "hydro" (water) and "pono" (tough work) are the source of the modified and derived term hydroponics. Since it makes it possible to use more water and minerals, as well as have more control over the climate and pests, hydroponic crop production has grown significantly in recent years. Crop productivity will rise as a result of hydroponic farming, leading to increased competitiveness and financial gain. Because they are not fighting soil-borne diseases, hydroponically grown crops can unquestionably grow faster and more healthily than soil-grown crops.

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## Aeroponic growing

The aeroponic system is one of the strategies of the soilless growing style, in which the plant grows inside the air with the assistance of artificial assistance in place of soil. The nutrient solution is provided via unique atomization nozzles without excessive air stress. Furthermore, numerous research studies considered aeroponics as a present-day agricultural interest that's practiced in an enclosed growth chamber under completely controlled conditions, as it is able to get free of the environmental factors that interfere with conventional agriculture in assessment. Choi, et al. advised that the atomization nozzle the tiny amount of the water nutrient and offers an excellent environment for the plant [5]. Lenzi, et al. stated it is far from a modern-day agricultural research system which affords several agricultural research opportunities for a researcher with huge results by using artificial growth conditions [6]. Maboko, et al. studies determined that aeroponics contributes to the advances plant root research [7]. Furthermore, research used the method to develop vegetables, fruits, herbs, and medicinal roots primarily based on plants, such as tomato, potato, soybean, maize, lettuce, *Anthurium andreaeanum*, and *Acacia mangium*.

## Aquaponics growing

Aquaponics combines two powerful structures already in widespread use: Recirculating Aquaculture Strategy (RAS) and hydroponic cultivation. Recirculating aquaculture involves the farming of fish in a tank, at the same time as hydroponic cultivation includes the cultivation of vegetables in soilless medium. Aquaponics emerges as a key technology with the capability to transform agriculture and provide food protection, especially in arid regions [8]. Aquaponics in a single shape has been practiced for centuries in numerous countries. In comparison to standard food production strategies it lack many thing and essentially practiced on small scales using human beings. The commercial-scale production practical and upgrades in design and exercise that have significantly increased both fish and crop output capacities and production efficiencies. Design and functions have transformed aquaponic structures from a water-reuse innovation into a green energy and wastewater recycling system.

## Benefit of hydroponic vegetable production

It is now possible to provide a very high yield of vegetables on a small area because a possibility of creating favorable environment for plant growth in hydroponic system. The minerals and water that the plant desires are applied at all times. This method might be very useful for areas where environmental injured places like drought, dessert, and lots of others [9]. Plants in hydroponic systems are can be cultivated year-round and brought to attention during the off season, commercial hydroponic systems are robotically operable and several traditional agricultural practices may be eliminated, which include weeding, spraying, watering, and tilling [10]. The aggravation of pests and diseases can be managed with consequences, while weeds are absent. Plant yields are better compared to traditional agriculture [11].

## The key blessings of hydroponics

This technique use water and minerals. Due to the fact that there may be a minimal risk of chemical substance loss, it may result in a reduction in land and stream pollution. Using this useful resource, plant diseases transmitted by soil can be successfully eradicated. The whole control of the climate is practical with the utilization of the framework (*i.e.*, all around planned supplement use, water system and root climate) and one of the sorts of nursery activities, where the light, temperature, moistness, and arrangement of the air might be controlled effectively easily. Plants grown hydroponically are easier to obtain than those grown using more conventional methods. Hydroponically grown crop is more palatable and higher in consumption. Plants grown in hydroponic systems may be blanketed from UV radiation in a similar way that they will be in a protected shape. With vertical hydroponic gardening, area control may be completed. For plants that are grown locally, carbon loss can be reduced [12].

## Contribution of aeroponics to enhance vegetable production

A holistic approach to agriculture's production management that promotes and enhances agroecosystems and biodiversity includes the aeroponic system. Because of how it affects the financial and technical aspects of agriculture, the system is widely known in the horticulture field. The aeroponic system, which is attracting the interest of all farmers, policymakers, marketers, and agricultural researchers, is the most effective of all agriculture systems. Chemical inputs like fertilizers, insecticides, herbicides, and other exceptional agrochemicals should be reduced by the grower. Farmers can grow a lot in rural areas thanks to aeroponic systems. The ranchers can foster a plant in their homes by getting ready counterfeit development environmental elements [13].

## Contribution of aquaponics to enhance vegetable production

Modern-day discussions on food security and sustainable food production have highlighted the "water-energy-foods nexus" approach as key to studying and handling the interactions among global beneficial aid structures. The nexus method acknowledges the interconnectedness of land, water, strength, capital, and labor and their associated drivers. An important component of the foods safety timetable in most African countries is to carry out an exercise or program that now assists food-insecure people to achieve some level of food self-sufficiency, primarily mineral safety. Fish may be very important for human minerals and fitness, and it is expected to play an important role in nutrition. Even in small quantities, fish can enhance the nutritional profiles of human diets by contributing vital amino acids that may be lacking in plant components [14].

## Key benefits of aquaponics

**Benefits for the diet:** Vegetables grown in an aquaponic system are more nutritious, energizing, and undoubtedly natural. Insecticides and weed killers do not infect fish or plants. Everything used to grow plants that produce vegetables and fruits are natural and free of chemicals. This includes fertilizers made to make an aquaponic system work better overall. Food can be grown year-round in aquaponics with the ability to change temperatures at any time. Aquaponics farmers can now cultivate herbal food without relying on the weather. There may be no need to use additional water to support plant and fish growth because the water used in an aquaponics system is constantly recycled and reused. Extended plant development: When plants have constant access to abundant nutrients and natural fertilizers, they grow at a much faster rate. A constantly regulated water supply also enhances plant growths.

## DISCUSSION

### The key challenges and difficulties of the hydroponics system

Hydroponic growing needs technical ability than developing plants in soil [15].

**Tank-farming framework spill:** Any joint or valve in your system can leak. They can also occur when the system becomes blocked, such as when an implement in the foundation becomes clogged, resulting in water backing up and overflowing. If the construction tool has a reservoir that is unable to store all of the nutrient solution, leaks may also occur. A decrease in strength or a malfunctioning pump could also cause your reservoir to overflow in this scenario. It is essential to examine the system prior to planting. Adjust any valves and check that all connections are secure and tight. If you're using a small system, you might want to set it on a tray or other water-resistant surface if you're using an indoor tool.

**Erroneous utilization of manure:** A number of the trace micronutrients that are probably necessary for healthy plant growth are not required to be present in fertilizer that is made for growing plants in soil.

**There is no monitoring or adjusting of the pH:** One of the most crucial aspects of hydroponic growth is the pH level of your nutrient solution. The soil itself acts as a pH buffer and prevents rapid pH changes as plant life develops in it.

**Toxicity and deficiency of nutrients:** Your plant life may suffer from nutrient deficiency or toxicity due to a variety of factors. There are different signs to find lack and poisonousness a few minerals and you might get better at distinguishing issues with time.

**The use of messy water in your aquaculture framework:** A hydroponics system may encounter difficulties when using difficult water, as previously mentioned. Building a badly designed tank-farming; There are many things that could make a hydroponics system more difficult to use. It can be challenging to install a system in a small space where there is not enough room to work around it or where your system is not easily accessible.

## The key challenges and difficulties of the aeroponics

Aeroponic cultivation is done under controlled conditions outside, indoors, or in a greenhouse. Chamber is sprayed with nutrient solution *via* an atomization nozzle on a regular basis; the aeroponic system offers the threat of controllability over the whole increased chamber environment exactly. The aeroponic system is the modern-day method of agriculture that continues to be under improvement. Until now, limited studies have been completed research has concluded that the implement has problem. Studies showed that aeroponics is completed without soil or any stable media; thus, the number one issues are any failure of the water pumps, nutrient solution distribution and atomization nozzle clogging, and so on, which cause the fast drying of the grown plant. Researchers advised mentioning that the aeroponic system offers higher control of the plant's growth and managing of various diseases and root rot [16].

## The key challenges and difficulties of the aquaponics

Aquaponics system is multidisciplinary approach drawing from environmental, mechanical, and civil engineering format concepts in addition to aquatic and plant-associated biology, biochemistry, and biotechnology [17]. System specifically requires information on topics related to the area of computer science for automatic control structures. This high stage of complexity necessarily demands in-depth understanding and understanding of all the involved fields. The biggest task in aquaponics is multidisciplinary, which wants further in economics, finance, and advertising and marketing. Consequently, a high degree of subject-particular insight in terms of both practical and in-depth theoretical understanding is wanted. This leads to an increasing degree of complexity, which right away affects the efficiency factors of implement. In order to achieve the highest performance and productivity, some advancement is encouraged. They encompass pH stabilization, nutrient balance, and pest management [18].

## The future scope of hydroponics, aeroponics, and aquaponics

Hydroponics, aquaponics, and aeroponics are examples of recent advancements. These methods of food production have advanced agriculture by requiring much less land and water. These systems have the ability to produce a lot of food in a small space. The plant's primary system develops in an oxygen-rich nutrient. When combined with a greenhouse, it produces a high yield despite its technological and financial demands [19]. Aqua-farming designs think about both the establishment and the airborne environmental factors: The production must take place within a structure that is controlled or regulated. Hydroponics makes aquaculture one stride further. In aquaponics, fish, snails, or crayfish are added to the hydroponic cycle through a closed loop system. The plants get their nitrogen from the aquatic animals, who then use the plants as food for the aquatic animals. Aeroponics is a method for growing plants without the use of a growing medium and little or no water [20].

## CONCLUSION

In addition to the indiscriminate use of chemical compounds and pesticides, the production of vegetables is challenging due to rising production costs and declining net profits. Mineral nutrient solutions are used in hydroponic growing structures to feed plant life in water without soil media. With the possibility of creating a favorable environment for plant growth in a hydroponic system, it is now possible to produce a large quantity of vegetables from a small area. Aeroponics is a modern agricultural practice that is carried out in an enclosed growth chamber under completely controlled conditions, according to numerous research studies. Aquaponics is a hybrid of hydroponics and aquaculture. Numerous studies of commercial-scale production of hydroponics, aeroponics, and aquaponics demonstrated that cutting-edge technology can help safeguard and produce sustainable food. Horticultural cultivating designs can be one practical chance to offer a remarkable sort of item that calls for less water, less manure, and less region so you can build the yield per unit region. The essential advantages of these high level development structures are water preservation and less or no requirement for agrichemicals, which are perilous to the human body when utilized and polished off in food. In addition, research is currently developing vegetables, fruits, herbs, and medicinal roots primarily based on plants like tomato, potato, soybean, maize, lettuce, and *Acacia mangium* using hydroponic, aeroponic, and aquaponic production methods.

## AUTHOR CONTRIBUTIONS

Nuru Seid Tehulie: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; supervision; validation; visualization; writing-original draft; writing review and editing. Fikru Mekonnen, Agegnehu Mekonnen, Ahmed Hassen, Semira Ebrahim and Solomon Abebe: Validation; visualization; writing review and editing.

## CONFLICTS OF INTEREST

The authors declare that they do not have any conflict of interest.

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