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Review Article

An overview of hydroponics on soil: A need for future generation

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ABSTRACT

The anthropogenic activities and climate change effects kjwigsu on soil and soil-based agriculture is currently experiencing problems. Additionally, unforeseen natural disasters, climate change, and the uncontrolled use of agricultural chemicals reduce soil fertility and quality. Because of this, scientists have created a brand-new alternative method of cultivation called hydroponics, also known as soilless agriculture. Plants can be grown hydroponically by being submerged in a nutrient-rich solution of water. Many different plants, crops, or vegetables can be grown with hydroponics. In general, hydroponically grown produce has superior nutritional value, flavour, and yield quality than naturally grown produce on soil. Soilless farming is becoming more and more well-liked over the world, in both developed and developing nations. It is economical, disease-free, and eco-friendly. Along with advanced space research, it offers significant potential in many nations to fill the gap left by a lack of suitable cultivable land. Therefore, hydroponics would be a superior approach to produce various fruits, vegetables, and livestock feed as well as to meet the future demand for world nutrition. Hydroponics may become an emerging approach for feeding the world's population in the future.

Keywords: Hydroponics, soilless, cultivation, emerging

INTRODUCTION

Ever-changing modern agricultural systems (rural and/or urban) around the globe and in India are becoming more and more precise addressing the constraints of resources (*viz.*, water, soil, land and energy). Hydroponics can be briefly defined as cultivation of plants without soil (Savvas, 2017). Professor William Gericke first used the term "hydroponics" in the early 1930s to refer to the practise of growing plants with their roots suspended in nutrient-rich water. Hydroponics is thought to have the largest market in Europe, in which the top three manufacturers are France, the Netherlands, and Spain, followed by the United States and the Asia-Pacific area. According to the most recent research, these systems are growing more prevalent worldwide. Additionally, producers frequently said that the greater quality of hydroponic produce was due to the highly controlled environment and more uniform production that was possible without any water or nutrient loss. Additionally, hydroponics does not depend on seasonality, thus their productivity is better and uniform throughout the year (Okemwa, 2015). Additionally, growers frequently state that hydroponic productions are simpler and lighter and cleaner due to the lack of cultural activities like weeding, ploughing, fertilising the soil, and crop rotation (Nguyen et al., 2016).

Undoubtedly, one of the most significant global sectors is agriculture, which is prone to natural disasters including

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droughts, fires, floods, and hail, is regrettably one of the most unreliable businesses. In fact, according to the U.S. Department of Agriculture, weather is to blame for 90% of all crop losses (Orsini et al., 2013). It is generally known that when agricultural output is significantly reduced, prices will rise disproportionately and overall revenue expenditure will increase. Arable area under cultivation will continue to shrink as a result of increased urbanisation, industrialization, and iceberg melting (a clear result of global warming). Once more, soil fertility has reached a saturation level, and productivity is not rising any further with greater fertiliser application levels (Sengupta & Banerjee, 2012).

Hydroponics

The art and science of soilless crop cultivation is known as hydroponics. In hydroponics, plants are grown without soil by being given nutrient-rich water solutions, which they would normally get from the soil in conventional farming. The basic goal of hydroponics is to provide the best nutritional environment for the best plant performance, which is further enhanced by regulating the climate. In traditional farming, soil serves as more than just a reservoir for nutrients; it also serves as a natural habitat for plant roots and a foundation for the construction of plants (Somerville et al., 2014). For a number of reasons, hydroponic culture continues to be of interest. First off, there is no requirement for soil and a lot of plants may be grown in a very tiny space. Second, optimal production is possible when animals are fed properly (Khan et al., 2020). Thirdly, the utmost degree of control is possible over nutrients, water, and aeration. In solid media, it's challenging to duplicate this level of control. Today, the field of agronomic research known as hydroponics is well-established (Steinberg et al., 2000).

Contrary to conventional farming, hydroponics does not use soil to grow food. This method involves growing plants on artificial or natural substrates so that the roots may easily uptake nutrients from a prepared nutrient solution. The implementation of various hydroponic farming techniques varies depending on the type of plant, regional climate, and financial constraints, among other things.

Techniques and systems of hydroponics

The following are the different types of Hydroponic systems.

- Nutrient film technique (NFT)
- Vertical system
- Media based system
- Deep water culture system
- Wicking bed system

Nutrient film technique (NFT)

In this technique, the plants are hung above the water and a thin layer of water and nutrients is flowed through a horizontal pipe or gutter. The roots consume the "thin film" of nutrients and water that they come into contact with. The nutrient film technology uses lightweight, affordable, and robust components. They are very scalable and don't need any additional pumping (Datta, 2016).

Vertical system

Hydroponic systems that allow growing of plants in a vertical fashion are known as vertical hydroponics. Vertical hydroponics works by using conventional hydroponic techniques in a vertical, gravity fed system. The nutrient-rich water is fed from the top and collected at the bottom.

Media based system

A soilless grow medium is utilised in media-based hydroponics to assist plant roots in bearing the weight of a developing plant (Domingues et al., 2012). A media-based hydroponics system can use a wide range of media, including rockwool, coco coir, expanded clay, perlite, gravel, vermiculite, growstones, and more.

Deep water culture

Hydroponics is the cultivation of plants that use water as a planting medium without using soil. One of the simplest hydroponics is Deep Water Culture (DWC). DWC is a hydroponic technique that allows plant roots to always be submerged in water containing nutrients (Saaid et al., 2013).

Wicking bed system

Wicking Beds, which allow vegetables to be irrigated from below the plant's root zone, are effectively an enclosed water reservoir (Domingues et al., 2012). It's the best approach to raise root vegetables. Contrary to popular belief, wicking beds can be used to grow any plant, including ornamental or edible plants, fruit trees, and vegetables.

Crops that can be grown in hydroponics

This strategy can be used to cultivate any type of vegetable, fruit, fodder, or grain. Flowers produce more blooms and when grown hydroponically. Because hydroponics systems are mechanized, they are well managed and superior for end product collection. Several plants, including vegetables, fruits, flowers, and medicinal crops, can be produced in soil-less or hydroponics culture. Table 1 illustrated suitable vegetables, herbs, fruits and flowers that can be grown in hydroponics system.

The benefits of hydroponics system

Surplus and scarcity

With increased urbanization, already precious land becomes even more scarce. People are not being given enough room to live in the city. Furthermore, as the population of cities grows by the day, so does the demand for food. According to Reuters' Mike Segar, "people are starving everywhere." This clearly shows the disparity between food demand and supply, emphasizing the importance of preparing for more food. In such a case, geoponics, or large-scale farming, does not appear to be a viable alternative. To combat this, some people are attempting to change to hydroponics, which has the advantage of producing food in a comparatively smaller space.

Better growth rate

If you feed a plant exactly what it needs, when it needs it, the plant will grow as healthy as genetically possible. This is especially true in hydroponics, where it is relatively easy to create an artificial habitat by adding a light or air conditioning to a space surrounded by four walls. Because the atmosphere established will be best suited

Table 1: Crops that are commonly cultivated in hydroponics system (Swain et al., 2021)

S.No.	Vegetables	Herbs	Fruits	Flowers
1	Lettuce	Basil	Strawberries	Most garden varieties
2	Beans	Thyme	Watermelon	
3	Squash	Cilantro	Cantaloupe	
4	Zucchini	Sage	Tomatoes	
5	Broccoli	Lemongrass		
6	Peppers	Wheatgrass		
7	Cucumbers	Oregano		
8	Peas	Parsley		
9	Spinach			

to the needs of the various plants, they will produce superior outcomes in terms of being fresher, greener, and tastier to consume (Qureshi, 2017).

Conservation of water

It takes only two to three litres of water to create one kilogramme of lush green feed, as opposed to 60-80 litres in the standard system.

Reduced labour cost

In conventional fodder production, continuous intensive labour is necessary for fodder cultivation, but hydroponics requires only 2-3 hours of labour every day.

Therefore it summarizes the use of hydroponic cultivation viz., Land use and environment effect, labour

Table 2: Advantages of hydroponics over soil culture

S.No	Issue	Hydroponic	soil culture	Reference
1	Land usage and effect of environment	Less affected by soil and external factors Indoor system; easy nutrient control; control of the environment such as temperature, humidity and lighting time; cultivation all year round everywhere	Unsuitable if soil is contaminated with heavy metal and plant disease; Limited by nutrients in soil; hard to control external environments; cultivation all year round is limited in certain areas	Gibeaut et al. (1997); Jones (1997); Noren et al. (2004); Norstrom et al. (2004)
2	Labor	Traditional practices are largely eliminated	Cultivating, weeding, watering, tilling and additional practices	Jovicich et al. (2003)
3	Sanitation	Easy handling of medium and all materials and maintaining sanitary conditions	Difficult to sanitize soil and equipment; hard to maintain sanitation conditions consistently	Knutson (2000)
4	Water	Efficient water usage; water can be recycled or reused; no nutrient waste due to water runoff; Water goes directly to root areas; possibility of controlling water-holding ability by using different kinds of medium	Inefficient water usage; water cannot be recycled or reused; eutrophicastion of the environment due to run-off; hard to control water-holding capacity	Güohler et al. (1989); Midmore & Deng-lin (1999)
5	Diseases and pest	Prevent soil-borne diseases; easy to control insects and animals; reducing amount of pesticide usage	Soil-borne diseases; hard to control insects and animals (loss of crop yield)	Zlnnen (1988); Jones (1997)
5	Fertilizers and nutrient solution	Even distribution to crops; efficient use of fertilizers and saving the cost; easy control of pH and amount of nutrient	Uneven distribution to crops (partial deficiency); often use of excessive amount of nutrient; high variation, hard to control pH & amount of nutrient	Rolot (1999); Resh (2013)
6	Quantity and quality of crop	Stable and even amount of production; tomato, 14–74 kg per m^2; cucumber, 6900 kg per m^2; lettuce, 5200 kg per m^2; bean, 5 kg per m^2; even quality of production	Unstable and uneven amount of production due to pests/soilborne pathogens; tomato, 1.2–2.5 kg per m^2; cucumber, 1700 kg per m^2; lettuce, 2200 kg per m^2; bean, 1.2 kg per m^2; uneven quality of production	Cornish (1992); Sarooshi & Cresswell (1994); Rolot (1999); Resh (2012)

cost, sanitation, water disease, pest, fertilizers and nutrient use, improving the quantity and quality as shown in Table 2.

Nutrients

The presence of nutrient in soil as well as hydroponic system balance nutrients is required. To provide the plant all it requires in terms of nutrients is one of the fundamental tenets of growing vegetables, both in soil and in hydroponic systems. Plant development and production require a number of chemical components. Without the use of soil, plants are grown in highly oxygenated, nutrient-rich water. The key to a good hydroponic system is fertilizer solution control (Aviles & Light, 2018; Sato et al., 2006).

Hydroponics: The hydroponic fertilizer solution is necessary to provide soluble forms of the vital mineral components, water, and oxygen to the plant roots.

Soil: Organic matter in the soil is broken down into basic nutrients via biological decomposition, providing food for plants. These nutrients are subsequently dissolved in water and taken up by the roots. Everything in the soil needs to be in ideal condition in order to give plants a balanced diet. Plants need seventeen different components in order to grow properly. Nine of these are needed in large quantities for plant growth and are referred to as macronutrients: carbon (C), hydrogen (H), oxygen (O_2), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Small amounts of the remaining eight macronutrients-Iron (Fe), Zinc (Zn), Copper (Mn), Manganese (Cu), Boron (B), Chlorine (Cl), Cobalt (Co), and Molybdenum (Mo) are also required (Sato et al., 2006; Malavolta, 2006).

Soil and hydroponics concentration level of nutrients

Different nutrients levels in soil and hydroponics as listed in Table 3.

Table 3: Comparative Concentration ranges of macronutrients (mM) in soil and soilless crops

Nutrients	Soil (mM)	Hydroponics (mM)
$N\text{-}NO_3^-$	0.5-10	5-20
$N\text{-}NH_4^+$	0.02-0.05	0.5-2
$P(H_2PO_4^-)$	0.0005-0.05	0.5-2
K^+	0.2-2	5-10
Ca^{2+}	0.5-4	3-6
Mg^{2+}	0.2-2	1-2
$S\ (SO_2^-)$	0.1-2	1.5-4

Table 4: Limitations of hydroponics system

S.No.	Limitations	References
1	High initial setup cost for supplies and continuous replacement cost for maintaining	Zekki et al. (1996);
2	Generation of waste materials and hydroponic waste solution containing high nutrients	Knutson (2000);
3	Vulnerable to power outage leading to problems in water or nutrient supply, and witheredness	Sutton et al. (2000);
4	Easy spread of phytopathogens throughout water tubing systems	Guo et al. (2002);
5	Requirement of experts to maintain the systems for optimum production	Schnitzler (2004);
6	Needs of nutrients background to controlling amounts of nutrients	Domingues et al. (2012);
7	Growth of unwanted algae and fungus in nutrient solution	Resh (2013)
8	Biofilm build-up in the system interfering nutrient uptake and reducing life span of the system	
9	Not all plants are available for hydroponic systems	

Limitations of hydroponics system

In this system initial investment, Cost availability, Balance nutrient availability, power outage, disease per plant, trained supervision although further limitations are been listed in Table 4.

CONCLUSION AND FUTURE SCOPE

Finally, hydroponics is spreading globally, and such systems provide many new chances for producers and customers to obtain high-quality outputs, such as vegetables boosted with bioactive components. Because it is feasible to develop soilless culture in extremely small spaces with little labour and in a short period of time, hydroponics can make a significant contribution to the impoverished and landless. Furthermore, it can improve people's lifestyles and a country's economic progress. The hydroponic business in India is predicted to grow at an exponential rate in the near future. To stimulate commercial hydroponic farms, low-cost hydroponic technologies that reduce reliance on human labour and lower overall start-up and operational expenses are needed.

The traditional farming system cannot currently and possibly cannot supply the world's food needs. Therefore, it is imperative to create a new agricultural strategy that encourages plants to grow more quickly. Additionally, the overuse of herbicides and insecticides has made the ground less fertile, which has forced farmers to switch to soilless farming. Rivers provide the majority of the water used for agriculture, yet as industrialization advances, toxic waste is thrown in these rivers. As a result, they get contaminated with heavy metals and other contaminants, making it impossible to use the water for conventional farming. One will therefore need to switch to hydroponics, which uses 80–90% less water.

Conflict of interest

Authors have declared that no competing interests exist.

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