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Hydroponics – A Review

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Soil based cultivation is now facing difficulties due to different man made reasons such as industrialization and urbanization. Also, sudden natural disasters, climate change and unrestricted utilization of chemicals for agriculture purposes cause the depletion of soil fertility and quality. That is why, scientists have developed a new alternative approach for cultivation system namely soil-less cultivation or hydroponics. Hydroponics is a method of growing plants in a water based, nutrient rich solution. Through hydroponics a large number of plants and crops or vegetables can be grown. The quality of yield, taste and nutritive value of end products produced through hydroponically is generally higher than the natural soil based cultivation. This cultivation is cost effective, disease free, eco-friendly and is gaining popularity all over the world, in both the developed and the developing countries. It has a great prospect in many countries along with high space research to fulfil the lack of arable land where proper cultivable land is not available. So, hydroponics would be a better technique to produce the different kinds of fruits, vegetables and fodder as well as meet the global nutrition demand with making advance future. In the future, hydroponics could be emerging techniques for the supplying of food to the world wide population.

Introduction

Hydroponics can be briefly defined as cultivation of plants without soil (Savvas, 2017). In short, hydroponics, a Greek word meaning "hydro" (water) and "ponos" (labour) is the method of growing plants in different types of substrates (chemically inert), sand, gravel, or liquid (water), in which nutrients are added, but no soil is used (Savvas, 2003; Douglas, 1975) or hydroponics is a technique of growing plants in soil-less condition with their roots immersed in nutrient solution (Maharana and Koul, 2011). The word hydroponics was coined by Professor William Gericke in the early 1930s describe the growing of plants with their roots suspended in water containing mineral nutrients. Europe is considered the biggest market for hydroponics in which

France, the Netherlands, and Spain are the three top producers, followed by the United States of America and Asia-Pacific region. These systems are becoming increasingly widespread over the world, and according to the most recent report (Jensen and Collins, 1985), it is expected to reach a world growth of 18.8% from 2017 to 2023, corresponding to a global hydroponic market USD 490.50 Million by 2023.According to growers continuous production is possible only through hydroponic systems i.e, production round the year and in a short growing period, requires less space, and plants can be produced anywhere, i.e., in a small spaces with a controlled growth environment (Hughes, 2017). Growers often reply that hydroponics always allows them to have higher productivities and yields without any constrains of climate and weather conditions (Sarah, 2017). In addition, growers often claimed that quality of hydroponic produces is superior because it uses a highly controlled environment and enables a more homogeneous production without any loss of water and nutrients. Moreover, hydroponics is not dependent on seasonality, and therefore, their productivities are higher and homogenous throughout the year (Okemwa, 2015). Growers also often report that hydroponic productions are easier, and since they do not require cultural operations such as ploughing, weeding, soil fertilization, and crop rotation, they are light and clean (Nguyen *et al.,* 2016).

It is also necessary and effective to control nutritional solutions and take daily measurements of liquid nutrients to avoid excess salinization and control microbial diseases and pests to avoid any loss of production (Barbosa *et al.,* 2015). Nonetheless, growers often argue that this technique allows the possibility to grow healthier food and helps in the reduction of wastes. An example of this waste reduction can be seen in lettuce, the most hydroponically cultivated crop in the world, in which about 99% of their hydroponic leaves are valid and they can be sold to a value approximately of 40% more expensive than a lettuce grown traditionally (Barbosa *et al.,* 2015). Moreover, with hydroponics, there is a better opportunity to place the fresh produces in the market since their average nutritional quality and consumer's acceptance are higher (Mehra *et al.,* 2017). In addition, growers reported that with hydroponics, some of the negative impacts of conventional agriculture are avoided including high and inefficient use of water, large land requirements, high concentrations of nutrients and pesticides, and soil degradation accompanied by erosion (Treftz and Omaye, 2016; Horrigan *et al.,* 2002). Worldwide consumers are increasingly interested in having more environment-friendly fresh vegetables due to the strong and well-established inverse relationship between vegetable consumption and the risk of many types of chronic and degenerative diseases like cancer, cardiovascular, and neurological disorders (Kris *et al.,* 2002). Due to this increasing consumer interest, the content of health-promoting compounds is becoming a vital consideration for fruit and vegetable growers. These beneficial compounds can be influenced by several key factors including environmental conditions (light, temperature, humidity, atmospheric CO2). Contrary to the conventional agricultural system, hydroponic relies on the manipulation of nutrients, which according to different authors allows having produces with high accumulation of some beneficial nutrients (Sgherri *et al.,* 2010; Buchanan and Omaye, 2013) (Table 1).

Hydroponics for vegetable and fruit production

Food security started to be more important as witnessed by higher demand of hygienic food than production. Global warming and climate change like drought, heavy rain, flood, high temperature, pests etc. cause many impacts on plants. Determination of natural resource, soil fertility and quality of water induce hydroponic vegetable production more than traditional soil grown. For certain crops such as temperate lettuce and herbs that are normally imported and for some other popular food crops, farmers prefer hydroponic technique to conventional cultivation method (Wattanapreechanon and Sukprasert, 2016).

Quality improved by hydroponics

Consumption of Fruits and vegetables highly decrease the rate of risk of many types of chronic disease in human (Giovannucci *et al.,* 2002; Dorais *et al.,* 2008). Several bioactive compounds or nutrients like beta-carotene, antioxidants present in the vegetables have beneficial effects for health status. So, it is possible to increase the health promoting compounds and improve the quality of fruits and vegetables by using green technique such as hydroponics. It is intensively used to control the environment and to avoid uncertainties in the water and nutrient status of the soil in the protected agriculture. The controlled light and temperature can also change the nutritional quality of fruits and vegetables.

A significant difference has been seen in quality of yield between hydroponically and conventionally grown lettuces (Murphy *et al.,* 2011). The taste and acidity, carotenoids and vitamins in tomatoes were better in hydroponic systems (Gruda, 2009). It was found that thirty percent more yield of tomatoes in a mixture of 80% pumice + 10% perlite + 10% peat medium in comparison to the soil (Mastouri *et al.,* 2005). Tomatoes grown hydroponically were considered softer and tastier than the traditional cultivation.

Crops grown on soil-less or hydroponics culture

It is practically feasible to grow any kinds of vegetables, fruits, fodder or crops using this technique. Flowers give a better bloom and colour when grown hydroponically. Hydroponics system might be automated, that is why it is well controlled and better for end product collection. Several plants including vegetables, fruits, flowers, medicinal crops can be grown using soil-less or hydroponics culture (Sardare and Shraddha, 2013).

Fodder production under hydroponics

Growing of plants without soil but in water or nutrient solution in a greenhouse (hi-tech or low cost devices) for a short duration(approx. 7-8 days) is hydroponics fodder Production. In India, maize grain is preferred over other cereal grains for hydroponics fodder production. The hydroponics fodder has more health benefits due to its palatability, easily digestibility and nutritious. Hydroponics fodder can be produced by the farmers for feeding their dairy animals using low cost devices in those situations where conventional green fodder cannot be grown successfully (Ramteke *et al.,* 2019).As per the 19th Livestock census 2012, the livestock population of the country is 529.70 million including 199.08 million (37.59%) cattle, 108.7 million (19.89%) buffaloes, 71.56 million (13.51%) sheep, 140.54 million (26.54%) goats and 11.00 million Pigs. The growth rate during last 56 years (1951-2007) shows increasing trend in cattle (28.19%), buffaloes (142.72%), sheep (83.02%) and goat (197.76%) and the overall growth rate in livestock is 80.91% (GOI, 2012). The increase in the livestock population along with the intensive rearing system has resulted in the increase demands for feeds and fodder in the country.

Table.1 Main types of hydroponic systems and their respective characteristics, according to growers, farmers and researchers (Okemwa, 2015; Nguyen *et al*., 2016; Lopes *et al*., 2008)

Hydroponic system	Description
Deepwater culture (DWC)	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. Plants are placed in net pots and roots are suspended in nutrient solution where they grow quickly in a large mass. It is mandatory to monitor the oxygen and nutrient concentrations, salinity and pH (Domingues *et al*., 2012) as algae and moulds can grow rapidly in the reservoir. This system work well for larger plants that produce fruits especially cucumber and tomato, grow well in this system.
Drip system	In this system, the nutrient solution is set apart in a reservoir, and the plants are grown separately in a soilless medium. Water or nutrient solution from the reservoir is provided to individual plant roots in appropriate proportion with the help of pump (Raphael and Colla, 2005). Drip systems dispense nutrients at a very slow rate, through nozzles, and the extra solutions can be collected and recirculated, or even allowed to drain out. With this system, it is possible to simultaneously grow several kinds of plants.
Ebb and flow	This is first commercial hydroponic system which works on the principle of flood and drain. This system utilizes a grow tray and a reservoir that is filled with a nutrient solution. A pump periodically floods the grow tray with nutrient solution, which then slowly drains away. it is possible to grow different kinds of crops but the problem of root rot, algae and mould is very common (Nielsen *et al*., 2006) therefore, some modified system with filtration unit is required.
Nutrient film technique (NFT)	NFT was developed in the mid1960s in England by Dr. Alen Cooper to overcome the shortcomings of ebb and flow system. Similar to aeroponics, the nutrient film technique (NFT) is the most popular hydroponic system. In this method, a nutrient solution is pumped constantly through channels in which plants are placed (Domingues *et al*., 2012). When the nutrient solutions reach the end of the channel, they are sent back to the beginning of the system. This makes it a recirculating system, but unlike DWC, the plants roots are not completely submerged, which is the main reason for naming this method NFT.
Wick system	This is simplest hydroponic system requiring no electricity, pump and aerators (Shrestha andDunn, 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 is supplied to plants through capillary action. This system works well for small plants, herbs and spices.

The feed scarcity has been the main limiting factor in improving the livestock productivity (Brithal and Jha, 2005). The land allocation for cultivation of green fodder is limited to only 5% of the gross cropped area; but at present, India would require a total 526, 855 and 56 million tons of dry matter, green fodder and concentrates. The unavailability of quality green fodder adversely affects the productive and reproductive efficiency of the livestock. The less availability of land, more time for harvesting, more labour for cultivation, non-availability of same quality around the year, requirement of manure and fertilizer; the uncertainty of rain fall, water scarcity and natural calamities due to climate change are the major constraints for green fodder production encountered by the livestock farmers. Due to the above constraints the hydroponics technology is coming up as an alternative to grow fodder for farm animals and is an effective solution for fodder scarcity and is a very promising technology for sustainable livestock production in different regions of india (Naik, 2012; Naik *et al.,* 2013).

Advantages of hydroponics over the traditional farming method

Surplus and scarcity: With more and more urbanization, the already scarce land is getting scarcer. People are not getting an adequate amount of space to stay in the city. Additionally, as the population of cities is increasing day by day the demand for food is growing. Mike Segar from Reuters has even termed this as “People are hungry everywhere.” This clearly signifies the gap between the demand and supply for food and brings out the most important fact of arranging for more food. In such an instance, geoponics, i.e. farming with lots of lands does not seem a viable option. Thus, to curb these people are trying to shift to hydroponics with the advantage of growing crops in a comparatively smaller space.

Farming at heights: Farming at heights means that less space is used to generate a high amount of outputs. This is possible via the fact that hydro farms extended vertically in even places such as marginal lands, inside warehouses, water scarce areas. This is not possible with geoponics for obvious reasons and thus if comparing both the situations then it can be evident that per cubic feet of hydroponics generates more output turning out to be more profitable and fruitful (Goenka, 2018).

Pesticide free: In geoponics, farmers generally use fertilizers and pesticides for improving the crop quality that makes the produce un-organic, medicated and not of the best quality. In hydroponics, this problem does not pop up. This is because there is no need for the farmer to add any kind of fertilizer to the nutrient-rich water the crop extracts the required minerals, also it has been proven that hydroponically greens are better to taste. Thus, it is another aspect in which hydroponics wins over geoponics (Goenka, 2018).

Better growth rate: If you give a plant exactly what it needs and when it needs, the plant is likely to grow as healthy as genetically possible. In hydroponics, this is exactly the case as it is very much possible to create an artificial environment with the addition of a light or air conditioning in an area enclosed between four walls. As the environment created will be suited best according to the different plant's needs, they will give better results in terms of turning out to be fresher, greener and tastier to eat (Qureshi, 2017).

Conservation of water: it requires just 2- 3 litres of water to produce one kg of lush green fodder, as compared to 60-80 litres to conventional system of fodder production.

Reduction in growth time of green fodder: For obtaining nutritious fodder only 7 days are required from seed germination to fully grown plant of 25–30 cm height and also biomass conversion ratio is as high as 7-8 times as compared to traditional fodder grown for 60-80 days.

Increasing nutritive value of fodder: Through hydroponics nutritive value of the fodder can be increased by adding additional growth promoters, nutrients, etc. to have quality milk from the dairy animals.

Fodder quality: The crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and Ca content increased, but organic matter (OM) and non-fibrous carbohydrates (NFC) content decreased in the hydroponic green forage compared with the conventionally produced green forage. (Abdullah, 2001; Fazaeli *et al.*, 2012; Kide *et al.*, 2015; Mehta and Sharma, 2016). Hydroponic fodder is a rich source of vitamin A, vitamin E, vitamin C, thiamin, riboflavin, niacin, biotin, free folic acid, anti-oxidants like β-carotene (Finney, 1982; Cuddeford, 1989; Naik *et al.*, 2015) and minerals (Bhise *et al.*, 1988; Chung *et al.*, 1989; Fazaeli *et al.*, 2012). Shipard (2005) and Naik *et al.*, (2014) found that hydroponic fodder is also a rich source of bioactive enzymes (Bakshi *et al.*, 2017).

More palatability: Hydroponically grown fodder is more succulent, palatable and nutritious as compared to conventionally grown fodder and this results in more milk and meat production (Ramteke *et al.*, 2019).

Reduced labour requirement: Continuous intense labour for cultivation of fodder is required in conventional fodder production, but in hydroponics labour required is 2- 3 hours / day only.

Future prospect

Hydroponics technique presents a “new” door of science helping more crop production for food, fodder and ornamental use as well as produce improved yield quality (Putra and Yuliando, 2015). Hydroponics can produce high yield of local crops, such as leafy vegetables or flowers in the over-populated areas. If it is possible to modernize the hydroponics technique, all plants and crops can be cultivated through all over the world. Hydroponics canfeed millions in areas of Asia and Africa, where water, land and crops are insufficient. Thus, hydroponics gives the ray of hope for the management of crop and food production (Maharana and Koul, 2011). Japan has started hydroponics technique for rice production to feed the people (De Kreij *et al.*, 1999). Israel grows large quantities of berries, citrus fruits and bananas in the dry and arid climate through hydroponics technique (Van Os, 2002). To speak the truth, hydroponics technique can be a versatile knowledge in both rural or town and high-tech space stations. Hydroponics can be a proficient practice for food cultivation from adverse environmental ecosystems such as mountainous regions, deserts or arctic communities. Currently, demand of hydroponics cultivation has been increased, in all the developing and developed countries (Trejo-Téllez and Gómez-Merino, 2012). So, government should make public policies and give subsidies for such production systems.

In conclusion the hydroponics is extending worldwide and such systems offer many new opportunities for growers and consumers to have productions with high quality, including vegetables enhanced with bioactive compounds. As it is possible to cultivate soil-less culture in very low spaces with low labour and short time, so hydroponics can play a great contribution for the poorer and landless people. Besides, it can improve the lifestyle of people and enhance the economic growth of a country. In India, the hydroponic industry is expected to grow exponentially in near future. To encourage commercial hydroponic farm, it is important to develop low cost hydroponic technologies that reduce dependence on human labour and lower overall start up and operational costs.

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