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Soilless cultivation-hydroponic techniques: A review

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Abstract
In the present scenario, soil based cultivation is now facing difficulties due to different problems such as industrialization, urbanization and nematode related problems. Nature's calamities, such as low rainfall, climate change and the use of chemicals for horticulture crops cause the depletion of soil fertility as well as poor quality produce. Horticulture scientists have developed a new technique, which is an alternative approach to soil cultivation called hydroponics. Hydroponics or soilless cultivation is a method of growing plants without soil in water based nutrient solution. In hydroponics, a large number of plants and crops can be grown in any season throughout the year. The quality of yield, taste, and nutritive value of crop produced hydroponically is higher than that of soil-based cultivation. Soil-less culture is becoming more relevant and appropriate in the present scenario, to cope-up with all these challenges. Soil-less culture is becoming more relevant and appropriate in the present scenario, to cope-up with all these challenges. In hydroponics, plants are raised without soil and every plant is supplied with specific nutrients as per their requirement. Improved space and water conserving methods of food production under soilless culture are showing promising results all over the World.

Keywords: Hydroponics, industrialization, soil fertility, water

Introduction
Hydroponics can be briefly defined as the cultivation of plants without soil. The hydroponics word is taken from the Greek language "hydro" means water and "ponos" means labour, *i.e.* the working water. In this method of growing plants in different types of substrates (chemically inert), sand, gravel, or liquid (water), nutrients are added, but no soil is used (Savvas, 2003) [32]. The hydroponics is the technique of growing plants in soil-less conditions with their roots immersed in nutrient solutions (Maharana and Koul, 2011) [16]. Hydroponics was coined by Professor William Gericke in 1930 and describes growing plants roots suspended in water containing mineral nutrients.

Europe is one of the biggest markets for hydroponics, in which France, Netherlands and Spain are leading countries, followed by the USA and some Asian countries. This technique is growing day-by-day and expected to grow by 18.8% from 2017 to 2023. The growers can grow crop production throughout the year, in any season, through hydroponic systems with a controlled growth environment (Hughes, 2017) [12]. Growers often reply that hydroponics helps them to take higher productivity and yields without any constraints of climate and weather conditions (Sarah, 2017) [30]. In addition, growers often claimed that the 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 the seasonality, fertility of the soil (Okemwa, 2015) [26]. 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 (Nguyen *et al.*, 2016) [24]. In India, hydroponics was introduced in 1946 by, W. J. Shalto Duglas and he established a laboratory in Kalimpong area of West Bengal. He has also written a book on Hydroponics, named as Hydroponics. During the 1980s, many automated and computerized hydroponics farms were established in the world.

The consumption of fruits and vegetables decrease the rate of risk of many chronic disease in human (Giovannucci *et al.*, 2002; Dorais *et al.*, 2008) [10, 7]. Several bioactive compounds or nutrients like Vitamins-A, Vit-B and Vit-C, beta-carotene and antioxidants present in the fruit and vegetables have beneficial effects for human health. So, it is possible to increase the health promoting compounds and improve the quality of fruits and vegetables by growing through hydroponics.

Hydroponics technique helps us to grow horticulture crops where land and climatic condition are not suitable for soil cultivation. The controlled light and temperature can also improve the nutritional quality of fruits and vegetables. A significant difference has been reported in quality of yield, taste, carotenoids and vitamins in lettuce and tomato between hydroponically and conventionally (Murphy *et al.*, 2011 and Gruda, 2009) [19, 9]. It was discovered that soilless tomato yield thirty percent more than soil tomatoes (Mastouri *et al*., 2005) [17]. Tomatoes grown through hydroponically were softer and tastier than the soil cultivation.

Crops grown in soil-less or hydroponic culture

It is practically possible to grow different types of vegetables, fruits, leafy crops using these hydroponics. Flowers can produce better bloom and color when growing hydroponically. Hydroponics system might be automated and it is well controlled and better for quality. Several plants including vegetables, fruits, flowers, medicinal crops can be grown using soil-less culture (Sardare and Shraddha, 2013) [31]. The major six types of hydroponics (Lopes *et al*., 2008; Okewa, 2015; Nguyen *et al*., 2016) [13, 28, 25] are:

1. Deep Water Culture System (DWC)

In this system, the plants are suspended in aerated water. DWC is one of the easiest and most popular methods of hydroponics. A DWC system consists of pots holding plants over a deep reservoir of oxygen-rich nutrient solution. The plant's roots are submerged in the solution, providing it access to nutrition, water, and oxygen. The proper water oxygenation is vital for plant survival. If not enough oxygen is supplied to the plant's roots, the plant will drown in the solution. Add an air stone connected to an air pump at the bottom of the reservoir to supply oxygenation to the entire system. The bubbles from the air stone will also help circulate the nutrient solution. It is mandatory to monitor the oxygen, nutrient level, salinity and pH (Domingues *et al*., 2012) [6]. This system is mainly for cucumber and tomato.

2. Wick System

In a wick system, plants are snuggle in growing media on a tray that sits on top of a reservoir. This reservoir container solution filled with dissolved nutrients. Wicks travel from the reservoir to the growing tray. Water and nutrients flow up the wick and saturate the growing media around the root systems of the plants. These wicks can be made of material as simple as rope, string, or felt. Wick systems don't require mechanical parts like pumps to function. This makes it ideal for situations where electricity is either unreliable or unavailable. Wicks systems work by a process called capillary action. The wick absorbs the water like a sponge. Cocopeat has excellent moisture retention and having pH neutral. Similar character is also shown by Perlite and vermiculite possesses a high cation-exchange capacity. Wick systems work quite slowly.

3. Nutrient Film Technique System (NFT)

Nutrient film technique (NFT) systems suspend plants above a stream of continuously flowing nutrient solution that washes over the ends of the plant's root systems. The channels holding the plants are tilted, allowing water to run down the length of the grow tray before draining into the reservoir below. The water in the reservoir is then aerated via air stone. A submersible pump then pumps the nutrient-rich water out of the reservoir and back to the top of the channel. In this method, a nutrient solution is pumped constantly through channels in which plants are placed (Domingues *et al*., 2012) [6].

4. Ebb and Flow System

This is the 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) [25].

5. Drip System

In drip 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. 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. It is possible to grow several kinds of plants through this system.

6. Aeroponics

In this, the roots of the plant extend only in air and the roots are directly sprayed with a nutrient water mix. The primary difference is the availability of oxygen to the roots. In aeroponics, oxygen is surrounding the roots at all times. The surplus oxygen accelerates nutrient absorption at the root surface. For aeroponics, the roots dangle directly in the air and the nutrient salts are mixed with water and sprayed as a vapor directly onto the roots.

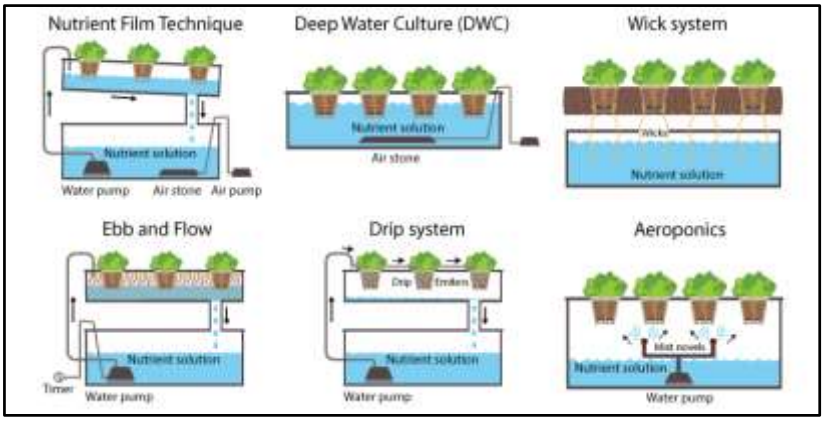

Fig 1: Different types of Hydroponics System

Major Crops grown in Soilless Media

Type of Crops	Name of the crops
Fruits and Vegetables	*Fragaria ananassa* (Strawberry), *Solanum lycopersicum* (Tomato), Capsicum *annum* (Chilli), Brassica oleracea var. capitata (Cabbage), *Cucumis sativus* (Cucumbers), and *Lactuca sativa* (Lettuce).
Condiments	*Petroselinum crispum* (Parsley), *Mentha spicata* (Mint), *Ocimum basilicum* (Sweet basil)
Flower and medicinal plants	*Tagetes patula* (Marigold), *Rosa berberifolia* (Roses), *Dianthus caryophyllus* (Carnations), *Chrysanthemum indicum* (Chrysanthemum)

Supply of nutrients to the plants

Two aspects of nutrition need to be considered: the supply of nutrients from the nutrient delivery system and the plant nutrient response. For most common crop plants critical levels for most nutrients have been determined. The frequency and volume of the nutrient solution applied depends on the type of substrate used (volume and physical-chemical characteristics), the crop (species and stage of development), the size of the container, the crop and irrigation systems used and the prevailing climatic conditions. Plants should be fed daily. The best time to administer the nutrient solution is between 6.00 and 8.00 am, though water requirements will vary considerably throughout the day, and from one day to another. The solution should be applied to the roots, trying to avoid wetting the leaves to prevent damage and the appearance of diseases. Under no circumstances should plants be allowed to suffer from water stress, as this will affect their final yield. It is generally recommended that you apply only water to the plants once a week, in order to flush away any excess salts that have remained. Use double the amount of water normally applied, but without adding nutrients. Between 20 and 50% of the solution should be drained-off to prevent the accumulation of toxic ions and an excessive increase of electrical conductivity in the root area. The excess nutrient solution that is drained away from containers during daily watering can be reused in the next watering.

Desirable pH Range of Nutrient Solutions

In hydroponic systems, pH is constantly changing as the plant grows. Changes in pH of less than 0.1 unit are not significant. Thus pH control is a necessity in hydroponic solutions. The pH range of 5.5 to 6.5 is optimal for the availability of nutrients from most nutrient solutions for most species, but species differ significantly and several can grow well outside of this range.

Control of Contaminants

Maintenance of a sterile root-zone environment is essential to have good plant vigour under soil-less culture. It is extremely difficult to achieve and critical to minimize population of plant pathogens in the root zone. Commonly encountered disease in hydroponic solution is wilt, caused by Fusarium and Verticillum. Species of Pythium and Phytophthora destroy all but the main roots. No effective fungicides are there which can be safely used in hydroponics. Only Metalaxyl has been found highly effective for the control of Pythium on vegetable crops, but it is not registered for use. Heat treatment of nutrient solution has also been found effective in keeping the root-zone free of pathogens. Root death of tomatoes by Pythium was overcome by heating nutrient solutions at 20-22 °C. In aeroponic system with a heated nutrient solution, the roots of ginger plants matured faster and produced slightly higher fresh rhizome yields than plants in the same medium without bottom heat.

Advantages of hydroponics over the traditional 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 land 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.

Higher Production: The crop grown through hydroponics always produce higher yield than soil cultivation. This can be grown in any season and soil conditions etc.

Farming at heights: Farming at heights means that less space is used to generate a high amount of output. 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 situations then it can be evident that per cubic feet of hydroponics generates more output turning out to be more profitable and fruitful.

Pesticide free: In geoponics, farmers generally use fertilizers and pesticides for improving the crop quality which 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.

Better growth rate: If you give a plant exactly what it needs and when it needs, the plant is likely to grow as healthy. In hydroponics, this is exactly the case as it is very much possible to create an artificial environment with the addition of 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.

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; Mehta and Sharma, 2016) [1, 8, 18]. 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) [9, 5, 23] and minerals (Bhise *et al.,* 1988; Chung *et al.,* 1989; Fazaeli *et al*., 2012) [3, 4, 1] and Naik *et al.,* (2014) [20] found that hydroponic fodder is also a rich source of bioactive enzymes (Bakshi *et al.,* 2017) [2].

More palatability: Hydroponically grown fodder is more succulent, palatable and nutritious as compared to conventionally grown fodder. The hydroponically crop obtains proper nutrient levels as compared to normal cultivation.

Limitations of Soil Culture

Despite of many advantages, soil–less culture has some limitations. Application on a commercial scale requires technical knowledge and high initial investment, though returns are high. Considering the high cost, the soil-less culture is limited to high value crops. Great care is required with respect to plant health control. Finally, energy inputs are necessary to run the system.

Future Prospects

Hydroponics is the fastest growing sector of agriculture, and it could very well dominate food production in the future. As the population increases and arable land declines due to poor land management, people will turn to new technologies like hydroponics and aeroponics to create additional channels of crop production. In Tokyo, land is extremely valuable due to the surging population. To feed the citizens while preserving valuable land mass, the country has turned to hydroponic rice production. The rice is harvested in underground vaults without the use of soil. Because the environment is perfectly controlled, four cycles of harvest can be performed annually, instead of the traditional single harvest.

Hydroponics also has been used successfully in Israel which has a dry and arid climate. A company called Organic Tech has been growing crops in 40-foot long shipping containers, using hydroponic systems. They grow large quantities of berries, citrus fruits and bananas, which can’t grow normally in Israel's climatic conditions. The hydroponics techniques produce a yield 10 times greater than the same sized area of land could produce annually. This process is completely automated, controlled by robots using an assembly line-type system, such as those used in manufacturing plants. The shipping containers are then transported throughout the country. Though the upfront capital costs of setting up hydroponics systems are currently a barrier but in the long-run, as with all technology, costs will decline, making this option much more feasible. Hydroponics has the ability to feed millions in areas of Africa and Asia, where both water and crops are scarce. Hydroponics also will be important to the future of the space program. NASA has extensive hydroponics research plans in place, which will benefit current space exploration, as well as future, long-term colonization of Mars or the Moon. As we haven't yet found soil that can support life in space, and the logistics of transporting soil via the space shuttles seems impractical, hydroponics could be key to the future of space exploration. The benefits of hydroponics in space are twofold: It offers the potential for a larger variety of food, and it provides a biological aspect, called a bio-regenerative life support system. This simply means that as the plants grow, they will absorb carbon-dioxide and stale air and provide renewed oxygen through the plant's natural growing process. This is important for long-range habitation of both the space stations and other planets.

Conclusion

The industry is expected to grow exponentially in future, as conditions of soil growing becoming difficult. In country like India, where people are moving towards urban each day, there is no option but adopting soil-less culture to help improve the yield and quality of the produce for upcoming challenges. However, Government intervention and Research Institute can give the exact efficacy the use of the hydroponics technique.

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