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Hydroponics : An upcoming and innovative way of future farming

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ABSTRACT

Agriculture needs to be capable of supporting the world's entire population. Due to accelerated urbanization and industrialization as well as other manmade and natural factors, the fraction of cultivated and arable land continues to decrease. At the same time, the population of the world continues to increase steadily. In 1960, each hectare of arable land fed about 2 people, however presently every hectare of land needs to feed 4 and by 2050, it is expected to feed 6.25 people. Thus, as population increases the same patch of land is expected to feed more and more people because of these twin factors. These circumstances predict a very difficult tomorrow under the current paradigm of open field system of agricultural production. In near future it likely will become impossible to feed the world population.To match this ever increasing agricultural demand, it is often assumed that abundant water and soil and copious sunlight are required, which directly translate into more productive farming. While this has been sufficiently true for most of human history, several newer and better technologies have proven that this is certainly not necessarily true in modern day. Specifically, it is understood that soil is not a needed component of successful agriculture. Moreover, plants don't actually need true sunlight, but a mere slice of the whole spectrum. New research and its application have shown that the true requirements are actually are quality seeds, water and nutrients. Improved space and water conserving methods of food production under soil-less culture have shown some promising results all over the world. It is on this idea that hydroponics and aeroponics have become more relevant in the present scenario.

Key words – *Aeroponics, hydroponics, nutriculture, open field agriculture, soil-less culture*

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INTRODUCTION

While there has been a near continuous increase in fertility of soil until now, currently, this soil fertility increase has stagnated. This is due to a saturation effect, where further application of fertilizers only produces a marginal and diminishing return in productivity. Moreover, certain cultivable areas see poor soil fertility due to continuous cultivation which does not allow the soil to build-up its fertility over time due to growth of natural microbes. Further causes in decrease of productivity include natural phenomena such as repeated drought conditions and unpredictable nature of climate and weather as well as human caused pollution of rivers and other sources of water due to poor water management and wastage of a large quantity of water causing groundwater level decline [1-2].

Conventionally, soil has been the only and thus most ubiquitous medium for growing plants while providing the dual role of anchorage as well as supplying nutrients and water to the plants allowing for successful plant growth. This dependency on soil, however, causes inherent problems such as the constant presence of disease causing organisms and nematodes. Moreover the soil may be unsuitable or unfavorable to the plant in cultivation.

More correctable and preventable problems such as soil compaction and poor drainage may also occur and degradation due to erosion causes an avoidable decrease in fertility. Evidently, soils pose serious limitations for plant growth in general causing farmers to face difficulty due to the tradeoff between large space requirement or reduction in plant growth and thus productivity. Currently, it is difficult to hire manpower for open field agriculture. These problems are mitigated to a large extent due to the introduction of hydroponics and aeroponics, both of which are soilless cultures [3-5].

The word hydroponics comes from hydro meaning water, and ponos meaning labour. Hydroponics thus, is the growing of crops in any medium containing nutrients, be it solid or even liquid but without soil. The medium can be anything from a mineral nutrient solution or some inert substrate such as gravel, sand, wool or perlite or even rice husks. In contrast, aeroponics uses a fine mist of liquid nutrient solution instead of a solid or liquid medium but it is otherwise very similar to hydroponics. Without the disadvantages of soil, the benefits of vertical farming may truly be leveraged for more efficiency with the same amount of land. This is because this type of farming allows for plants to be grown in layers or shelves with one layer over another. A number of these layers may be stacked over one another and thus growth can occur in the vertical dimension.

Hydroponics is not new to India, having been introduced in 1946 by W. J. Sholto Douglas. The earliest modern reference for hydroponics (in the last 100 years) was a man named William Frederick Gericke. Dr. W. F. Gericke in 1936 from the University of California was the first person to carry out large-scale commercial experiments in which he grew tomatoes, lettuce and other vegetables. While working at the University of California at Berkeley he began to popularize the idea that plants could be grown in a nutrient solution and water instead of soil. Naturally, the general public, as well as William's colleagues, questioned this claim. They were quickly shown to be wrong when they saw the growth of very tall tomato plants using only water and nutrients. He decided to call this growing method of hydroponics. The shocking results of Gericke's experiment with tomatoes prompted additional research in the field. Then there were further investigations by the University of California in which scientists discovered a lot of benefits related to the cultivation of soilless plants. Hydroponics was also applied during World War II between 1939 and 1945 in order to provide plants for the troops (in arid soils and in Greenland). Currently NASA uses the hydroponics technique to provide food for space travelers. Later on during 1960s and 70s, commercial hydroponics farms were developed in Abu Dhabi, Arizona, Belgium, California, Denmark, German, Holland, Iran, Italy, Japan, Russian Federation and other countries. During 1980s, many automated and computerized hydroponics farms were established around the world. Home hydroponics kits became popular during 1990s.

Following are the objectives of this research paper:

1. To discuss different available techniques for soil-less culture
2. To review the current methods for hydroponics
3. To discuss the benefits and disadvantages of soil-less culture over conventional open agriculture
4. To review the potential for growth of hydroponics in India

RESEARCH METHODOLOGY

This Research Paper is created on the basis of research journals, books, websites and various reports with the help of secondary data. This study reviews the current material related to hydroponic/soil-less culture techniques. The present study is of analytical and exploratory nature using available literature.

DISCUSSION [6-12]

Benefits of hydroponics

1. In hydroponics, healthiest crops are produced with high yields per unit area .Using nutrient solutions, artificial lights, heaters and other pieces of equipment, plants can be made to develop faster, produce larger yields and grow all year round.
2. The conservation of water is the biggest advantage of hydroponics compared to the common crops. Water can be recirculated in hydroponics allowing unused water to be recycled back into a reservoir, ready for use in the future. Plants only use about 10% of the water compared to the uses by a normal farm crop.

3. The amount of nutrients that are to be given to plants can be controlled thereby reducing the cost of nutrition. As it is a closed system, nutrients are not allowed to flow out with water. An efficient hydroponic farm uses only 25% of the fertiliser compared to a traditional open agricultural system. This also prevents eutrophication due to growth of aquatic plants (like algae) in excess on rivers and lakes caused by accumulation of fertilizer and plant nutrients leached into river water.
4. Hydroponic crops are least affected by the environment and plants can therefore, be grown closer to consumers, reducing transport emissions and providing people with fresher goods.
5. Less occurrence of pests and diseases in hydroponic system of planting and it is much easier to treat them. There is no chance of soil-borne insect pest, disease attack and weed infestation. Soil pests are non-existent, and in enclosed greenhouses natural predators can be used to control insect pests and no pesticide is required.
6. Nutrients are fed directly to the roots; as a result plants grow faster with smaller roots.
7. Crop growing is clean and extremely easy.
8. Less space is required (higher density planting) for growing plants in hydroponics.
9. Farmers do not need to worry about exhausting their fields of certain nutrients through growing the same crop over and over – there is no need for crop rotation, so in-demand crops can be focused on.

LIMITATIONS OF HYDROPONICS

Despite of many advantages, hydroponics has some limitations.

1. Technical know-how for growing crops in hydroponics on commercial scale is required which is either not easily available or costlier.
2. It requires high initial investment
3. Due to high cost, only high value crops are grown in hydroponics for high net returns.
4. High energy inputs are necessary to run the system.

Techniques for soil-less culture

a. Factors for selection of suitable techniques for hydroponics

The selection of a viable technique for application of hydroponics is crucially dependent on many different factors. We have large numbers of hydroponics culture techniques are available but these factors need to be considered before selecting a suitable technique.

1. Availability and Cost of space and other related resources
2. Availability of suitable growing medium.
3. Expected yield for profitability.
4. Expected productivity from the current method.
5. Quality expected from the application of hydroponics including crop size, colour and appearance

b. Classification of techniques

We can classify the techniques as follows:

1. Liquid Hydroponics: In liquid hydroponics, only a mineral solution is used for carrying the minerals to the plant. The nutrient solution may be flowing or stagnant or passive. The solution also must contain inorganic and organic substances to replace the soil nutrients

a. Circulating methods (closed system)/ Continuous flow solution culture
- Nutrient film technique (NFT)
- Deep flow technique (DFT)

b. Non-circulating method (open systems)/ Static solution culture
- Root dipping technique
- Floating technique
- Capillary action technique

2. Media culture: In medium culture method a solid medium is used or the anchoring of roots. The culture is usually named after the inert medium. The media used can be abiotic like sand, gravel, rock or biotic like rice husk, wool or coir. There are two main variations for each medium, sub-irrigation and top-irrigation. However, it is classified as follows:

1. Hanging bag technique
2. Grow bag technique
3. Trench or trough technique

4. Pot technique

LIST OF CROPS THAT CAN BE GROWN IN SOIL-LESS CONDITION

Table1. List of crops that can be grown on commercial level using hydroponic technique

Type of crops	Name of the crops
Cereals	Rice, Maize
Fruits	Strawberry
Vegetables	Tomato, Chilli, Brinjal, Green bean, Beet, Winged bean, Bell pepper, Cabbage, Cauliflower, Cucumbers, Melons, Radish, Onion
Leafy vegetables	Lettuce, Kang Kong
Condiments	Parsley, Mint, Sweet basil, Oregano
Flower crops	Marigold, Roses, Carnations, Chrysanthemum
Medicinal crops	Indian Aloe, Coleus
Fodder crops	Sorghum, Alfalfa, Barley, Bermuda grass, Carpet grass

Source:https://www.researchgate.net/publication/277017205_A_Review_On_The_Science_Of_Growing_Crops_Without_Soil_Soilless_Culture_-_A_Novel_Alternative_For_Growing_Crops

Generally, in a hydroponic system use of pesticides is avoided. The reason is that the need for pesticides is much less: There are few pest problems and the infected plants can be easily identified and dealt with. With the constant feeding of nutrients to the roots, productivity in hydroponics is much higher and is only limited by the amount of carbon dioxide that the atmosphere can provide and the limited amount of light that permeates the greenhouse. Some greenhouses even inject carbon dioxide into their sealed environment to help growth (CO2 enrichment), or add lights to increase the amount of available light that the plants may consume increases.

Supply of nutrients to the plants

In Hydroponic systems, usually, the liquid or solid medium is not as capable at buffering the nutrients in the system as soil would be and is therefore much more susceptible to the rapid changes in the nutrient levels. It is therefore that careful monitoring of the nutrient level is required in such a system while this can easily be automated. Two very different aspects of nutrition of the plant i. e. the supply of nutrients from the nutrient delivery system and the plant nutrient response are needed to be considered. Following are the sources of nutrient elements used in hydroponics.

Table -2: Sources of nutrient elements with their characteristics

Source	Element	Characteristics
Potassium nitrate KNO_3	N, K	Very soluble salt
Potassium phosphate monobasic KH_2PO_4	P, K	Corrects phosphorus deficiency
Magnesium sulfate $MgSO_4$	S, Mg	Cheap, highly soluble, pure salt
Iron chelate	Fe Cit	Best sources of iron
Boric acid H_3BO_3	B	Best source of boron
Calcium nitrate $Ca(NO_3)_2$	N, Ca	Very soluble salt

Source:https://www.researchgate.net/publication/277017205_A_Review_On_The_Science_Of_Growing_Crops_Without_Soil_Soilless_Culture_-_A_Novel_Alternative_For_Growing_Crops

The amount of nutrient needed is variable, and depends on the actual substrate (volume and physical- chemical characteristics) used and the crop (species and stage of development). It also depends on size of the container holding the plants the crop the size of the container and the irrigation method used and the prevailing climatic conditions. The feeding of the plants should be done every day without fail. Plants should be fed daily ideally between 6.00 and 8.00 am, though water requirements will vary considerably throughout the day, and from one day to another. Only the roots should be fed and the leaves are to be dry to avoid disease. The plants should not be allowed to suffer from water stress, as this will affect their final yield. It is recommended to flush out salts by watering once a week. The flushing dosage should be double the water and no nutrients. The extra nutrients drained from the solution can be reused in the next feeding [11].

Desirable pH range of nutrient solutions

There is a narrow range of pH for the optimal growth of the plant for the availability and absorbability of nutrients from the solution. However, as the plant grows, it itself brings about some changes to the pH of the solution. Thus external monitoring and control of the pH of the solution is vital to the productivity of the system. Still changes upto 0.1 units of pH in the solution are negligible. The optimal range of pH for a variety of plants lies between 5.5 and 6.5 units. This is sufficient for most common species and certain more tolerant species can survive and even thrive at much higher or lower pH. In fact there is a significant variability of pH requirement in various species [12].

Table 3 : pH requirement in various vegetable species

Vegetable Crops	Required pH range
Artichoke	6.5-7.5
Cabbage	6.5-7.0
Onions	6.0-6.7
Potato	5.0-6.0
Sweet Corn	6.0
Tomato	6.0-6.5
Turnip	6.0-6.5
Cucumber	5.5
Carrots	6.3
Okra	6.5
Pea	6.0-7.0

Source: https://www.gtghydroponics.com/faq/veggieph.aspx

Control of contaminants

Contaminants need to be eliminated under a strictly sterile root-zone environment. This is essential for good plant vigour under a soil-less culture. This is the most difficult step as it is extremely hard to achieve and also maintain such an environment in the root zone. Still, it is critical to minimize population of plant pathogens like *Fusarium* and *Verticillum* which cause wilt and *Pythium* and *Phytophthora* which destroy all but the main roots. No effective fungicides have been discovered which can be safely used in hydroponics however complete heat treatment (at about 20-22 °C) of the solution is found to be effective in sterilization [7-9].

FUTURE SCOPE OF THIS TECHNOLOGY

While it might not have a large market share, hydroponics does have incredible growth making it the fastest growing sector in agriculture. In the future it is projected to dominate all of the world’s food production. Hydroponics is likely to thrive as more and more land is devastated by poor farmland management and overuse causing people to turn to newer innovative methods of farm production.

Certain countries like Japan have already adopted a proactive approach to these technologies due to its lack of arable land and rising land prices being an island nation. Japan's hydroponics is for the most part done with NFT or sand/gravel techniques. Using bio-technical approaches such as posed by hydroponics, the Japanese have come up with newer and more productive plants for hydroponic rice production. Due to the environment control four harvest can be performed within a single year, compared to the traditional single harvest per year. As the global population becomes more urban, cities like

Indianapolis are investing in more local food production systems that offer economic development opportunities and reduce a city's carbon footprint using 90 percent less water than traditional farming methods [13].
Desert climes such as those in Israel have also been the subject of immense agricultural innovation. Due to arid climate and a general lack of water, the country has been using hydroponics to grow berries and bananas in shipping containers. These fruits cannot actually be grown in that climate but still are capable of yielding 1,000 times greater produce. Even certain large businesses have realized the value of hydroponic systems. The large store chain Target began a series of trials in spring 2017 hydroponic gardens were installed at selected locations. These gardens can provide customers with very fresh vegetables and herbs with minimal water usage.

CONCLUSIONS

In a world where fresh water and food supplies are becoming more and more scarce, hydroponics emerges as an important way to mitigate these problems in a sustainable and ecologically conscious way. In the future, it is expected that the hydroponics industry will grow exponentially especially as conditions for soil based growing are becoming increasingly difficult. Eventually, in a country like India where urban growth is exceeding all expectations, soil-less culture is bound to eclipse conventional agriculture to increment the quantity and quality of the produce and ensure future food security for the nation. The progress of hydroponics can however, be accelerated by increased interest through governmental intervention and focus of research institutes.

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