Hydroponics: Producing plants In-vitro on artificial support medium.

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Abstract— With the advent of civilization, open field/soil-based agriculture is facing some major challenges; most importantly decrease in per capita land availability. In 1960 with 3 billion population over the World, per capita land was 0.5 ha but presently, with 6 billion people it is only 0.25 ha and by 2050, it will reach at 0.16 ha. Due to rapid urbanization and industrialization as well as melting of icebergs (as an obvious impact of global warming), arable land under cultivation is further going to decrease. Again, soil fertility status has attained a saturation level, and productivity is not increasing further with increased level of fertilizer application. Besides, poor soil fertility in some of the cultivable areas, less chance of natural soil fertility build-up by microbes due to continuous cultivation, frequent drought conditions and unpredictability of climate and weather patterns, rise in temperature, river pollution, poor water management and wastage of huge amount of water, decline in ground water level, etc. are threatening food production under conventional soil-based agriculture. Under such circumstances, in near future it will become impossible to feed the entire population using open field system of agricultural production only. Naturally, soil-less culture is becoming more relevant in the present scenario, to cope-up with these challenges. In soil-less culture, plants are raised without soil. Improved space and water conserving methods of food production under soil-less culture have shown some promising results all over the World. Growing plants such as Zea mays (Maize), Aloe vera (Indian Aloe), Sorghum bicolor (Sorghum), artificially on sponge support in contact with nutrient medium, it was found that the growth was much more pronounced than the same plants grown on soil. In addition, since only organic nutrients were supplied, the plant products produced were purely organic.

1. INTRODUCTION

The word 'Hydroponics' was coined by Dr. W.F. Gericke in 1936 to describe the cultivation of edible and ornamental plants grown in a solution of water and dissolved nutrients. It literally means working water; 'hydro' meaning 'water' and 'ponos' meaning 'labour'. For example, the hanging gardens of Babylon and the floating gardens of the Aztecs of Mexico and those of the Chinese. The first commercial hydroponic unit in the USA developed by Gericke in 1930. American forces employed this system in the Pacific to produce vegetables during World War II. In 1842 a list of nine elements believed to be essential to plant growth had been made out, based on the discoveries of the German botanists, Julius von Sachs and Wilhelm Knop. Solution culture is now considered a type of hydroponics where there is no inert medium. Today, it is a well know fact that in some parts of the world, plant life does not grow in the available soil. One reason behind the drive to develop
hydroponics was the need for growing fresh produce in non-arable areas of the world.
Consumption of herbal medicines is widespread and increasing. Harvesting from
the wild, the main source of raw material, is causing loss of genetic diversity and habitat destruction. Domestic cultivation is a viable alternative and offers the opportunity to overcome the problems that are inherent in herbal extracts, misidentification, genetic and phenotypic variability, extract variability and
instability, toxic components and contaminants. The use of controlled environments can overcome cultivation difficulties and could be a means to manipulate phenotypic variation in bioactive compounds.

In India, Hydroponics was introduced in year 1946 by an English scientist, W. J. Shalto Duglas and he established a laboratory in Kalimpong area, West Bengal. He has also written a book on Hydroponics, named as Hydroponics The Bengal System_. 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.

2. COMPARISON BETWEEN HYDROPONICS AND GEOPONICS:

Table 1: The Advantages of Hydroponics Gardening Over Classic Geoponics Gardening:

Sl. No.	Hydroponics	Geoponics
1.	Hydroponics gardening can be packed and kept it alive and fresh for longer periods of time.	Plant is killed when it is removed from the ground
2.	Hydroponics gardening doesn't even use any kind of solid medium.	In this type of gardening we have to dispose, sterilize and reuse a solid medium every time.

3.	Full control of the plant's root system and in eye contact always.	Roots are hidden in the ground.
4.	No need to worry about over watering or under watering.	Always have to change and adjust your watering techniques according to the weather and the soil condition
5.	It can be developed in areas where there's no quality soil present. E.g. In areas covered with snow or in a space station.	Geoponics gardening should always be developed in quality soil in order to produce best crops.
6.	An excellent plant research and plant learning tool and can be transferred anywhere without any hassle.	Studies on geoponics plant you have to be conducted at the place where the plant grows
7.	In hydroponics gardening there is no soil at all no weeds and no pesticides of course	Plants grown with geoponics methods may suffer from all kinds of diseases, pesticides, weeds etc. caused by the presence of soil.
8.	The use of water to maintain and preserve the plant can be dramatically reduced.	Always more water is used than need for irrigation.
9.	A hydroponics garden may be set up with timer systems to automatically fertilize the plants.	Fertilizing the plants is always a pain and most of the times it must be done manually.
10.	Healthier because they receive a balanced and controllable portion of nutrients.	In geoponics, the plant's nutrition cannot be assured because there are too many factors to consider, for example whether the soil already contains enough minerals to grow the plants or whether it should be enriched with the right mix of minerals etc.
11.	Stable, safe and high yields	Unstable and the Yield vary according to surrounding condition.

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3. HYDROPONIC TECHNIQUES AND THEIR CLASSIFICATION

3.1. Wick Hydroponic System

The wick hydroponic system is the simplest and typically the most inexpensive system and it is a "passive system", which means that it does not have any moving parts. It works by drawing the necessary nutrients into the growing medium from a reservoir with a wick. This should only really be used for smaller plants that do not require much nutrients or moisture, as the wicks cannot supply the plants with these things very quickly.

3.2. Ebb and Flow Hydroponic System

The Ebb and Flow system, which is sometimes referred to as the "Flood and Drain" system, is a much more advanced and complicated system. This system works by using a pump that is placed into the reservoir to regularly flood the grow tray with the nutrient solution and then draining it back into the reservoir. The pump floods the tray or bucket at regular intervals for a set period of time by using a timer. The advantage of the bucket or modular system is that each plant is grown in its own container and therefore can be moved or handled much more easily.

3.3. Nutrient Film Technique

This system delivers a constant flow of nutrients to the plants with a pump, so no timer is required. This system doesn't require a growing medium; the plants are simply suspended in a plastic tray with the roots dangling in a nutrient solution.

3.4. Drip Irrigation Hydroponic System

In this system, a timer delivers the nutrient solution through the base of each plant
through drippers. Continuous drip systems can be recovery or non-recovery, meaning that the used nutrient solution can either be returned to the reservoir or run off as waste. Recovery systems are more cost effective because they use the nutrient solution more effectively, but non-recovery systems require less maintenance because the pH balance and nutrient strength remains constant.

3.5. Aeroponic Hydroponic System

Aeroponics is a newer and more high tech method of hy-

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droponic growing. There is no growing medium as like the nutrient film technique. The plants are suspended with the roots in the air and the nutrients and moisture are supplied in the form of a mist. A timer ensures that the pump delivers a new spray of mist every few minutes. Like the nutrient film technique, it is imperative that the pump is always functioning correctly, because even a brief interruption can cause the roots to dry out. Root Mist Technique (RMT) and Fog Feed Technique (FFT) are the two important Aerophonic Hydroponic Techniques in use.

3.6. Grow Bag Technique

Thoroughly soak the medium in the grow bag with dilute nutrient solution, before inserting the plants. Plants should receive nutrient when required. Use a plastic watering can or drippers to apply the nutrient solution.

37. Sub-irrigation

This system is based on the capillary action of the growing medium which carries the nutrient solution up to the root growing zone. In this particular method, a pot is permanently left to sit in nutrient solution. When river sand is used as the growing medium, the nutrient will rise approximately 15 cm above the level of the solution.

3.8. Rock Wool Technique

Horticultural Rockwool can be used as a soilless growing medium. The Rockwool referred to is a horticultural grade of Rockwool capable of absorbing water and made to a specific density. Standard thermal Rockwool products should not be used as these are water repellent, and may have toxic fire retardants. The advantage of using Rockwool as a growing medium lies in the fact that the plants at no point need to be removed from the Rockwool. Deep Flow Technique – (DFT), Root Dipping Technique, Floating Technique, Capillary Action Technique, Trench or Trough
Technique, Pot Technique, Deep Water Culture (DWC), Surface Watering Technique and Soak and Drain are the other hydroponic techniques.

4. BASIC REQUIREMENTS OF HYDROPONICS

4.1 Growing Medium

The growing medium for hydroponic gardening is an inert medium which does
not provide any nutrients to the plant. It only provides the basis for the roots to grow in. Coco coir fibre Rockwool, Perlite, Vermiculite, LECA, Expanded clay, Natural or Synthetic Sponge, Crushed granite, Sand, Scoria, Gravel are the various types of growing mediums available for growing plants hydroponically. A growing medium allows us to add the correct amount of nutrients and also monitor the pH in a hydroponic system. In addition, using a growing medium other than soil has several advantages that include:

1. Prevention of root infestations,
2. Retention of adequate oxygen and water and
3. Increased aeration and draining.

4.2 Mineral Nutrients

There are approximately seventeen elements required for proper growth of hydroponic plants.

4.2.1 Macro-nutrients

1. Carbon – Formation of organic compounds, 2. Oxygen- Release of energy from sugar, 3. Hydrogen- Water formation, 4. Nitrogen- Chlorophyll, Amino Acids and Proteins synthesis, 5. Phosphorus- Vital for photosynthesis and growth, 6. Potassium- Enzyme activity , 7. Calcium- Cell growth, cell division and the components of cell wall, 8. Magnesium-Component of chlorophyll, enzyme activation, 9. Sulphur- Formation of Amino Acids and Proteins.

4.2.2 Micro- nutrients

10. Iron- Used in Photosynthesis, 11. Boron – Vital for reproduction, 12. Chlorine -
Helps root growth, 13. Copper- Enzyme activation, 14. Manganese- Component of
chlorophyll, Enzyme activation, 15. Zinc- Component of enzymes and auxins, 16.
Molybdenum- Nitrogen fixation, 17. Cobalt- Nitrogen fixation. Other elements like Sodium- Vital for water movement, Nickel- Nitrogen liberation, Silicon- Cell wall toughness, can also be used.

4.3 Nutrient solution

Most herbs grow well with a basic nutrient solution. Many readymade choices are
available. Care must be taken to avoid minor nutrient deficiencies. Several different herbs may be grown in a single nutrient solution.

Table 3: Micronutrient requirement.

Elements	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn	Ma
ppm	210	70	300	180	67	1.25	3.0	0.26	0.5	0.40	0.06

4.4 Temperature

Temperature affects plant in two ways. High temperatures tend to accelerate the growth of the plant which increases the plant need for water. High temperatures also increase the plants consumption of water for cooling itself through evaporation.

4.5 Air

Wind or air movement has a dramatic influence on the plants consumption of water particularly when combined with high temperature in much the same way as clothes dry much faster on our clothes line on a windy day. In some plants it helps in pollination.

4.6 Shelter and support

Shelter for hydroponic gardening depends upon the type of cultivation to be carried out. The cultivation of the vegetables for the household gardening backyard waste land or the terrace is sufficient. The commercial production of the food crops and the medicinal plants requires the large area. Supporting arrangements can be made depending on the type of plant grown which may help in the increased yield.

4.7 Water

As a general rule, all water suitable to drink or used to irrigate greenhouses is ideal for hydroponics. To be more precise, water suitable for hydroponics should have conductivity less than 500 uS/cm, or a total salt concentration less than 350 ppm. Harmful amounts of sodium and boron can cause problems in some areas. Very soft water should be used with calcium-containing nutrients.

4.8 Light

Areas that already get sunlight will need fewer hydroponic lights than a hydroponic garden grown in a fully enclosed room. Remember that sunlight is less predictable than artificial lighting. If greenhouse is used to grow hydroponic garden, it won't need much artificial light during the spring and summer. Expect to supplement the sun with hydroponic lights once the amount of available light begins to wane. Indoor growers often rely almost completely on artificial light, since limited amounts of sunlight gets to their plants.

4.9 LED (Light Emitting Diode) Grow Lights for Hydroponic Gardens

LED grow lights are becoming very popular for hydroponic gardening due to cost of maintenance. The technology of LED grow lights is to emit only the color spectrum required for the plant photosynthesis. Hence, they consume less amount of electricity in comparison to the traditional lighting system and other grow lights. On an average, a LED grow light consumes less than 5 watts of power for operation. In LED grow lights, wide-spectrum red light and narrow-spectrum blue light of specific wavelengths are configured in a particular manner. The red spectrum supplements natural sun rays, whereas the blue spectrum makes an ideal light for the plant growth. Thus, LED grow lights provide ideal light conditions for the better growth of all types of plants and/or crops. In addition, this lighting system contains no toxic mercury, which is used in fluorescent lights and metallic vapor. Another advantage of LED grow lights is the less production of heat. With minimum heat production, water requirement also reduces due to less evaporation. The problem of high temperature root damage and plant dehydration is thus solved by using LED grow lights. Hence, with this lighting system, there is no need for installation of fans or cooling ducts. As these grow lights are available readily with plugs, no ballast is required for the initiation and regulation of the lights. Thus, there is no problem for ballast burning and/or replacement, which is so in case of fluorescent bulbs. LED grow lights are long-lasting; a superior quality may last for 10-12 years. Overall, LED grow lights are easier to maintain and cheaper than other lighting systems used for hydroponic gardening.

5. LIST OF CROPS THAT CAN BE GROWN IN SOIL-LESS:

Table 3: list of crops that can be grown on commercial level using soil-less culture.

Type	Name of the crops
Cereals	Oryza sativa (Rice), Zea mays (Maize)
Fruits	Fragaria ananassa (Strawberry)
Vegetables	Lycopersicon esculentum (Tomato), Capsicum frutescens (Chilli), Solanum melongena (Brinjal), Beta vulgaris (Beet), Brassica oleracea var. capitata (Cabbage), Brassica oleracea var. botrytis (Cauliflower), Cucumis sativus (Cucumbers), Allium cepa (Onion)
Leafy vegetables	Lactuca sativa (Lettuce),
Condiments	Mentha spicata (Mint), Ocimum basilicum (Sweet basil), Origanum vulgare (Oregano)
Medicinal	Aloe vera (Indian Aloe), Solenostemon scutellarioides (Coleus)
Fodder	Sorghum bicolor (Sorghum), Medicago sativa (Alphalfa), Hordeum vulgare (Barley).

6. AGENDA:

The basic idea was to use a modified sub-irrigation technique to grow certain plants in a nutrient medium having requisite components in required concentrations. The nutrient medium was loaded onto a PVC well whereas the seeds or grafts of the plants to be grown were implanted on cylindrical sponge bars fitted onto PVC pots. The pots were then suspended onto the medium held in the well. The seeds embedded deep inside the sponge bars derive nutrition from the nutrient solution as it seeps upwards against gravity, through capillary action. The separate PVC hose was fitted onto the nutrient well, so as to facilitate the growth of the plants.
Simultaneously the same plants were grown on earthen pots containing soil.

Table 3: The plants chosen for consideration were:

Type of crops	Name of the crops
Cereals	Zea mays (Maize)
Medicinal crops	Aloe vera (Indian Aloe).
Fodder crops	Sorghum bicolor (Sorghum).

After 15 days of growth period it was observed that all the three-plant species grew substantially on the sponge medium. In addition, the plant height and plant stem thickness, both of which are considered parameters for plant growth were found to be much more developed than that of the same plants grown on soil medium. Since only organic nutrients were used the plants grown produced only pure organic products s and were free from any poisonous or harmful complexes that are usually encountered and taken up by plants growing in the natural environment.

7. FUTURE SCOPE OF THIS TECHNOLOGY

Hydroponics is the fastest growing sector of agriculture, and it could very well dominate food production in the future. As 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. To get a glimpse of the future of hydroponics, we need only to examine some of the early adopters of this science. 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 Organitech has been growing crops in 40-foot (12.19-meter) long shipping containers, using hydroponic systems. They grow large quantities of berries, citrus fruits and bananas, all of which couldn't normally be grown in Israel's climate. The hydroponics techniques produce a yield 1,000 times greater than the same sized area of land could produce annually. Best of all, the 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. There has already been a great deal of buzz throughout the scientific community for the potential to use hydroponics in third world countries, where water supplies are limited. Though the upfront capital costs of setting up hydroponics systems is 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 two-fold: It offers the potential for a larger variety of food, and it provides a biological aspect, called a bioregenerative life support system. This simply means that as the plants grow, they will absorb carbon-di-oxide 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.

8. CONCLUSION:

These days land is being lost at such a rapid rate, that there is no telling how soon the land will run out for farming. If the growth continued at such a speed eventually the only land that will still be able to be developed is farmland. We will have no more room for our crops that we grow to survive. This has been a potential issue for years which is why scientists have developed another way to grow food and plants without utilizing land which is a fast depleting resource. More over with the rapid degradation of environment, even if land is available most of them are likely to contain harmful substances which may produce plants bearing harmful products Hydroponics is the only alternative for such associated problems. The great positive of hydroponics growing is that anyone can do it. If you have the knowledge and the right equipment you can do it yourself out of your home. This means that individuals that live in downtown areas and have no yard space for a garden can grow vegetables and fruits and herbs without having to trudge down to the grocery every day. The equipment to grow plants using a hydroponics system is easy to obtain and can be easily picked up at a local store or over the internet.

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