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HYDROPONICS - A FUTURE APPROACH TO AGRICULTURE

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ABSTRACT: Hydroponics: It is a technique of growing crops or plants without soil by utilizing an aqueous solution and substrate.**Hydroponic Culture:** In hydroponic culture, the plants, vegetables, and flowers are planted in the substratum and provided with oxygen and nutrient-rich aqueous solution. The key benefit of following hydroponic culture is it produces good quality crops in less time. The selection of the substratum depends on the technique of hydroponics. The substrate used in this farming include sheep wool, sand, perlite, rice husks, coconut coir, gravel, clay aggregates, rock wool, stones, wood fiber, etc.The five main techniques of hydroponics are mentioned below.

1- Ebb and Flow
The substratum-filled tray is placed above the nutrient aqueous solution and crops are planted in a standing position. The tray is supplied with a nutrient solution that drains downward in the aqueous solution.
2- Aeroponics
It is a method of growing plants by using nutrient mist. It doesn't require soil and substratum like other techniques of Hydroponics.
3- Static Solution Culture
In static solution culture, the crops are planted in small tanks, buckets, pots, etc that contain the nutrient solution.
4- Run-to-waste
The Bengal system is based on the technique of applying water and nutrients to plants periodically.
5- Deep Water Culture
In this method, the plant roots are suspended in an oxygenated aqueous solution enriched with nutrients.

KEYWORDS: hydroponics, water, agriculture, future, soil, minerals, nutrients, transgenic, plants

INTRODUCTION

Hydroponics[1] is a type of horticulture and a subset of hydroculture which involves growing plants, usually crops or medicinal plants, without soil, by using water-based mineral nutrient solutions in aqueous solvents. Terrestrial or aquatic plants may grow with their roots exposed to the nutritious liquid or in addition, the roots may be mechanically supported by an inert medium such as perlite, gravel, or other substrates.[2]

Despite inert media, roots can cause changes of the rhizosphere pH and root exudates can affect rhizosphere biology and physiological balance of the nutrient solution by secondary metabolites.[3][4][5] Transgenic plants grown hydroponically allow the release of pharmaceutical proteins as part of the root exudate into the hydroponic medium.[6]The nutrients used in hydroponic systems can come from many different organic or inorganic sources, including fish excrement, duck manure, purchased chemical fertilizers, or artificial nutrient solutions.[7]Plants are commonly grown hydroponically in a greenhouse or contained environment on inert media, adapted to the controlled-environment agriculture (CEA) process.[8] Plants commonly grown hydroponically include tomatoes, peppers, cucumbers, strawberries, lettuces, and cannabis, usually for commercial use, and Arabidopsis thaliana, which serves as a model organism in plant science and genetics.[9]Hydroponics offers many advantages, notably a decrease in water usage in agriculture. To grow 1 kilogram (2.2 lb) of tomatoes using intensive farming methods requires 214 liters (47 imp gal; 57 U.S. gal) of water;[10] using hydroponics, 70 liters (15 imp gal; 18 U.S. gal); and only 20 liters (4.4 imp gal; 5.3 U.S. gal) using aeroponics.[11]Hydroponic cultures lead to highest biomass and protein production compared to other growth substrates, of plants cultivated in the same environmental conditions and supplied with equal amounts of nutrients.[12]Since hydroponics takes much less water and nutrients to grow produce and climate change threatens agricultural yields, it could be possible in the future for people in harsh environments with little accessible water to grow their own plant-based food.[13][8]Hydroponics is not only used on earth, but has also proven itself in plant production experiments in space.[14]

The formulation of hydroponic solutions is an application of plant nutrition, with nutrient deficiency symptoms mirroring those found in traditional soil based agriculture. However, the underlying chemistry of hydroponic solutions can differ from soil chemistry in many significant ways. Important differences include:

- Unlike soil, hydroponic nutrient solutions do not have cation-exchange capacity (CEC) from clay particles or organic matter. The absence of CEC and soil pores means the pH, oxygen saturation, and nutrient concentrations can change much more rapidly in hydroponic setups than is possible in soil.
- Selective absorption of nutrients by plants often imbalances the amount of counterions in solution.[14] This imbalance can rapidly affect solution pH and the ability of plants to absorb nutrients of similar ionic charge (see article membrane potential). For instance, nitrate anions are often consumed rapidly by plants to form proteins, leaving an excess of cations in solution.[15] This cation imbalance can lead to deficiency symptoms in other cation based nutrients (e.g. Mg^{2+}) even when an ideal quantity of those nutrients are dissolved in the solution.[16]
- Depending on the pH or on the presence of water contaminants, nutrients such as iron can precipitate from the solution and become unavailable to plants. Routine adjustments to pH, buffering the solution, or the use of chelating agents is often necessary.[17]
- Unlike soil types, which can vary greatly in their composition, hydroponic solutions are often standardized and require routine maintenance for plant cultivation.[18] Under controlled laboratory conditions hydroponic solutions are periodically pH adjusted to near neutral (pH 6.0) and are aerated with oxygen. Also, water levels must be refilled to account for transpiration losses and nutrient solutions require re-fortification to correct the nutrient imbalances that occur as plants grow and deplete nutrient reserves. Sometimes the regular measurement of nitrate ions is used as a key parameter to estimate the remaining proportions and concentrations of other essential nutrient ions to restore a balanced solution.[19]
- Well-known examples of standardized, balanced nutrient solutions are the Hoagland solution, the Long Ashton nutrient solution, or the Knop solution.

As in conventional agriculture, nutrients should be adjusted to satisfy Liebig's law of the minimum for each specific plant variety.[20] Nevertheless, generally acceptable concentrations for nutrient solutions exist, with minimum and maximum concentration ranges for most plants being somewhat similar.[21] Most nutrient solutions are mixed to have concentrations between 1,000 and 2,500 ppm.[11] Acceptable concentrations for the individual nutrient ions, which comprise that total ppm figure, are summarized in the following table. For essential nutrients, concentrations below these ranges often lead to nutrient deficiencies while exceeding these ranges can lead to nutrient toxicity. Optimum nutrition concentrations for plant varieties are found empirically by experience or by plant tissue tests.[12]

II.DISCUSSION

Organic fertilizers can be used to supplement or entirely replace the inorganic compounds used in conventional hydroponic solutions.[14] However, using organic fertilizers introduces a number of challenges that are not easily resolved. Examples include:

- organic fertilizers are highly variable in their nutritional compositions in terms of minerals and different chemical species. Even similar materials can differ significantly based on their source (e.g. the quality of manure varies based on an animal's diet).
- organic fertilizers are often sourced from animal byproducts, making disease transmission a serious concern for plants grown for human consumption or animal forage.
- organic fertilizers are often particulate and can clog substrates or other growing equipment. Sieving or milling the organic materials to fine dusts is often necessary.
- biochemical degradation and conversion processes of organic materials can make mineral ingredients available to plants.[15]
- some organic materials (i.e. particularly manures and offal) can further degrade to emit foul odors under anaerobic conditions.
- many organic molecules (i.e. sugars) demand additional oxygen during aerobic degradation, which is essential for cellular respiration in the plant roots.
- organic compounds (i.e. sugars, vitamins, a.o.) are not necessary for normal plant nutrition.[16]

Nevertheless, if precautions are taken, organic fertilizers can be used successfully in hydroponics.[19]Micronutrients can be sourced from organic fertilizers as well. For example, composted pine bark is high in manganese and is sometimes used to fulfill that mineral requirement in hydroponic solutions.[20] To satisfy requirements for National Organic

Programs, pulverized, unrefined minerals (e.g. Gypsum, Calcite, and glauconite) can also be added to satisfy a plant's nutritional needs. Compounds can be added in both organic and conventional hydroponic systems to improve nutrition acquisition and uptake by the plant. Chelating agents and humic acid have been shown to increase nutrient uptake.[16] Additionally, plant growth promoting rhizobacteria (PGPR), which are regularly utilized in field and greenhouse agriculture, have been shown to benefit hydroponic plant growth development and nutrient acquisition.[87] Some PGPR are known to increase nitrogen fixation. While nitrogen is generally abundant in hydroponic systems with properly maintained fertilizer regimens, *Azospirillum* and *Azotobacter* genera can help maintain mobilized forms of nitrogen in systems with higher microbial growth in the rhizosphere.[17] Traditional fertilizer methods often lead to high accumulated concentrations of nitrate within plant tissue at harvest. *Rhodopseudomonas palustris* has been shown to increase nitrogen use efficiency, increase yield, and decrease nitrate concentration by 88% at harvest compared to traditional hydroponic fertilizer methods in leafy greens.[17] Many *Bacillus* spp., *Pseudomonas* spp. and *Streptomyces* spp. convert forms of phosphorus in the soil that are unavailable to the plant into soluble anions by decreasing soil pH, releasing phosphorus bound in chelated form that is available in a wider pH range, and mineralizing organic phosphorus.[18]Some studies have found that *Bacillus* inoculants allow hydroponic leaf lettuce to overcome high salt stress that would otherwise reduce growth.[19] This can be especially beneficial in regions with high electrical conductivity or salt content in their water source. This could potentially avoid costly reverse osmosis filtration systems while maintaining high crop yield.Managing nutrient concentrations, oxygen saturation, and pH values within acceptable ranges is essential for successful hydroponic horticulture. Common tools used to manage hydroponic solutions include:

- Electrical conductivity meters, a tool which estimates nutrient ppm by measuring how well a solution transmits an electric current.
- pH meter, a tool that uses an electric current to determine the concentration of hydrogen ions in solution.
- Oxygen electrode, an electrochemical sensor for determining the oxygen concentration in solution.
- Litmus paper, disposable pH indicator strips that determine hydrogen ion concentrations by color changing chemical reaction.
- Graduated cylinders or measuring spoons to measure out premixed, commercial hydroponic solutions.

Chemical equipment can also be used to perform accurate chemical analyses of nutrient solutions. Examples include:[20

- Balances for accurately measuring materials.
- Laboratory glassware, such as burettes and pipettes, for performing titrations.
- Colorimeters for solution tests which apply the Beer–Lambert law.
- Spectrophotometer to measure the concentrations of the key parameter nitrate and other nutrients, such as phosphate, sulfate or iron.

Using chemical equipment for hydroponic solutions can be beneficial to growers of any background because nutrient solutions are often reusable.[16] Because nutrient solutions are virtually never completely depleted, and should never be due to the unacceptably low osmotic pressure that would result, re-fortification of old solutions with new nutrients can save growers money and can control point source pollution, a common source for the eutrophication of nearby lakes and streams.Although pre-mixed concentrated nutrient solutions are generally purchased from commercial nutrient manufacturers by hydroponic hobbyists and small commercial growers, several tools exist to help anyone prepare their own solutions without extensive knowledge about chemistry. The free and open source tools HydroBuddy[15] and HydroCal[13] have been created by professional chemists to help any hydroponics grower prepare their own nutrient solutions. The first program is available for Windows, Mac and Linux while the second one can be used through a simple JavaScript interface. Both programs allow for basic nutrient solution preparation although HydroBuddy provides added functionality to use and save custom substances, save formulations and predict electrical conductivity values. Often mixing hydroponic solutions using individual salts is impractical for hobbyists or small-scale commercial growers because commercial products are available at reasonable prices. However, even when buying commercial products, multi-component fertilizers are popular. Often these products are bought as three part formulas which emphasize certain nutritional roles. For example, solutions for vegetative growth (i.e. high in nitrogen), flowering (i.e. high in potassium and phosphorus), and micronutrient solutions (i.e. with trace minerals) are popular. The timing and application of these multi-part fertilizers should coincide with a plant's growth stage. For example, at the end of an annual plant's life cycle, a plant should be restricted from high nitrogen fertilizers. In most plants, nitrogen restriction inhibits vegetative growth and helps induce flowering.[73]With pest problems reduced and nutrients constantly fed to the roots, productivity in hydroponics is high; however, growers can further increase yield by manipulating a plant's environment by constructing sophisticated growrooms.[11] To increase yield further, some sealed greenhouses inject CO_2 into their environment to help improve growth and plant fertility.

III.RESULTS

Smart Hydroponic farms use vertically stacked growing beds and less than 1% of the space, which is a precious commodity in densely populated urban areas. Compared to the conventional farming, smart farms use 90% less water. Since most farms are located within city limits, the average distribution time from harvest to table averages 60 minutes, cutting down greenhouse gas-emitting travel time. Smart farms promise consistent pricing since the produce can be grown indoors, all year long. While traditional farming takes 45-60 days -- from growing seeds to harvesting -- smart farming does that in only 25 days. Transforming India's food system is key to attaining zero-hunger goal and the progressive agritech industry sure looks promising.Agricultural technology allows growers to increase performance while lowering costs at the same time.[15] And so, the expanding agritech market can prove to be a saviour for the country's suffering farmers. The smart techniques can help the retailers, exporters and farmers to contribute to India's GDP more than ever before. Healthy farming will lead to healthy produce that in turn will lead to healthy lifestyle.Did you know that the average head of lettuce travels over 1,500 kilometres to get to your table. Also the Contamination and Chemicals in India is 800 times more than desired level.The produce in Hydroponic is healthier, fresh and more nutritious and has longer shelf life which helps in creating healthier ecosystem. The technology helps in saving valuable water, land and labour resources moreover the controlled growing system enables to produce food with NO use of harmful chemicals and is also 100% residue free. State of art climate-controlled smart farm uses vertically stacked growing beds, up to 5 levels high, they use less than 1% of the space required by conventional growing, a precious commodity in densely populated urban areas. In our soil-less[16] Controlled Environment Agriculture (CEA) farms, we can recycle and filter water for responsible resource use. As a plus, we don't waste water from runoff or excess evaporation from the soil. We save 90% water compared to conventional agriculture. Since most farms are located within city limits, the average distribution time from harvest to table averages 60 minutes, cutting down greenhouse gas-emitting travel time. The CEA farms itself acts like in-built cold storage for plants. Cloud based data analytics and farm output AI software. Farmers can get their farm and production details sitting in the comfort of their home or office. It measures important indicators that helps in crop planning and help connect in food security ecosystem. The food production needs to be increased by 70% in the next 30 years. If we don't bring technology to agriculture, we're not going to get there. The good thing is that technology will allow us to increase performance and lower costs at the same time. There is going to be a point where vertical farming costs will keep going down and will match with the traditional agriculture costs. [17]

IV.CONCLUSIONS

The millennials and generations after that have purchasing power and are starting to control the market wallet. They are not tech resistant, but they love technology. They want pure and healthy leafy greens in their houses every week.[18] Hence, we need to take it further, which means doing it better and always driving down costs. It's quality food for everyone and not only for a few.Currently millennials are 50% of the labour force. By future, they will be 75% of the labour force, so they are defining the market preference. Millennials are the generation that is reading product labels, more than any other generation in the past has done. In the past, people were loyal to brands, volume vs. price, but that has completely changed. That is why this generation is perfect for new-age farming because they will value all these attributes that smart farming brings. [19]They will get informed; it's just about finding the right communication strategy.Going forward, in the near future, all households will be able to consume food that we can blindly trust to not harm us in any way.Healthy Farming will lead to Healthy Produce that in turn will lead to a Healthy Lifestyle.[20,21]

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