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Research on Hydroponics Farming

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ABSTRACT:

In this study, we review current research and applications of hydroponic farming, including the different types of hydroponic systems, plant species that can be grown using hydroponics, nutrient management, and environmental control. We also discuss the current challenges facing hydroponic farming, such as disease and pest management, energy use, and cost, and highlight areas for future research. We aim to provide a comprehensive overview of hydroponic farming and its potential impact on agriculture and food production.

Keyword: Hydroponics, Urban agriculture, Plant growth, Sustainable agriculture, Controlled environment, Nutrient management.

Introduction:

Hydroponic farming is an innovative agricultural method that involves growing of plants in a soil-free environment, using water which is nutrient-rich instead of soil. This method is based on the premise that the water-based environment can provide all the necessary nutrients for plant growth, and that the plants can extract these nutrients from the water. Hydroponics has been in existence for over 75 years and has been used for various applications, including research, commercial production, and education. This system has become increasingly popular in recent years due to its numerous benefits, including increased water and nutrient efficiency, reduced land use, and increased crop yield and quality. Despite these advantages, hydroponic farming is still considered an emerging field, and further research is needed to fully understand its potential and limitations.

Types of Hydroponic Systems

Although there are many other hydroponic farming techniques, there are six fundamental varieties that can be divided into active and passive systems:-

1. **Wick System**

   The Wick System, which is frequently thought of as the most straightforward kind of hydroponics, is referred to as a passive system, which simply means that it has no moving parts. Instead, wicks are utilized to draw nutrient solution into the growing media. These wicks hang down into a water reservoir. Perlite, Vermiculite, Rockwool, and Coconut Fiber are among the most widely used growing mediums that can be utilized with this technique. Although it is the most straightforward approach, it is not recommended for growing large plants or plants that require a lot of water since these plants may use the nutrient solution more quickly than the wicks can replenish it.

2. **Water Culture**

   This system is active since it contains moving pieces. Water Cultures are still regarded as the most basic type of active system, nevertheless. With this technique, the plant roots are fully submerged in the water reservoir containing the nutritional solution. The water is usually oxygenated with the aid of a pump, allowing the roots to breathe. Although this technique is sometimes regarded as the most straightforward active system, few plants are suitable for it. Similar to the Wick System, big plants are not a good fit for this technique.

3. **Ebb & Flow System**

   With these methods, the water-based fertilizer solution temporarily floods the grow tray. The solution is then used to encircle the plant roots before being drained back into the reservoir using a pump that is submerged in the liquid. Usually, a timer is used to automate this operation. These adaptable systems work with a range of growing media.

4. **Drip System**

   The most common kind of hydroponic system in use today. A network of raised misting jets that spray the plants from above are controlled by a submerged pump that pumps water and fertilizer solution from a reservoir. This system comes in two main forms: one with a recovery

system that collects nutritional solution and returns it to the reservoir, and the other without. Non-recovery systems require less upkeep since they keep the reservoir's pH level from fluctuating, even though recovery systems can use the nutrient solution more efficiently.

5. **N.F.T. System**

Most people probably envision a system like this when they think of hydroponics. The nutrient Film Technique, also known as NFT, is a technique that uses a continuous flow of nutrient solution that is pumped from the reservoir into the growing tray. This system has the significant benefit of not requiring a growing medium because the plants are supported by tiny plastic baskets, allowing the roots to hang down and absorb nutrients directly from the solution. In order to avoid technical problems, this type of system can be rather high maintenance; however, once the flow of nutrients stops, plant roots can quickly dry out.

6. Aeroponic System

This hydroponic technique is frequently thought of as high-tech. Similar to the NFT system, there is no growing medium; instead, the nutrient solution is misted onto the roots every few minutes. This method, like the NFT system, necessitates considerable attention because if the misting cycle is broken, the roots quickly dry out.

SWOT Analysis of Hydroponics Company

1. **Strengths**:
    a. Water conservation: Hydroponics systems use up to 90% less water than traditional soil-based agriculture, which can be a significant advantage in water-scarce regions.
    b. Space efficiency: Hydroponic systems can be set up vertically or horizontally, allowing for efficient use of space in areas where land is limited.
    c. Higher crop yield: With hydroponics, plants can grow faster and produce higher yields because they have access to consistent nutrient and water supply and are not limited by soil quality.
    d. Reduced pesticide use: Because hydroponic plants are grown in a controlled environment, there is less risk of pest infestation, reducing the need for harmful pesticides.
    e. Year-round production: Hydroponic systems can be used indoors, which allows for year-round production regardless of climate.
2. **Weaknesses**:
    a. High setup costs: Setting up a hydroponic system can be expensive, particularly for larger commercial operations.
    b. Dependence on technology: The reliance on technology is evident in hydroponics as it necessitates specific tools and a certain level of technical proficiency to sustain, which may impede some cultivators.
    c. Susceptibility to power outages: In the absence of power, hydroponic plants may not receive the necessary nutrients and water, which could lead to crop failure.
    d. Disposal of nutrient solutions: The nutrient solutions used in hydroponics can be harmful to the environment if not disposed of properly.
3. **Opportunities**:
    a. Growing demand for locally sourced produce: Hydroponics provides an opportunity for growers to produce fresh, locally sourced produce, which is becoming increasingly popular with consumers.
    b. Increased urbanization: As urban areas continue to grow, hydroponics can provide a means of producing food in a limited space.
    c. Sustainable food production: Hydroponics can be an environmentally sustainable means of producing food, particularly when combined with renewable energy sources.
    d. Experimentation with new crops: Hydroponics allows for experimentation with growing crops that are not traditionally suited to certain climates or soil types.
4. **Threats**:
    a. Competition from traditional agriculture: Despite the benefits of hydroponics, traditional agriculture methods remain dominant and may be seen as a more affordable option.
    b. Lack of consumer awareness: Some consumers may not be familiar with hydroponically grown produce and may be hesitant to purchase it.

c. Regulatory issues: Some countries may not have regulations in place for hydroponic production, which can make it difficult for growers to operate.

d. Energy costs: Hydroponic systems require significant energy use, particularly for heating and lighting, which can be expensive and potentially unsustainable if not powered by renewable energy sources.

Market size and trends

In 2020, the hydroponics industry had a value of USD 2.1 billion and is predicted to grow at a CAGR of 20.7% from 2021 to 2028. The rapid growth of the industry can be attributed to the increasing acceptance of hydroponic systems for indoor vegetable cultivation. Moreover, countries such as Canada, the Czech Republic, and South Africa have legalized marijuana, resulting in unconventional agricultural methods being used for marijuana production. As consumers become more aware of the harmful effects of pesticides and artificial ripening agents, the use of hydroponics is expected to increase since it eliminates the need for these substances and produces healthier vegetables.

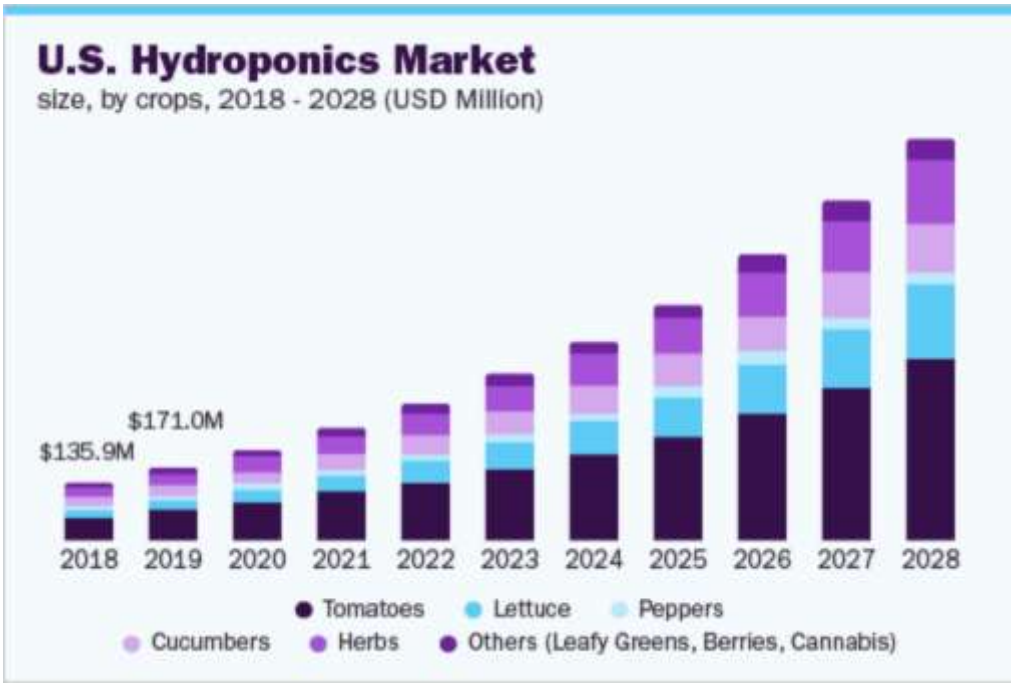

Fig. U.S Hydroponic Market (2018-2028)

In 2020, aggregate systems dominated the hydroponics market, accounting for about 55% of the market share. These systems are popular among indoor hydroponic growers due to their easy installation and affordability. They use inert and solid media, such as sand, rock wool, vermiculite, and peat, to support the plants. Different technologies, such as drip, ebb, flow, and wick systems, are used in aggregate systems. The ebb and flow system is the most preferred and commonly used technology due to its simplicity and low construction costs.

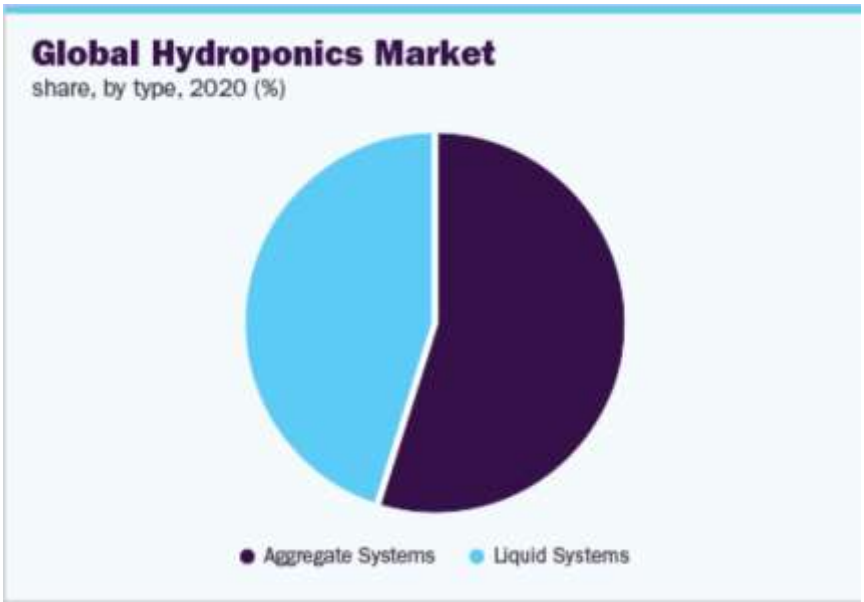

Fig Aggregate and Liquid Global Hydroponic System

The liquid systems segment is expected to experience the highest CAGR growth from 2021 to 2028 due to growers' preference for closed-system cultivation. This segment comprises deep water culture and nutrient film technique (NFT) systems, which are increasingly used for growing leafy vegetables like lettuce. Liquid systems eliminate the need for a solid medium and enable roots to be directly placed in the nutrient solution, which promotes growth and increases yields. While soilless farming techniques reduce the risk of soil-borne diseases, recirculating nutrient solutions in closed systems may increase the risk of pathogen spread. As a result, liquid systems require frequent maintenance to monitor and replace nutrient solutions to avoid these risks.

Objectives:

The study's objectives are to

Review the current state of hydroponic farming research and applications.

Identify the benefits and limitations of hydroponic farming.

Discuss the challenges facing hydroponic farming, including disease and pest management, energy use, and cost.

Highlight areas for future research in hydroponic farming.

Review of Literature:

1. Hydroponic systems are widely used in the commercial production of various crops, such as lettuce and tomatoes, and have been a favoured method for conducting plant biology research. Numerous hydroponic systems have been created by the plant research community to investigate how plants respond to biotic and abiotic stresses. This process offers detailed guidance on establishing a hydroponic system and preparing plant material.
2. The consumption of nutrient solutions is vital for the growth of crops, particularly tomatoes. A study was conducted to assess the impact of two hydroponic systems on the yield components, nutrient solution effectiveness, and stomatal gas exchanges of two greenhouse tomato cultivars. The traits examined in this study included crop yield, fruit number, fruit weight, cluster weight, nutrient solution efficiency, and stomatal gas exchanges such as net photosynthesis rate, stomatal conductance, transpiration rate, intercellular CO2 concentration, and leaf temperature.
3. As the global population continues to grow, the demand for many products, especially food, increases. This rising demand is expected to cause a food crisis in the coming years. To avert such crises, alternative farming practices and food sources must be utilized. This essay aims to compare and contrast two farming practices to identify which one can best fulfil current and future demand while minimizing resource use and cost.
4. All of our daily activities are now affected by automation, and since we humans have grown accustomed to it, we now anticipate it in all aspects of our lives. However, several industries still need to advance at different levels, and one of these industries is agriculture. This system

finds a gateway to the cultivation of plants in areas like deserts, barren lands and buildings as all the nutrients like oxygen, nitrogen, phosphorus, etc. are supplied manually to the plants.

5. Soil-based agriculture is facing challenges due to human activities such as industrialization and urbanization, as well as natural disasters and climate change, and the unregulated use of chemicals in farming which all decrease soil fertility and quality. To address these issues, researchers have developed an alternative method known as hydroponics, which involves cultivating plants in a water-based, nutrient-rich solution.

6. The purpose of this study of the literature is to provide readers with a knowledge base on which future research in the area of global sustainable food production may be built. The possibility exists for hydroponic growing systems to at least partially replace conventional soil-based growing methods in the global food supply. Some benefits of hydroponic growing systems include the ability to grow crops in controlled environments and the ability to alter environmental factors to increase production in small areas.

7. This study's goal is to evaluate a hydroponic farm (using the nutrient film technology) while taking risk, sustainability, and the system's utility in the primarily desert environment into consideration. The hydroponic farm's objective is to enable individuals and organizations to grow their plants. Given the geographical circumstances, the hydroponic system might be advantageous in the Gulf environment and lead to food sustainability and security. Several support programmes that can be used to invest in businesses that can increase the nation's food security have also been launched by the UAE government.

8. The objective of this study is to investigate the utilization of two categories of agricultural technologies by new farmers (i.e., those with 10 years or less of experience) operating in the speciality crops sector. This study investigates the idea that inexperienced farmers are less likely to use agricultural technology, such as growth methods (like hydroponics and hoop houses) and value-added (VA) methods (such as drying and cutting products into sections suitable for sale). Using a distinct primary dataset of speciality crop farmers, the dependent variable for each model is the binary decision to adopt each agricultural technology. The primary variables of interest are the dummy variables "beginning farmers" and "land farmed," "per cent of land farmed," and the interaction terms between these variables.

9. The primary goal of this essay is to analyze the correlation between smart farming and Sustainable Development Goal (SDG) 2, which aims to eradicate hunger. The article also employs a SWOT analysis to identify the benefits, drawbacks, opportunities, and risks of implementing smart farming in Southeast Asia (SEA). This study makes use of a SWOT analysis to look at the advantages of smart farming in Southeast Asia in order to end world hunger. To conduct the SWOT analysis, a thorough review of prior and relevant literature on smart farming and its relationship to SDG 2 is conducted. The use of SWOT analysis provides a foundation for figuring out the desired future position, and identifies current

10. The difficulties in achieving food security are framed by six ideas in this essay. It has been suggested that having a better understanding of the factors may aid decision-makers in communities, organisations, and businesses, improving food security. Relevant strategies or policies can then emerge and be established so that strategic and operational interventions can be prioritised at the national, regional, or industrial level. Underpinning everything mentioned above, waste from within and throughout the food supply chain contributes to the six criteria, highlighting areas that may need more attention if food supply networks are to be sustained.

11. The development of sustainable agriculture may be aided by the use of organic wastes in high-value applications. Keratin and cellulose are two typical natural biopolymers found in biowastes like hair, bird feathers, wood shavings, and vegetable trimmings. These waste-derived biopolymers are used in this study to break down keratin and create bioactive nutrient substrates that can support crop development in hydroponic culture systems. This study demonstrates the viability and potential of recycling keratinous and cellulosic wastes to provide crops with specific nutrients in a sustainable way.

12. Agriculture has long been the most widely used means of obtaining food supplies. It is also closely related to the elimination of poverty, rural development, and food security. Although hydroponics techniques are now among the most widely used plant-growing techniques globally, the soil has historically been thought to be the most important requirement for growing food crops. Plants can be grown without soil and still benefit the environment with the right fertiliser solution. Numerous studies have used hydroponics to look at how plants respond to biotic and abiotic stimuli. The food security crisis facing the world has a promising solution in this agriculture system, which will also advance technology towards the goal of becoming a self-sustaining model for future generations.

13. United Nations' Food and Agriculture Organization states that there will be nine billion people on the planet by 2050, with 75% of them living in cities. One of the biggest issues will be feeding everyone, as farmland is being lost due to issues like soil contamination, a lack of water, and climate change, among other things. In this case, hydroponics, an agricultural method that doesn't use soil, offers a workable solution to this problem. Additionally, in remote locations with restricted access to acceptable technologies.

14. Acid mine drainage (AMD) is produced when supplied minerals are exposed to oxidising conditions as a result of mining and other excavation processes. Because AMD can continue to be produced for hundreds of years even after mining activities have ended, when AMD is discharged to the ground, it will severely pollute the soil and nearby water bodies, lower the pH of surface water, impede the growth and reproduction of aquatic organisms, and destroy the granular structure of the soil. In addition to having a high concentration of heavy metals, sulphates, and other pollutants, AMD is also very acidic. It is urgently necessary to look into reasonably priced and efficient treatment options due to AMD's significant pollution problem in order to lessen its negative effects.

15. The primary objective of this study is to demonstrate the distinctiveness and benefits of smart innovation in agriculture and to highlight the widespread availability of Agriculture 4.0 through the example of vertical farms that incorporate hydroponics, deep learning, and artificial intelligence. The research approach is based on comparative analysis, which is used to compare pre-digital technologies traditionally used in agriculture with smart technologies used in affordable smart farming innovation. The goal of this analysis is to establish and implement highly efficient agriculture in cities and northern territories with defined and improved nutritional properties of food, increased productivity, and year-round continuity of agriculture regardless of climate .

Methodology:

This study conducted a systematic literature review to identify relevant articles on hydroponic farming. A search was conducted using various electronic databases, such as Web of Science, Scopus, and Google Scholar, with specific keywords like "hydroponics," "soilless cultivation," "plant nutrition," and "environmental control." The search was limited to peer-reviewed journal articles in English published from 2015 to 2022. The articles were screened for relevance based on their titles and abstracts, and only those deemed relevant were selected for full-text review. A total of 20 articles were included in the study.

The articles were analyzed for information related to hydroponic farming, including the different types of hydroponic systems, plant species that can be grown using hydroponics, nutrient management, and environmental control. The analysis also focused on the benefits and limitations of hydroponic farming, as well as the challenges facing hydroponic farming.

The results of the analysis were synthesized to provide an overview of the current state of hydroponic farming research and applications, as well as to identify areas for future research. The limitations of the study include the exclusion of non-English language articles and the potential for publication bias, as only peer-reviewed journal articles were included in the review.

The study conducted a systematic literature review by searching electronic databases for articles related to hydroponic farming using specific keywords. Relevant articles were screened and 20 were included for full-text review. This methodology provides a comprehensive and objective approach to synthesizing information.

Analysis and Findings:

Literature analysis on hydroponic farming showed that different hydroponic systems, such as deep water culture, nutrient film technique, drip irrigation, and aeroponics, have their own strengths and weaknesses, concerning plant growth, nutrient management, and environmental control.

The literature also highlighted the potential of hydroponic farming for growing a wide range of plant species, including leafy greens, herbs, tomatoes, cucumbers, strawberries, and flowers. Hydroponic systems can provide precise control over nutrient delivery and environmental conditions, leading to increased crop yields and higher-quality produce.

In terms of nutrient management, the literature showed that hydroponic farming allows for precise control over the nutrient solution, resulting in optimal plant growth and productivity. However, nutrient imbalances can still occur, which can lead to nutrient deficiencies or toxicities if not monitored and corrected promptly.

Environmental control is another crucial aspect of hydroponic farming, as it allows for precise control over temperature, humidity, light, and CO2 levels. However, the cost of energy and equipment required to maintain optimal environmental conditions can be a significant challenge for hydroponic farmers.

The literature also highlighted several challenges facing hydroponic farming, including disease and pest management, high energy use and associated costs, and the need for specialized knowledge and expertise. In addition, the high capital costs associated with setting up a hydroponic system can be a barrier to entry for small-scale farmers.

Overall, the analysis of the literature suggests that hydroponic farming has significant potential to revolutionize agriculture and food production, but further research is needed to fully understand its potential and limitations and to address the challenges facing hydroponic farming. Areas for future research include the development of more efficient and cost-effective hydroponic systems, optimization of nutrient management and environmental control, and exploration of new plant species for hydroponic cultivation.

Conclusion:

Hydroponic farming is a soilless cultivation method that has the potential to revolutionize agriculture and food production. The systematic literature review conducted in this study revealed that hydroponic systems offer precise control over nutrient management and environmental conditions, resulting in increased crop yields and higher-quality produce.

However, hydroponic farming also has its challenges, including high capital costs, energy consumption, and the need for specialized knowledge and expertise. Disease and pest management is another important issue that must be addressed in hydroponic farming, as it can lead to significant crop losses.

Despite these challenges, the potential benefits of hydroponic farming are significant, including increased crop yields, reduced water consumption, and improved food security. The technology has already been applied in a variety of settings, from small-scale urban farms to large-scale commercial operations.

In order to maximize the benefits of hydroponic farming, more research is required to improve nutrient and environmental management, enhance the efficiency and affordability of hydroponic systems, and identify new crops that can be grown using hydroponic techniques. Additionally, solutions must be developed to overcome challenges related to pest and disease management, energy consumption, and the significant initial costs of establishing a hydroponic system.

In conclusion, It summarizes the potential of hydroponic farming as a sustainable and efficient alternative to traditional agriculture, and emphasizes the importance of further research and development in order to fully realize its potential. Overall, hydroponic farming has the potential to address the challenges of a growing global population while also reducing environmental impact.

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