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SUSTAINABILITY OF HYDROPONIC AGRICULTURE WITH IMPACT ON TECHNOLOGY AND WATER EFFICIENCY: A SMART FARMING PRACTICE

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ABSTRACT

Purpose: Studies investigate how plants respond to biotic and abiotic stresses various hydroponic systems have been created by the community of research. This method intensifies the usage of necessary nutrients for growth of plant and extracts the nutrient from water.

Design: This literature highlights the customers' expectation towards factors driving sustainable choice on organic wine consumption in developed economy and data is obtained from various case studies, reviews of literature, journals and internet sources.

Findings: Due to numerous technological advancements, the hydroponics market is shows significant growth from past 2021 and expected to grow till 2028. Hydroponic system of commercial production and have been a favoured method for conducting plant biology research.

Originality Value: Hydroponic systems which is considered sustainable food production technology with an innovative, eco-friendly. The cultivation yields, healthier plants, and sustainable agricultural practices.

Paper type: Case Study

KEYWORDS
Sustainability, Hydroponic Agriculture, Technology, Water Efficiency, Smart Farming Practice, SWOC Analysis

Introduction

Hydroponic farming is the modern method of agriculture which connects towards soil-free environment with water as a nutrient instead of soil. This method intensifies the usage of necessary nutrients for growth of plant and extracts the nutrient from water. Studies from grass root level show the term "hydroponics" is originated from 'hydro' which means, water and 'ponos' means labour derived from Greek word. Some of the inert media used in hydroponic system to support the root are rock wool, perlite, coconut coir, peat moss, gravel and charcoal. Studies delineate on the system are engineered to provide plants the nutrients, optimal water quantity and oxygen for plant development. Shedding insight on hydroponic smart technology the method proved to be effective and environmentally friendly for crop production. Furthermore, the technology eliminates the water usage by giving nutrients directly to the plants root. The 'smart farming' involves Internet of Things (IOT), sensors and automation which constantly monitors the nutrient level, soil conditions and vitality of plant. However, technology-driven factors reinvigorate crop output, improves growth rates, and maintains conditions ideal for all weather. Comprehensive study adds more evidence towards smart farming reducing organic chemical inputs, fosters safe method of pest management and reduces waste production. Relevant information provides a ground-breaking strategy considered significant to alter the agriculture sector by encouraging regionalized production and ensuring food security and adding resilient farming practices (Ganapathy Rajaseger, et al., 2023).

Another stream of literature suggest electrical conductivity, pH level and temperature levels are crucial in hydroponics farming. In addition, light intensity signifies the efficiency rate in plant growth. Further a stream of narrow passage of water involving dissolved nutrients necessary for plant growth moves towards the root through a water tight gully which is known as channels. In addition an insect net is covered the whole farm in order to reduce the insects and control humidity of the farm. Ultimately UV plastic roofing is constructed in order to reduce the abrupt changes brought by changes in weather condition (Melchizedek Alipio, 2017).

Objectives

To understand the hydroponic agriculture system in cultivation.
To identify the impact of technology towards hydroponic cultivation.
To study water efficiency in smart farming practices.
To list out the SWOC analysis of the smart farming of hydroponic agriculture system.

Scope and Methodology

The study includes the secondary data, with related literatures. This literature highlights the customers' expectation towards factors driving sustainable choice on organic wine consumption in developed economy and data is obtained from various case studies, reviews of literature, journals and internet sources.

Literature Review

The sustainable hydroponic agriculture with impact on technology and water efficiency in the smart farming process. The study is taken from the Google scholar search engine of the published journals connecting from 2001-2023 with the help of key words.

Table 1: A sustainable hydroponic agriculture with impact on technology and water efficiency in a smart farming process

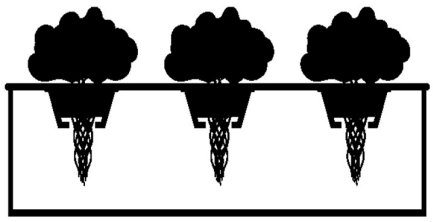
S. No	Focus/Area	Contribution	References
	Hydroponically cultivated plants	Plants grown had a high electrical conductivity with sub irrigation in the upper and lower layers of the pots in both growing seasons	Rouphael, Y. & Colla, G. (2005).
	Growth of fresh food in the city	Hydroponics is regaining popularity due to it viable technological solution to the issues faced in the agriculture system.	Ankitha Panda, et al., (2024).
	To reduce global hunger hydroponic practices to be implemented.	in Colombia, this technology has been explored since 1984 and introduced in 13 countries.	Bradley, P. and Marulanda, C. (2001).
	Aquaponics is the integration of recirculating aquaculture	Hydroponic systems which are considered sustainable food production technology with an innovative, eco-friendly.	Li, G., (2008).
	Growing the Future of Sustainable Farming	An alternative to save the rapidly running-out land and water resources for sustainable production and to modifying the growth.	Resham Chawla, (2023).
	Farming in and on urban buildings	Urban buildings, including open rooftop farms, rooftop greenhouses and indoor farming exist in hydroponic farming.	Thomaier, S, (2015).
	Factors effecting the success and efficiency.	Hydroponic cultivation yields, healthier plants, and sustainable agricultural practices.	Kailash Kumar, (2023).
	Soilless cultivation	In the present scenario, to cope-	Khan, S,

		up with all these challenges Soil-less culture is becoming more relevant and appropriate.	(2023).

HYDROPONIC AGRICULTURE SYSTEM CONCEPT IN CULTIVATION

The hydroponics was discovered in 1937, by William Federick Gericke, popularized in 1940 and solidified in 2000s. The various crops, such as lettuce and tomatoes, are widely used in the Hydroponic systems of commercial production and have been a favoured method for conducting plant biology research. To investigate how plants respond to biotic and abiotic stresses various hydroponic systems have been created by the community of research. This process prepares plant material with detailed guidance on developing hydroponic system and the study was conducted to analyse the impact of two hydroponic systems on effectiveness of nutrient levels and stomata gas exchanges of two greenhouse cultivators of tomato. The traits examined in this study shows as the global population continues to grow, the demand for many products, especially food, increases. This rising demand may cause a food crisis in the coming years. To avoid such crises, alternative farming practices must be utilized. However, studies examine the soil-based agriculture is facing problems due to human activities with urbanization and industrialization and also climate change and chemical used non-organic cultivation which has created havoc and detriment effect on the fertility of soil. In order to address these issues, studies investigated the alternative method called hydroponic cultivation. Which involves cultivation of plants in a water-based nutrient-rich solution (Shrestha Sanchaya, 2023).

One of the major challenges associated with demanding for food is the farmland is lost due to climate change, water insufficiency, soil pollution etc. In the context of hydroponic farming, it is proved to be an efficient method to avoid the constraints. Studies advocated on experiments conducted by scientist in 1600 with the hydroponic cultivation demonstrated plants get nutrients from water. Moreover, plants grow better with solutions enriched with fertilizers, since it requires carbon, hydrogen, oxygen and nitrogen to grow healthy. Further studies done by scientist proved phosphor, sulphur, potassium, calcium and magnesium grow well which play a major role in development of seeds and high yield. Currently, hydroponics farming is becoming increasingly important due to global warming, desertification, water and oil shortages are becoming increasingly significant. (Roberto S. 2022).



Hydroponic farming

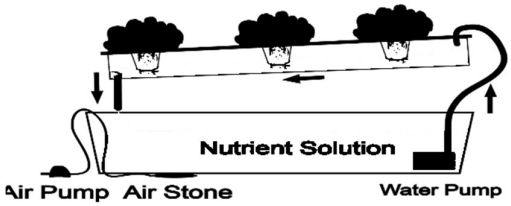
Source: Science Buddies

IMPACT OF TECHNOLOGY TOWARDS HYDROPONIC CULTIVATION

The hydroponic farming produces higher yield by exploiting both horizontally and vertically surface area.by meeting daily customers demand for nutritious product and around densely populated areas. Additionally, major hydroponics facilitates under controlled climate conditions, irrigation, lighting etc. Due to numerous technological advancements, the hydroponics market is shows significant growth from past 2021 and expected to grow till 2028. Moreover, new technologies maximize the cost-benefit at medium and small-scale levels. Furthermore, the optimization of water, nutrients and space is a key benefit of hydroponic. It has been found that water reduction is possible to 90% compared to conventional soil-based farming. Additionally, this method provides the provision for recycling and also reutilization of the solutions with high nutrients. The method of vertical farming techniques promotes sustainability a waste reduction, resulting in high density crop production and innovative technologies. The AI based systems and smart home technology add relevant applications in indoor hydroponics production (Ganapathy Rajaseger, et al., 2023).

The technology nutrient film technique (NFT) is used ubiquitously and will be considered as the classic hydroponics cultivation system. This system signifies nutrient solution flow and circulation introughs with 1-2 cm layer of water level.

NUTRIENT FILM TECHNIQUE



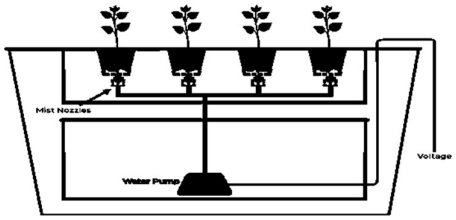
Source: No Soil Solutions

The Aeroponic systems is a technique which is mainly focuses on smaller horticulture species, which is not used highly because of the high cost. The plants support the plastic panels or the polystyrene, which is horizontally arranged commercial production and have been a favoured method for conducting plant biology research.

WATER EFFICIENCY IN SMART FARMING PRACTICES

The water smart farming was developed to investigate the challenges of agriculture water, since the irrigation accounts for staggering 70% of clean water. The practices and aims with regard to agriculture water in climate-smart agriculture encompasses several climate-responsive food cropping system and water-saving method, for food sustainability.

AEROPONIC SYSTEM



Source: Ponics Life

The examples of technologies and better practices in smart-water crop farming like breeding for drought-tolerant crops, promoting dry land system of cropping, alternative wetting and drying technology, water drainage systems, rain water harvesting, cover cropping and also inter cropping for moisture conservation are considered a smart technic in smart water cropping.

SWOT ANALYSIS OF THE SMART FARMING OF HYDROPONIC AGRICULTURE SYSTEM

A SWOC analysis is a quick and effective technique to assess the current state of affairs, pinpoint your comparative advantages, and explore avenues for performance enhancement (Mendon, Sujaya, et al., 2018); (Mendon Sujaya, et al., 2019); (Sujaya H, et al 2019); (Rachana & Sujaya H, (2023).

Table 4: SWOC analysis on Sustainability of Hydroponic agriculture with smart technology

Constructs	Features
Strengths of Sustainability of Hydroponic agriculture with smart technology	The hydroponic method intensifies the usage of necessary nutrients for growth of plant and extracts the nutrient from water. The technology-driven factors reinvigorate crop output, improves growth rates, and maintains conditions ideal for all weather.
Weakness of Sustainability of Hydroponic agriculture with smart technology	AI based systems and smart home technology add relevant applications in indoor hydroponics production which may be expensive for cultivators.
Opportunities of Sustainability of Hydroponic agriculture with smart technology	This method provides the provision for recycling and also reutilization of the solutions with high nutrients. It has been found that water reduction is possible to 90% compared to conventional soil-based farming
Challenges of Sustainability of Hydroponic agriculture with smart technology	The Aeroponic systems is a technique which is mainly focuses on smaller horticulture species, which is not used highly because of the high cost.

	This rising demand may cause a food crisis in the coming years. To avoid such crises, alternative farming practices must be utilized.

Result and Discussion

One of the main elements influencing a hydroponic experiment's success is the condition of the seedlings used. Prior to the plants being moved into the hydroponic system, sterilization of tools, seeds, and culture media is crucial in lowering the danger of contamination and giving the plants a healthy start. A suitable experimental setup requires a working area equipped with equipment such an autoclave, fume hood, cold room (4 °C), and growing space with controlled conditions (temperature and light intensity). The effectiveness of a hydroponic experiment is contingent upon the freshness of the nutrient solution, which also impacts plant health. It is advisable to replace the hydroponic solution at least twice a week since salt concentration changes owing to a reduction in total solution volume caused by water evaporating more quickly in direct illumination.

Findings

Hydroponic farming is practiced in urban settings, such as open rooftop farms, rooftop greenhouses, and indoor farming. Due to numerous technological advancements, the hydroponics market is shows significant growth from past 2021 and expected to grow till 2028. Hydroponic system of commercial production and have been a favoured method for conducting plant biology research. A thorough investigation strengthens the case for smart farming by lowering the need of organic chemical inputs, promoting safe pest management practices, and lowering waste output. Vertical farming systems yield high-density agricultural production and novel technology by promoting sustainability and waste reduction. In soil systems, as nutrients attach to soil particles and form micro-environments inside the soil, their bioavailability varies throughout the soil matrix. When doing tests that need exact control over the external concentration of nutrients or other substances, this variability may introduce an additional layer of complication.

Conclusion

Future growth in the sector is predicted to be exponential due to the increased difficulty of growing in soil. Especially in a nation like India where urban concrete conglomerates are expanding daily, adopting soil-less culture is the only way to help increase the quantity and quality of produce in order to guarantee our nation's food security. Nonetheless, the usage of this technology may be encouraged by government action and research institute interests. Hydroponics holds significant importance for the space program's future. NASA has large-scale plans for hydroponics research that will help with both long-term, future colonization of Mars or the Moon and present space exploration. 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. There are two advantages to hydroponics in space: It offers the potential for a larger variety of food, and it provides a biological aspect, called a bio-regenerative life support system.

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