Chapter 8

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Abstract

This article discusses hydroponics, a vertical farming technique that offers a thorough approach for setting up a hydroponic system. Hydroponics requires very little space, uses 90% less water, and supports year-round growing of practically organic produce. The cyclical and robustness of vertical farming systems are increased when Plant Growth-Promoting Rhizobacteria (PGPRs) are added to plant growth medium, thus enhancing microbial diversity. This method minimizes the demand for synthetic crop protection products and fertilizers. This paper investigates how vertical and hydroponic farming methods employ plant growth-promoting microorganisms (PGPMs). It advocates a coordinated strategy for treating post-germination PM10, which includes giving seeds or seedlings a microbial solution, particularly in aquaponic and aeroponic systems, and applying a biostimulant extraction to the hydroponic medium. The impact of vertical hydroponic farming on the environment in urban environments is explored in this article. It was demonstrated that the factors affecting the system's ecological impact were the growing media, pots, electricity use, and transportation. As per the study, there is a significant potential to reduce greenhouse gas emissions and the decline of abiotic resources by employing the fiber as the growing medium and substituting paper over plastic containers. In order to analyze data, this research study leverages big data analytics to showcase the design and implementation of automated vertical hydroponic farming techniques coupled with Internet of Things (IoT) platforms.

Keywords

Climate-Resilient Produce, Pgpms, PGPR, Vertical Farming, Vertical Hydroponic Farming

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1. Introduction

Vertical farming (VF) systems are emerging as an alternative to the demand for robust food production methods in urban environments due to the expanding population and dynamics of the global food market. Nevertheless, research evaluating their long-term effectiveness is inadequate [1]. Utilizing cutting-edge technologies like hydroponics, aeroponics, and aquaponics, VF is getting increasingly popular all over the world for producing high-quality food and managing resources sustainably. It is especially popular in urban areas with limited resources and has the potential to maximize crop productivity [2]. Plant growth-promoting microorganisms (PGPMs) strengthen plant growth, ecological stress resilience, and phytoremediation effectiveness. Hydroponics and soil-free systems are becoming more and more popular in agriculture owing to the efficient utilization of space, minimal water consumption, pesticide-free behaviors, precise nutrient input control, and user-friendly technology [3]. Focusing on technology innovations like LED lighting and hydroponic automation, VF is an emerging technique that is promoting sustainable food production. To enhance plant performance and resilience, recent studies have examined at microbial ecosystems, water quality, and Plant Growth-Promoting Rhizobacteria (PGPR) [4]. Using hydroponic cultivation techniques and customized growth environments, VF is a sustainable substitute for conventional food production that allows plants to thrive indoors. Preventing nutrient loss and inadequacies requires controlling nutrient levels, which are often assessed employing electrical conductivity (EC) [5]. VF is a multi-layer indoor crop-growing technology applied in urban environments. By minimizing the gap between producers and consumers, it improves the efficiency of resource utilization. VF requires an excessive amount of energy, though, considering it utilizes electric lighting [6]. By optimizing crop growth, minimizing transportation costs and carbon emissions, and cultivating crops without soil, controlled environment agriculture (CEA) technologies like hydroponics and VF are revolutionizing conventional farming methods and resulting in increased crop yields, less water and land utilization, and year-round production [7]. The shortage of cultivable land is a critical issue forced on by the exponential increase in the global population. Considering there is less arable ground available for agriculture as a result of urbanization and the migration of rural inhabitants to urban areas, vertical farming and hydroponics have been growing increasingly popular [8]. VF promotes crop productivity in constrained space by indoor plant production that is regulated by temperatures, light, gasses, and humidity. It fulfills customer demand for fresh, nutritious produce in densely populated areas, produces pesticide- and fertilizer-free, climate-resilient produce, while consuming less land and water [9].

2. Innovative Hydroponics and Vertical Farming

Hydroponic, aquaponic, and aeroponic soil amendment techniques represent examples of controlled environment farming approaches that maximize plant growth. An aspect of this strategy called "vertical farming" is attracting interest from entrepreneurs all over the world. It entails growing crops in well regulated indoor spaces with precision control over temperature, lighting, and fertilizers [10]. The concept of a VF has been completely transformed by innovations in greenhouse technologies including hydroponics, aeroponics, and aquaponics, that offer practical city farming techniques with less maintenance and greater yields. VF might become a reality owing to these technological advancements [11]. Both vertical farming and film farming, which use soilless crop cultivation and stacked shelves and beds to optimize growth environments while minimizing water consumption, can improve food safety and water-saving efficiency. However, their success centers on increased yield and plant quality, which could boost the volume of sales and costs [12]. Utilizing a microcontroller and an open internet of things (IoT) platform for remote control, an indoor automated vertical hydroponic system was created for home crop production. IoT platform assessments validate the system's ability to sustain healthy plant development with minimal input from human beings [13]. As an ecologically friendly and more productive alternative to traditional farming methods which involve an extensive amount of time and labor commitment, hydroponic farming makes utilization of IoT sensors to monitor crop health and restore nutrients and water in time frame [14]. Artificial intelligence, machine learning, deep learning, and IoT are all employed within vertical agriculture—a solution to the constraint of land and water in urban areas—to facilitate precision agriculture, especially in the framework of vertical farming [15]. By integrating real-time sensors, a deep learning convolutional neural network, and an Android-based application for farmers to monitor sensor data and plant disease status, the artificial intelligence (AI) application—integrated with an IoT framework—aims to revolutionize smart hydroponics [16]. Leveraging IoT technology, vertical farming—a cutting-edge agricultural technique for governed plant growth—is growing. In addition to sensors and an automatic pH and Total Dissolved Solids (TDS) balancing system, the system makes utilization of hydroponic Deep Flow Technique (DFT) [17]. An IoT-enabled hydroponic farming system regulates fertilizer delivery and monitor environmental conditions for crops. It has a Raspberry Pi, a microcontroller unit, actuators, and sensors. In addition to managing water pumps and serving as an intermediary for message queuing telemetry transport, the system records temperature, humidity, pH, and TDS [18]. With real-time environmental monitoring, energy savings, adaptability, versatility, and ecologically sound agriculture, IoT platform empowers operators to control soil moisture and supply plants with UV light [19]. A sustainable way to grow plants, veggies, and fruits without land is to use hydroponic techniques, especially those utilizing Rockwool. Substantial yields and shorter growing seasons can be achieved with this technique, particularly in places with polluted water. Smart IoT sensors monitor nutrient levels and productivity parameters [20]. Employing IoT sensors, the Hydroponic Farming Ecosystem (HFE) maintains an accurate watch on hydroponic conditions in real-time, delivering information on humidity, temperature, light intensity, and additional variables. This method is designed for novice urban farmers, people with limited expertise in farming, and anyone enthusiastic in urban vertical farming [21]. Figure 1 below shows a picture of IoT enabled vertical farming approach for crop cultivation.

Figure 1. IoT enabled vertical farming technique

3. Recommendations

After thorough review of the past and current literature available on the technology assisted Hydroponics and Vertical Farming practices adopted by urban population across the globe, we propose following recommendations for further enhancing and promoting vertical farming techniques.

- With the world's population growing and cultivable land becoming limited, the fast-expanding field of hydroponics agriculture has the potential to revolutionize food production. Innovations in hydroponics and vertical farming provide progressive producers with reduced cost disparities.
- In hydroponics, plants can be grown in any location, regardless of the season, as a result of continuous water circulation in tanks that replaces traditional insecticides and watering approaches and eliminates harmful residues.
- Crops grown indoors in vertical farms reduce the demand for heavy agricultural equipment and the burning of fossil fuels. Since crops are delivered closer to the production purposes, the implementation of such farms has the potential to significantly reduce air pollution and CO2 emissions.
- In addition to increasing local food alternatives and decreasing food transportation, this study emphasizes the environmental advantages of vertical hydroponic urban farming systems for growing herbs and green vegetables.
- In contrast to earlier research, the study highlights the need of integrating urban systems and making advantage of available space in order to minimize environmental consequences. This is mainly because untapped building spaces are being exploited.
- The Hydroponic Farming Ecosystem leverages the Blynk app, Raspberry Pi, Bayesian networks, and LabVIEW for principles to manage multiple crops at a single location employing IoT technologies.
- There is uncertainty around the certification of organic foods cultivated on vertical farms because of concerns with the entire soil ecology and natural system involved.

Conclusion

Growing in popularity globally, vertical farms are a relatively new urban concepts that concentrate on high-value, quick-growing crops. Future developments and technologies that will enhance energy efficiency and profitability are the subject of ongoing research. The pillars of environmental, social, and economic sustainability that are addressed by vertical farming have the potential to significantly influence food sustainability in urban environments. Crop production is being revolutionized by cutting-edge farming techniques including aquaponics, aeroponics, and hydroponics. Innovations in multidisciplinary research, greenhouse technologies, and renewable energy are reshaping industrial systems and encouraging collaboration across several domains. The future of vertical farming in agriculture is uncertain because of barriers including high startup costs, difficult implementation, and information-sharing reluctance, even if there are advantages like reduced water usage and better crop quality. With the goal to monitor significant variables including soil moisture, air humidity, and temperature, as well as allow users to manipulate moisture levels and apply UV light, the paper provides an IoT-based solution for vertical farming operations.

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