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Engineering Hydroponic Farming System using Household Waste Material: A Mini Farming Plant Approach

Yogarnav Pawar[1], Krupal Pawar[2], Vasudha Patil[3], Sunita Date[4], K. Ancy[5]
Fifth Class Student, Sri Chaitanya Techno School, Ahilyanagar Branch, Maharashtra, India[1]
Student's Father, Sri Chaitanya Techno School, Ahilyanagar Branch, Maharashtra, India[2]
Student's Mother, Sri Chaitanya Techno School, Ahilyanagar Branch, Maharashtra, India[3]
Fifth Class Teacher, Sri Chaitanya Techno School, Ahilyanagar Branch, Maharashtra, India[4]
Principal, Sri Chaitanya Techno School, Ahilyanagar Branch, Maharashtra, India[5]
krupalpawar@gmail.com

Abstract*: The paper is related to engineering hydroponic farming systems using household waste material for cultivating home-based plants. It is based on a project model made for a science exhibition. Various waste materials, such as plastic bottles, plastic glasses, coconut fibers, etc., are reutilized to fabricate the project. Finally, it is concluded that we can utilize household waste material to effectively develop such a hydroponic system for cultivating home-based plants such as spinach, coriander, chili, etc. This project supports soil-free farming techniques for better human health.*

Keywords: Hydroponic Farming, Household Waste, Human Health, Soil Free Farming.

I. INTRODUCTION

Hydroponics, a soilless plant cultivation method, has gained prominence as an efficient and sustainable approach to agriculture. This technique enables precise control over nutrients, water usage, and environmental conditions, making it a viable alternative to traditional farming [1]. Over the years, technological advancements have enhanced hydroponic systems through intelligent automation, artificial intelligence (AI)-driven optimization, and digital fabrication [2], [3]. However, conventional hydroponic nutrient solutions often rely on synthetic fertilizers, raising concerns about sustainability and environmental impact.

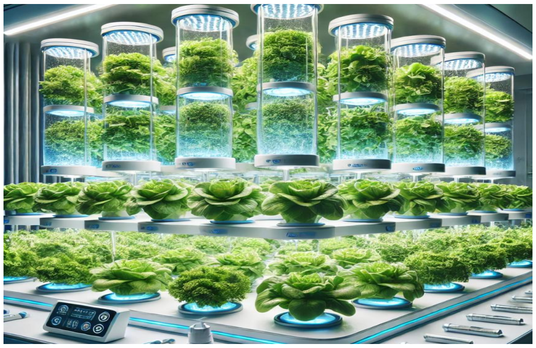

Fig.1 Advanced hydroponics as a soilless plant cultivation method.

Researchers have explored integrating waste-derived nutrients into hydroponic systems to address this issue. Studies have demonstrated that human urine, biogas slurry, and wood ash can be sustainable nutrient sources for plant growth [4], [5]. The use of aquaponics and anthroponics, where aquaculture wastewater and urine are utilized for plant nutrition, has further broadened the scope of sustainable hydroponics [6], [7]. Additionally, urine separation and treatment technologies have been investigated for their potential in circular agricultural systems [8]. Despite these developments, there is a need for further research on optimizing nutrient composition, long-term system performance, and large-scale implementation of waste-based hydroponics.

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II. LITERATURE REVIEW

Hydroponic systems have gained significant attention as sustainable alternatives to traditional soil-based agriculture due to their water efficiency, nutrient optimisation, and space-saving capabilities [1]. Researchers have explored various approaches to enhance hydroponic efficiency, including the use of digital fabrication [2], intelligent automation [3], artificial intelligence-based optimisation [4], and bioprinting for engineering complex hydroponic structures [14]. A key development in hydroponics is integrating waste materials as nutrient sources. Studies have highlighted the potential of aquaponics in recycling aquaculture wastewater and human urine for plant growth [5], [6]. Comparative biogas slurry and urine analyses have also been conducted to assess their efficacy in vertical farming systems [7]. Additionally, wood ash as a nutrient supplement for cucumbers in an aquaponics system has shown promising results [8]. Other studies have investigated human urine as a direct fertiliser in cultivating crops such as cabbage, with notable impacts on chemical composition and microbial properties [9].

Several studies have explored the potential of hydroponic systems in wastewater treatment. Research has demonstrated that hydroponic systems can effectively use urine-derived nutrients to sustain plant growth [12]. The use of urine catalysts, such as Citrullus lanatus seeds, has also been studied to enhance the nutrient composition in anthroponics [18]. The feasibility of using different waste materials, including wood ash and biogas slurry, for hydroponic farming has been examined to understand their impact on nutrient delivery and plant health [19]. Furthermore, lactuca sativa production in urine-based anthroponics systems has shown promising results, supporting the viability of human urine as a nutrient source [17]. The characterisation of faces and urine for advanced treatment technologies has been extensively reviewed, offering insights into their potential use as plant fertilisers [10].

Furthermore, ecological engineering approaches have explored theoretical foundations for wastewater treatment in hydroponic applications [11]. Several experimental studies have demonstrated the feasibility of source-separated human urine for hydroponic farming, emphasising its nutrient composition and impact on plant growth [12]. Studies have also explored the viability of using biogas slurry and urine as sustainable nutrient sources for hydroponic vertical farming, presenting comparative analyses of their effectiveness [16].

Despite these advancements, gaps remain in the widespread adoption of hydroponic systems utilising waste-derived nutrients. While existing studies have demonstrated feasibility, long-term performance assessments, scalability challenges, and economic viability need further exploration. Additionally, real-time monitoring and nutrient adjustment integration in waste-based hydroponics remain underdeveloped. Future research should focus on optimising nutrient composition, enhancing automation, and addressing regulatory concerns for safe implementation at the household level.

Hydroponics offers a sustainable solution for home-based plant cultivation, and incorporating waste-derived nutrients presents a promising approach to resource recycling. However, existing studies primarily focus on feasibility rather than scalability and long-term sustainability. Future research should address technological, economic, and regulatory challenges to facilitate broader adoption of hydroponic systems using waste resources. By bridging these gaps, hydroponics can contribute to food security and environmental sustainability on a larger scale.

III. MATERIAL AND METHODS

The working model of the project is made from various materials such as plastic bottles, wires, m-seal, tape, decorating material, pipe, coconut fibers, water pump, and perforated plastic glass.

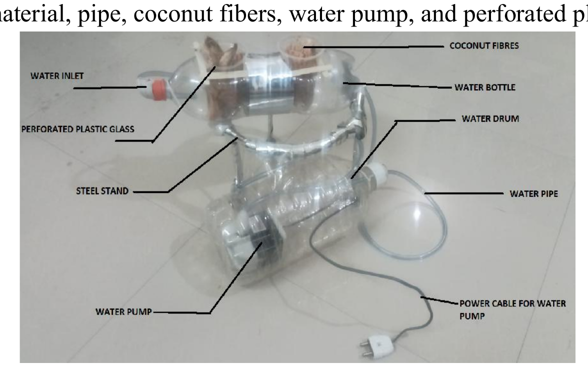

Fig. 2 Working model of Simple hydroponic system using Household Waste Materials.

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3.1 Methodology to Fabricate Model of Hydroponic Farming System

The methodology to fabricate the project is as follows:

Step 1: Collect all basic materials for the hydroponic farming systems, i.e., plastic bottles, wires, m-seal, tape, decorating material, pipe, coconut fibers, water pump, perforated plastic glass, etc.

Step 2: Assemble all material as per the planning sheet.

Step 3: Run Testing of the hydroponic system.

Step 4: Actual plant cultivation and Testing.

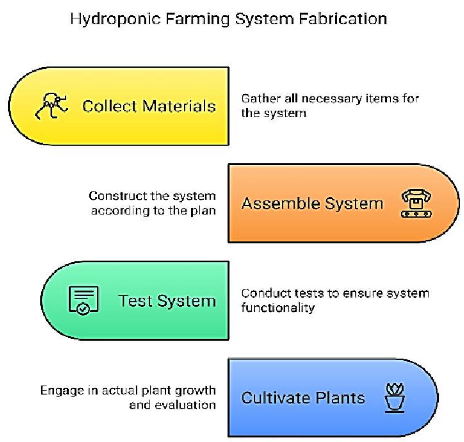

Fig.3 Methodology for Project Implementation.

IV. RESULTS AND DISCUSSION

4.1 Results

The hydroponic system was successfully fabricated using household waste materials such as plastic bottles, wires, coconut fibers, and perforated plastic glasses. The experimental setup was tested with various home-based plants, including spinach (Spinacia oleracea), coriander (Coriandrum sativum), and chili (Capsicum annuum). The plants grown in the hydroponic system using waste-derived nutrient sources exhibited promising growth rates compared to soil-based cultivation. The biogas slurry and human urine showed comparable effectiveness to conventional hydroponic nutrient solutions regarding plant health and yield. The hydroponic system demonstrated significantly lower water consumption than traditional soil-based farming, reinforcing its sustainability aspect. (see Figure 4)

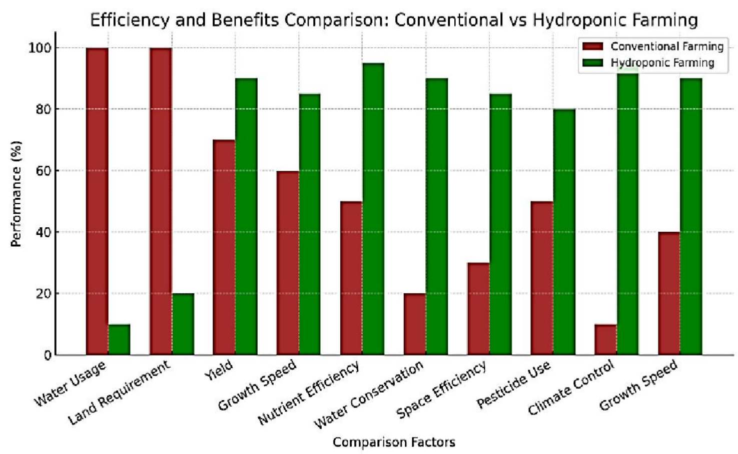

Fig.4 Comparison of Conventional Farming and Hydroponic Farming for Cultivating Vegetables.

4.2 Discussion

Integrating household waste materials in hydroponic farming presents a cost-effective and sustainable alternative for urban agriculture. Using waste-derived nutrients demonstrated potential in replacing synthetic fertilizers, aligning with circular economy principles. The results indicate that plants cultivated using biogas slurry and urine-based solutions achieved growth performance similar to those nourished with commercial hydroponic fertilizers. This supports the viability of waste-derived solutions for home-based farming. The recycling of household waste materials significantly reduces environmental pollution and production costs. This method can be implemented more to promote eco-friendly farming practices. While the study highlights the potential of waste-based hydroponics, specific challenges remain. These include further optimization of nutrient formulations, improved waste processing methods to eliminate contaminants, and enhanced automation for real-time monitoring. Overall, the study reinforces that hydroponic farming utilizing household waste materials is an efficient and sustainable solution for home-based plant cultivation. Future research should focus on refining nutrient combinations, expanding plant varieties, and integrating innovative technologies for enhanced system performance.

V. CONCLUSION

Finally, it is concluded that we can effectively develop a hydroponic system for cultivating home-based plants such as Spinach, Coriander, Chili, etc. This project supports soil-free farming techniques for better human health. Overall, the study reinforces that hydroponic farming utilizing household waste materials is an efficient and sustainable solution for home-based plant cultivation. Future research should focus on refining nutrient combinations, expanding plant varieties, and integrating smart technologies for enhanced system performance.

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Conflict of Interest: Author shows no conflict of interest.

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