

## AEROPONIC FARMING – A SOILLESS METHOD FOR NUTRIENT RICH CROP CULTIVATION

Sangram Kanade<sup>a</sup>, Mohammed Zaid Shaikh<sup>a</sup>, Rutvik Vatsa<sup>a</sup>, Raturaj Bhalekar<sup>a</sup>, Prof. Nilesh Dhokane<sup>b</sup>

<sup>a</sup> UG Student, School of Mechanical Engineering, Dr. Vishwanath Karad MIT World Peace University, Pune, 411038, India

<sup>b</sup> Assistant Professor, School of Mechanical Engineering, Dr. Vishwanath Karad MIT World Peace University, Pune, 411038, India

Email: sangramkanade3@gmail.com, zaidshaikh5088@gmail.com, rutvik.svatsa@gmail.com, raturajb5050@gmail.com, Nilesh.dhokane@mitwpu.edu.in, mandar.lele@mitwpu.edu.in

### ABSTRACT

This research paper examines the potential benefits and challenges of aeroponic farming, a soilless method of cultivating plants in a misted environment. Aeroponic farming has gained increasing attention as a sustainable and efficient solution to food production, especially in urban areas with limited space and resources. The paper discusses the key principles and technologies involved in aeroponic farming, as well as its potential advantages in terms of water efficiency, nutrient uptake, and yield. The findings suggest that while aeroponic farming holds significant promise for the future of agriculture, more research is needed to address its limitations and optimize its potential benefits.

**KEYWORDS:** Greenhouse, Hydroponic, Aeroponic, Misting,

### Introduction

Covid-19 worsened global food security, along with climate change, resource scarcity, energy crisis, population growth, and urbanization, emphasizing the need for comprehensive solutions. (Oh et al., 2021). Land degradation severely impacts global food security, reducing arable land for crop production and exacerbating scarcity.



Figure 1. Greenhouse inside is shown with all the Cooling systems, ventilation systems and Lighting systems. It also demonstrates the enormous area of land required to farm with the help

of a greenhouse which is very suitable for semi-urban and rural areas. But it is not so ideal in Urban areas.

To compensate for the reduced global land area, food production per unit hectare must increase by 50-100% by 2050.(Searchinger et al.,2018). Nations reliant on food imports face affordability challenges and limited access to healthy options due to higher prices and insecurity (Hardy et al., 2021). Therefore, we urgently need to rethink the way we farm.

Greenhouse technology has become increasingly popular in recent years as a sustainable way to grow plants in a controlled environment. In mechanical engineering, the design and construction of greenhouses can involve a range of mechanical systems, including heating and cooling systems which involves a range of approaches including using geothermal heat pumps, heat recovery systems, and thermal collectors Ventilation systems helps to control temperature, humidity, and air quality. A range of approaches to ventilation have been explored, including natural ventilation, mechanical ventilation, and hybrid systems. Lighting systems helps to ensure that plants receive the right amount and type of light for optimal growth. Researchers have explored a range of approaches to lighting, including using LED lighting, natural sunlight, and hybrid systems. The primary concern that discourages adoption of greenhouses in urban areas is the high cost, limited space, energy consumption, risk of diseases and pests that are associated with implementing a full-fledged greenhouse for crop cultivation.

Therefore, this review paper will aim to (i) present the current development of vertical farming and urban agriculture worldwide; (ii) determine state-of-the-art of vertical farming with modern and precision technologies; and (iii) identify current challenges and opportunities of hydroponic and aeroponic farming for crop cultivation.

### **Necessity of Soilless Farming Systems**

Urbanisation has continuously increased worldwide and 55% of the world's population inhabits urban areas. Whilst the population of rural areas residents is expected to drop by 11% in 2030, the number of urban settlements will be continuously increased (United Nations [UN], 2018). ecological impact of food production in terms of carbon emissions (Avgoustaki & Xydis, 2020b).



Figure 2. On the left is an aeroponic farming system which utilizes the nutrient rich mists sprayed in the air to supply nutrition to the roots which are suspended in air. Figure on the right

is hydroponic farming system in which plants are cultivated in nutrient-rich water solutions, without soil.

Urban agriculture addresses food security challenges by utilizing controlled and optimal growing conditions, including temperature, humidity, CO<sub>2</sub>, and lighting, to mitigate societal, environmental, and economic concerns.

It eventually contributes to shortening the growing cycle and increasing plant density and enhancing harvest yield (Khan et al., 2020; Treftz & Omaye, 2016). Owing to urban accessibility, urban agriculture alleviates energy and expenses for transportation, distribution, and storage management, and enables the reduction.

According to Armanda et al. (2019), several countries in Europe and Asia and the United States of America have been practising commercialised hydroponic and aeroponic systems. Unlike conventional controlled environmental agriculture such as greenhouses with natural sunlight, indoor hydroponic and aeroponic farm is based on fully controlling and monitoring the growing condition including artificial light sources with a high yield in less space. Farms vary in location, such as underground, in abandoned areas or on rooftops, reflecting that each farm applies various technologies for specific microenvironments. Overall, urban agricultural farms focus on growing leafy vegetables with a high annual food production (Armanda et al., 2019). In North America, the USA and Canada feature several urban farm projects (e.g., AeroFarms). The AeroFarms is based in New Jersey, and it is one of the largest indoor farms in the world with 8400 square metres of growing space using an aeroponic growing system (Hardy et al., 2021).

Urbanisation has continuously increased worldwide and 55% of the world's population inhabits urban areas. Whilst the population of rural areas residents is expected to drop by 11% in 2030, the number of urban settlements will be continuously increased (United Nations [UN], 2018).

Because of the rapid rate of urbanisation, urban agriculture is developing significantly and practised in Asian countries.

However, there are numerous challenges to its implementation in Asia. For instance, lack of arable areas in urban or peri-urban regions and enormous requirement for residential areas contrary to urban farms. Fluctuating legislation and regulations in different regions also hinder the urban agriculture development (Akaeze & Nandwani, 2020).

The importance of hydroponic and aeroponic farming is significant in low and low-middle-income countries such as in parts of Southern Asia. Unlike in high- or high-middle income countries, urban agriculture has greatly impacted small growers since it is practised for the purpose of self-sufficiency in low- and low-middle income countries. Therefore, there are relatively few urban agriculture projects on an extensive scale, such as at the community or national level.

However, recent urban agricultural programmes have attempted to enhance food security and mitigate the adverse effects on the environment based on an understanding of the current barriers to urban agriculture, including formal settlement issues, rights of property and distance from urban farms to food retailers (Davies et al., 2020; FAO, 2012).

### **Soilless Farming Technologies**

There are namely two popular techniques when it comes to soilless farming techniques. Hydroponic farming is a technique of rising plants in nutrient-rich water solutions,. This farming method has gained popularity due to advantages like higher crop yields, lower water usage, and reduced environmental impact compared to traditional techniques. There has been a significant amount of research done in the field of hydroponic farming, ranging from the design and optimization of hydroponic systems to the study of the effects of nutrient solutions on plant growth. The key factors that can maximize the efficiency of a Hydroponic system are the following-

- Design and optimization of hydroponic systems: Many studies have focused on designing and optimizing hydroponic systems to achieve maximum crop yields and reduce energy and water consumption. For example, a 2020 study published in the journal *Energies* evaluated the energy efficiency of different hydroponic systems and found that using LED lighting and optimizing the nutrient solution delivery system could significantly reduce energy consumption.
- Nutrient solution formulation: The composition of the nutrient solution used in hydroponic farming is critical to plant growth and productivity. A 2019 research printed in the *Journal of Plant Nutrition and Soil Science* evaluated the effect of different nutrient solution formulations on the development and harvest of cherry, tomato plants. The study found that a nutrient solution with a balanced composition of nitrogen, phosphorus, and potassium, along with micronutrients, resulted in the highest crop yields.
- Automation of hydroponic systems: Automation can help to reduce labour costs and improve the efficiency of hydroponic systems. A 2018 study published in the *Journal of Agricultural Engineering and Biotechnology* evaluated the use of artificial intelligence (AI) and machine learning (ML) algorithms to optimize the performance of a hydroponic system for lettuce cultivation. The researchers found that the AI- and ML-based system could significantly improve crop yields while reducing water and energy usage.
- Hydroponic system modelling and simulation: Modelling and simulation can help to optimize the design and operation of hydroponic systems. A 2020 study published in the *Journal of Agricultural Science and Technology* developed a dynamic model of a hydroponic system for lettuce cultivation. The model was used to simulate the system's performance under different environmental and operational conditions and to optimize the nutrient solution delivery and lighting system.
- Environmental impact of hydroponic farming: While hydroponic farming has many benefits, it is also important to consider its environmental impact. A 2018 study published in the journal *Environmental Science and Pollution Research* evaluated the carbon footprint of different hydroponic systems and found that the use of renewable energy sources and efficient water recirculation systems could significantly reduce the carbon footprint of the system.

Overall, the literature suggests that hydroponic farming has the potential to be an efficient and sustainable method of agriculture.

Aeroponic farming is a type of hydroponic agriculture in which plant roots are suspended in the air and sprayed with a nutrient-rich mist. This method of cultivation has several advantages over traditional soil-based farming, including higher crop yields, reduced water usage, and

faster growth rates. In recent years, there has been a growing interest in aeroponic farming as a potential solution to some of the challenges facing modern agriculture. The key factors that can maximize the efficiency of a Aeroponic system are the following-

- Optimize nutrient delivery: Proper nutrient delivery is crucial for the health and growth of plants in an aeroponic system. Make sure to regularly monitor and adjust the nutrient solution to maintain the ideal pH and nutrient levels for the plants being grown.
- Use high-quality seeds: Starting with high-quality seeds can help to ensure healthy and productive plants. Look for seeds that are specifically designed for hydroponic or aeroponic growing.
- Maintain a clean and sterile environment: A clean and sterile growing environment is essential for preventing the spread of disease and maintaining plant health. Regularly clean and sanitize the growing equipment and ensure that the growing area is free of pests and other contaminants.
- Automate systems: Automating various systems such as nutrient delivery, lighting, and temperature control can help to optimize efficiency and reduce labour costs.
- Optimize lighting: Adequate lighting is essential for plant growth and productivity. Make sure that the lighting system is optimized for the type of plants being grown and that the light intensity and duration are appropriate for the plant's growth stage.
- Monitor environmental conditions: Regularly monitoring environmental conditions such as temperature, humidity, and CO<sub>2</sub> levels can help to ensure optimal growing conditions for plants.

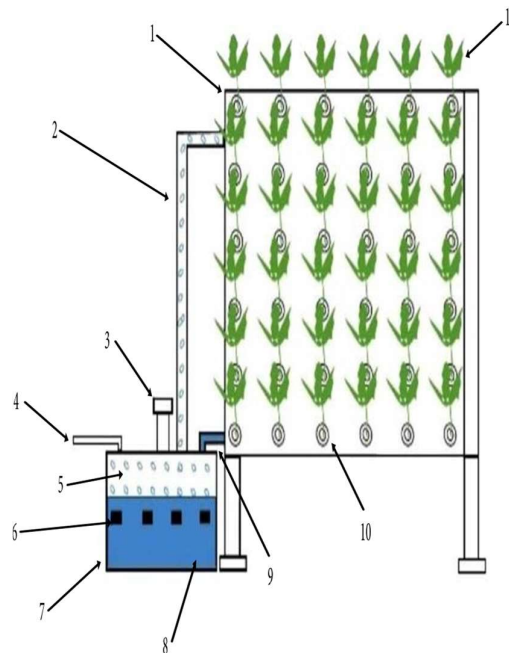


Figure 3. It shows an aeroponic system in action where the nutrient rich liquid is stored in the tank below and this liquid is periodically sprayed onto the roots of the crops via delivery tubes.

The plants are also provided adequate ventilation and weather conditions along with ample amount of light either to the roots or directly to the leaves depending upon the farming system.

**Advantages of Aeroponic Systems over Greenhouse Systems**

Aeroponic Farming System	Greenhouse Farming System
<p>Water efficiency: Aeroponic systems offer exceptional water efficiency, using 90% less water than soil-based agriculture and 70% less than greenhouses, making them ideal for water-scarce regions or conservation-focused areas.</p>	<p>Higher water usage: In greenhouse systems, water usage is higher compared to aeroponic systems due to two primary factors. Firstly, water is required for irrigating plants grown in soil within the greenhouse. This water is essential to provide adequate moisture for plant growth and maintain optimal soil conditions. Secondly, water is utilized to regulate and maintain the desired humidity levels within the greenhouse environment. Maintaining proper humidity is crucial for the healthy growth of plants and to create a favourable microclimate. While greenhouse systems offer advantages in terms of climate control and protection, their water requirements are relatively higher compared to water-efficient aeroponic systems</p>
<p>Faster growth and higher yields: Aeroponic systems promote faster plant growth and higher yields compared to plants grown in greenhouses due to their exposure to elevated oxygen levels and nutrient availability. By delivering nutrients directly to the plant roots in a misted or fogged form, aeroponic systems optimize nutrient absorption and minimize resource waste. This enhanced nutrient uptake, coupled with increased oxygen levels surrounding the roots, facilitates accelerated plant development, resulting in faster growth rates and improved productivity when compared to greenhouse cultivation..</p>	<p>Soil depletion: Greenhouse systems that use soil as a growing medium can suffer from soil depletion over time, as nutrients in the soil are depleted by plant growth.</p>
<p>Greater control over plant growth: Aeroponic systems allow for precise control over the plant's growing environment, including the amount of nutrients and water delivered to the roots, the amount of light received, and the temperature and humidity levels. This can result in better quality plants and higher yields.</p>	<p>Limited control over plant growth: Although greenhouse systems provide some control over plant growth, the control is limited compared to aeroponic systems, especially when it comes to precise control over nutrient delivery and oxygenation.</p>
<p>Reduced disease and pest issues: Aeroponic systems are less prone to disease and pest issues compared to greenhouse systems, as they are grown in an enclosed environment that is free of soil-borne pathogens and pests.</p>	<p>Higher risk of disease and pest issues: Greenhouse systems are more prone to disease and pest issues compared to aeroponic systems as they often rely on soil or other growing media, which can harbour pathogens and pests.</p>

Lower operating costs: Aeroponic systems require less labour and resources compared to greenhouse systems, as they do not require soil, manual watering, or as much maintenance.	Energy consumption: Greenhouse systems require significant amounts of energy to maintain the desired temperature, humidity, and light levels, especially in colder or darker climates, which can lead to higher energy costs and carbon emissions.
--	--

**Advantages of Aeroponic Systems over Hydroponic Systems**

<b>Aeroponic Farming System</b>	<b>Hydroponic Farming System</b>
Water efficiency: Aeroponic systems are more water-efficient than hydroponic systems, as they use misting or spraying systems to transport nutrients straight to the plant roots, resulting in less water waste.	Higher water usage: Hydroponic systems typically use more water than aeroponic systems, as the nutrient solution is recirculated through the system and can result in water loss due to evaporation and leaks.
Increased oxygenation: Aeroponic systems provide plants with increased oxygenation, which can promote faster growth and higher yields compared to hydroponic systems.	Reduced oxygenation: Hydroponic systems may not provide sufficient oxygenation to the plant roots, which can lead to slower growth rates and reduced yields compared to aeroponic systems.
Reduced disease and pest issues: Because plants in an aeroponic system are grown in an enclosed environment, they are less susceptible to pests and diseases than those in a hydroponic system.	Increased risk of disease and pests: Hydroponic systems are susceptible to disease and pest issues, as the nutrient-rich solution and warm, humid growing conditions can provide an ideal environment for pathogens and pests to thrive.
Higher nutrient absorption: In an aeroponic system, plant roots are exposed to a fine mist or spray of nutrient solution, which allows for maximum nutrient absorption compared to hydroponic systems.	Greater nutrient depletion: In hydroponic systems, the nutrient solution can become depleted over time as the plants absorb nutrients from the solution, resulting in lower plant yields and reduced nutrient quality.
Versatility: Aeroponic systems offer versatility in cultivating various plants such as vegetables, herbs, and fruits. They can be employed in different settings, including urban areas and indoor environments. This adaptability allows for efficient and space-saving cultivation, making aeroponics suitable for a wide range of applications and locations.	Root rot: Hydroponic systems can be prone to root rot, a fungal disease that can occur when roots are constantly submerged in water or when there is poor air circulation around the roots.

**Methodology:**

**Process parameters:**

1. Planting: Seeds or seedlings are placed in a growing medium or a specialized support structure, such as foam plugs or net pots. The roots of the plants are bare to the air.

2. **Nutrient Delivery:** A nutrient-rich mist or spray is delivered straight to the plant roots. This is typically achieved using high-pressure pumps and specialized nozzles that atomize the nutrient solution into fine droplets.
3. **Root Zone Environment:** The plants' root zone is maintained in a highly oxygenated environment. This can be achieved by providing continuous or intermittent misting, allowing the roots to take up oxygen directly from the air.
4. **Monitoring and Control:** Various environmental parameters such as temperature, humidity, pH levels, and nutrient concentration are continuously monitored using sensors. An automated control system adjusts these parameters as needed to maintain optimal growing conditions.
5. **Recirculation System:** In this setup, the excess nutrient solution that drips off the plant roots is collected and recirculated back into the system. This helps conserve water and nutrients, promoting sustainability.
6. **Lighting:** In indoor aeroponic setups, artificial lighting is provided to support photosynthesis and plant growth. Energy-efficient LED lights are commonly used to provide the necessary light spectrum and intensity.
7. **Harvesting:** When plants in aeroponics systems reach maturity, they are harvested by being carefully removed from the system. Prior to consumption or further processing, the harvested plants are often rinsed to eliminate any residual nutrient solution. This rinsing step ensures that excess nutrients are removed, promoting food safety and maintaining the desired flavour and quality of the harvested produce. By properly preparing the harvested plants, they are ready for direct consumption or can be utilized in various food processing and culinary applications.

#### **Selection of Pump:**

Ideally high-pressure pump is required for the aeroponics plant pods, 100-80 PSI required for reach plant pod. Height of the tower including the tank where the nutrient solution is stored is  $166+45=211\text{cm}=2.11\text{ m}$  low temperature (8 to  $10^{\circ}\text{C}$ ),

Fabrication:



**Fig 2.: Misting Pump**



Sr.No.	Parameters	Values
1.	Temperature of Liquid	Maximum 50°C
2.	Flow Rate	4l/min
3.	Head	80bar
4.	Max. Head	90bar
5.	Motor Ratings	800W
6.	Voltage	230 V
7.	Current	6.5 A

**4 Seed Selection:**

Two seeds grown were:

1. Green Spinach
2. Red Amaranths

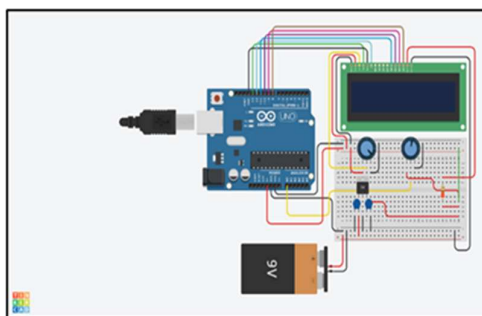
**Software Modelling**

Solidworks was used to make the models.

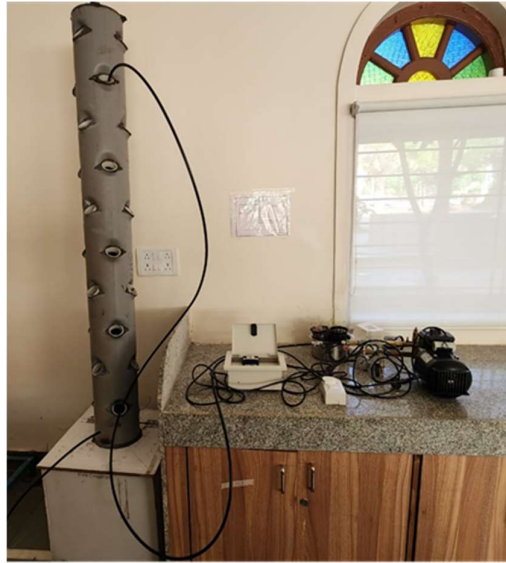


Aeraponics Tower CAD Model

TinkerCAD Model of the Ph Sensor



**Project Setup:**



A high-pressure pump and specialized nozzles deliver a fine mist of nutrient solution directly to the roots, providing the necessary nutrients and moisture.

The roots are exposed to air, allowing for optimal oxygenation, while the misting ensures efficient nutrient uptake. Environmental factors such as temperature, humidity, and pH levels are monitored and controlled using sensors and automated systems.

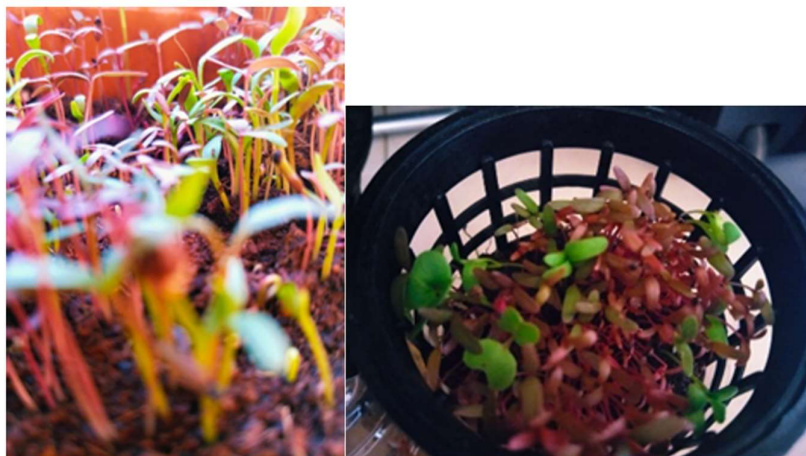
Artificial lighting can be provided in indoor setups to support photosynthesis. The setup is designed to maximize plant growth, minimize water and nutrient consumption, and provide an efficient and controlled environment for crop cultivation.

### **Seed Germination**

Two sets of seeds were used to germinate. The first set of seeds were sown in the soil and the second set of seeds were planted on cocopeat and grown indoors.

Cocopeat is not soil, instead it is the husk of coconuts which is fermented and later dried and powdered to form cocopeat which is an alternative of soil. The cocopeat absorbs water and helps the seeds to germinate.

After germination of the seeds in the pods they are transported to the aeroponics tower





### Results and Discussion

1 Growth Rate: Aeroponically grown plants exhibit faster growth rates compared to traditional soil-based cultivation methods. The increased availability of oxygen and nutrients to the roots in an aeroponic system promotes accelerated growth and development.

2 Root Development: Aeroponics encourages the development of a well-branched and dense root system. The absence of soil allows the roots to freely explore the air space, resulting in increased root mass and improved nutrient uptake efficiency.

3 Crop Yield: Aeroponic farming has the potential to produce higher crop yields compared to conventional methods. The optimized nutrient delivery system ensures that plants receive the necessary nutrients precisely and efficiently, leading to enhanced productivity.

4 Water and Nutrient Efficiency: Aeroponic systems are known for their efficient use of water and nutrients. By delivering nutrients directly to the roots in a mist form, less water and fewer nutrients are required compared to traditional soil-based farming, minimizing resource wastage.

5 Disease and Pest Resistance: Aeroponically grown plants are less prone to soil-borne diseases and pests. The absence of soil reduces the risk of soil-borne pathogens, and the controlled environment minimizes exposure to pests, resulting in healthier plants.

6 Quality and Nutritional Content: Aeroponically grown plants exhibit superior quality attributes such as improved flavor, texture, and nutritional content. The precise control over nutrient delivery and environmental conditions allows us to produce high-quality crops with enhanced nutritional profiles.

### Conclusion

In conclusion, aeroponic farming presents a promising and innovative approach to crop cultivation. Through the precise delivery of nutrients and the optimization of growing conditions, aeroponic systems offer numerous advantages over traditional soil-based farming methods.

Furthermore, the efficient use of water and nutrients, along with the reduced risk of soil-borne diseases and pests, highlight the sustainability and resilience of aeroponic farming. The superior quality and nutritional content of the harvested crops further emphasize the potential of aeroponic farming to meet the demands of a growing population.

Overall, this project underscores the viability of aeroponic farming as a modern and efficient approach to crop production, contributing to the advancement of sustainable agriculture practices.

## References

Papers from Journals or transactions:

- [1] Kaur Gagandeep, *Aeroponics Technology: Consecration or Curse*, International Journal of Engineering Study & Technology, Vol. 3, Issue 7, July 2014, pp 692
- [2] M. Jagadesh, et al., *IoT based Aeroponics Agricultural Intensive care Arrangement Using Raspberry Pi*, International Journal of Engineering Study & Technology, Volume 6, Issue 1 February 2018, pp 601 607.
- [3] Dholwani Sagar. J, *Introduction of Aeroponics Systems, and their Methods*, IJRTI, Vol. 3, Issue 3, 2018, pp 69 73.
- [4] M Chitra, et al., *IOT Based Smart Aeroponics*, IJRTI, Vol.7, Issue 8, August 2020, pp 1955 1958.
- [5] Nana Lal Mali, et al., *A Review on Aeroponics: Demand of Future*, Universal Study Journal of Humanities and Interdisciplinary Studies, Vol.2, Issue 6, June 2021, pp 320 332
- [6] Gokul Anand.K.R, et al., *Aeroponics a Sustainable Agriculture Production System*, International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-9 Issue 6, April 2020, pp 1861 1867.
- [7] Sahoo Deeptimayee, *Aeroponics System of Cultivation in Horticultural Crops*, Just Agriculture, Vol.1, Issue 1, September 2020, pp 32 40

## Links:

- [1] <https://www.udemy.com/course/iot-enabled-Aeroponics-indoor-automated-system/learn/lecture/14632664?start=15#content>
- [2] <https://www.youtube.com/watch?v=RQwSZa-1hQ8>