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IoT based Farming Techniques in Indoor Environment: A Brief Survey

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Abstract— **The past few decades, research is going on growing of plants without soil and supplying the nutrients with manual control to help farmers for high yield and less cost. The hydroponics technique was used for plants for its high growth of plants. These techniques had the problems of its high initial cost and required a trained person for the maintenance. These techniques were later interfaced with IoT for controlling the system via the internet. There was more water usage when compared to a new technique called Aeroponics. In recent years, the hydroponics technique was interfaced with machine learning algorithms which achieved accurate growth of plants based on the nutrients supplied to plants which reduced a little water usage. In aeroponics, which is reduced almost 98% less water usage when compared to the other existing techniques. In this paper, Considering the yield and the growth of plants, existing technologies are discussed and an efficient approach is provided for the accurate growth of plants with less water usage and minimum need of nutrients using machine learning based aeroponics technique with multiple input parameters like humidity, temperature, airflow, nutrients, carbon dioxide, and light intensity.**

Keywords: ***Aeroponics, IoT, Machine learning, Hydroponics***

I. INTRODUCTION

In India, most of the farmers depend on the rain and other environmental conditions for the growth of their fields. Farmers need fine quality of soil and natural minerals for the high quality of growth of fields. The farmers also require working cost for plowing and removal of weeds. Due to high labour cost, unfavorable environmental conditions, less rainfall and less area for farming, it is very essential to do indoor farming. These techniques stresses on indoor farming for preventing losses due to climate changes, pest attaches and soil borne diseases. The plants can be grown throughout the year by artificially controlling and adjusting the surrounding environmental conditions like humidity, temperature, airflow, nutrients, carbon dioxide, pH and light intensity[1], these are called input parameters. The system minimizes the environmental impact and improves crop yield when compared to traditional cultivation system [2]. Hydroponics and aeroponics are methods which are plant cultivation techniques with no soil usage by providing artificial environment for the cultivation. The nutrients to roots in aeroponics and hydroponics are provided by nutrient tanks by controlled environment [3] by making an artificial supporting structure. The basic diagram for aeroponics system is shown in fig 1.

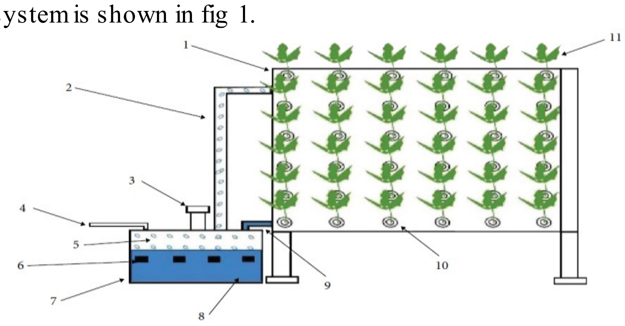

Fig 1: Aeroponics basic plant farming system by Lakhiar et al. [4].

1. Growing chamber. 2. Nutrient supplying pump. 3. Misting fan. 4. Power supply line. 5. Nutrient mist. 6. Atomizers 7. Reservoir for nutrients, 8. Solution of nutrients. 9. Nutrient recycling line. 10. Plant proprietor. 11. Plants.

The sensors are used for measuring the input parameters. For the high yields and optimum plant growth, the input parameters should be in range specified by the dataset. The dataset is designed after the analysis of the plants for its optimum growth. The aeroponics tank contains the (nutrient + water) solution with desired pH. The pH sensor continuously monitors the fluctuations. The levels of aeroponics tank are measured from by the water level sensor for prevention for fluctuations in the threshold values of tank levels. If the levels decrease, the water pump sends the water from the main tank. The water is sent to plants in the form of mist in order to reduce the water usage. The datasets are sent in the processor with Machine learning algorithm. The machine learning algorithm helps in taking the decisions because it is hard to appropriately control factors. For instance a sensor, attempting to increment encompassing moistness and another attempting to raise temperature or even neglect to trigger. In that case, the Artificial Intelligence framework will be helpful. An AI framework will have
the option to envision things like the slack between turning an AC unit on and the temperature diminishing, so it will have the option to be both progressively productive and increasingly exact in the manner it controls your condition.

Section II describes about related work in soil -less system. Section III describes about current status of the aeroponics system. Section IV describes about important artificial intelligence techniques in agriculture. Section V describes comparison with the current techniques. Section VI is the future scope with conclusion.

II. RELATED WORK

Several studies showed that hydroponics and aeroponics as modern farming. Using these techniques, the food crisis can be resolved [5]. The aeroponics technique can reduce the nutrient and water usage by 60 and 98% respectively. Using aeroponics, the plant yields[6] increased by 45 to 75%. Aeroponics is new technique for plant growth without using soil. Until now it is not implemented among farmers. Many researchers are practicing this technique, so as to provide an efficient and controlled environment for high growth of plants and make it almost automatic so that the human intervention is avoided and farmers can use it without many problems. But aeroponics has vulnerability of nutrient distribution, chances of water pump failures, clogging of atomized nozzles, so needs a special knowledge in order to avoid system failure [7]. So aeroponics system must be interfaced with intelligent system for making system automatic. Several techniques were tested for improving agricultural practices. The collection of data from sensors and using communication technology improved agricultural production. Zhang et al used sensor network [8] for monitoring humidity, temperature, light intensity and soil moisture. Jonas et al. developed [9] automatic monitoring system for controlling nutrient supply and environmental system for aeroponics system. They have used arduino board. Sani et al. designed web based monitoring and controlling system [10] for aeroponics system. The design was composed of Arduino, Raspberry Pi, actuators, Light Dependent Resistor (LDR) sensor, pH and temperature sensors and communication modules. The proposed system data was collected through sensors and passed over internet to servers.

III. CURRENT STATUS OF THE AEROPONICS SYSTEM

The aeroponics system is a soilless culturing of plant, where plant is grown in air without using soil but using artificial support. In this technique, roots of plants are hanged and grown with a controlled environment and providing all the required nutrition's in a definite proportions. The upper portions of plant are outside growth chamber. The roots are provided exposed in air and water is supplied as droplets in the mist form at interval basis. Buer et al. [11] used a atomized nozzle for water- nutrients solution and it has provided excellent growth for a plant. Until now, many research is being done with plant root response to drought[12], oxygen concentrations at different levels[13], root microorganism[14]. The studies also practiced this technique potato [15], tomato[4], maize[16], soybean[17]. Aeroponics is receiving full attention of farmers, entrepreneurs, policy makers and agricultural researches. The growers can reduce the usage of chemicals, fertilizers, pesticides; it will be like organic farming. The grower can get high yields with high accurate growth of plants. Anitha and periswamy reported [18] families are using aeroponics for growing the plants on terrace. The challenges in aeroponics system are: Any failure in water pumps, atomization clogging of nozzles, nutrient solution distribution can lead to effect the growth of plants. Some hand operated contribution is required, so in case of failure of system there can be need of expertise. If the input parameters like temperature, pH, light intensity etc if slight drift in these parameters can affect the growth of plants. The amount of attention and expertise required is high. In order to overcome these challenges, Artificial Intelligence (AI) can be used. The system can be interfaced with machine learning algorithms for more accurate growth of plants. The artificial intelligence techniques [19] can lead to easy fault detection and automate the system without any human intervention. Aeroponics can gain much popularity for controlling and monitoring the plants among farmers. The basic difference is the supply of nutrients in Aeroponics is through mist but in hydroponics, it uses water for the supply of nutrients.

Table 1: Dataset utilized to analyze the proposed work[7]

S. No	Parameters	Values	Instruments
1	Desired pH values of nutrient solution	The pH value generally depends on crop that is being grown. Like for carrot 5.8 to 6.4, potato 5 to 6 and Tomato 5.5 to 6.5 etc.	pH sensor
2	Humidity	70% to 100% moisture	Humidity sensor
3	Temperature	most favorable is 25°C to 30°C and not more than to 32°C	Temperature sensor
4	Atomization of Nutrient	Mist size flow of nutrients at high pressure from 10 to 100, low pressure from 5 to 50	Nozzle atomization for high and for low Pressure
5	Carbon dioxide ($C0_2$)	500 and 5000 parts per million	CO_2 sensor
6	Light intensity	8 to 10 hours in a day	Light intensity sensor

The table 1 describes about the range of parameter values for the different crops. The range for pH value is 5.5 to 6.5. The average temperature range is 25°C to 30°C. The atomization of nutrients is in the form of mist with a high pressure and

low pressure depending on requirement of the nutrient content. The carbon dioxide range should be 500 to 5000ppm. The light intensity should be on for 8 to 10 hours in a day. The data contains the details about the temperature, humidity, pH, LDR (Light Dependent Resistor) and carbon dioxide concentration with different iterations.
The methodologies involved in predicting the parameters are described below:

1) **Temperature Sensor**: For aeroponics system, the temperature is kept between 25°C to 30°C for optimum growth of plants. This sensor measures the temperature and is sent as an electrical signal to the system processor for further processing. The processor tries to maintain the temperature within 25°C to 30°C depending on crop of plant.

2) **Humidity Sensor:** This sensor measures the water content (moisture content) in the growth chamber. This plays an important part in plant growth. If moisture in the chamber is less than the nutrient + water tank must supply the water from the tank. The humidity is maintained between 80-100 % in the growth chamber.

3) **Light intensity sensor:** For some plants, the light intensity required is less and for some it's more. So depending on the crop that are grown the light intensity varies. The plants need 8 to 10 hours of day light. The light sensors can turn on or off the light depending on the signals got by actuators.

4) **CO2 sensor**: This sensor will monitor the carbon dioxide fluctuations in the growth chamber. There are carbon dioxide gas measurement is done by the characteristic absorption with infrared source, infrared detector, inference filter of light tube.

5) **pH sensor:** The pH will describe about acidity of solution. The pH sensor is put in the nutrient tank solution to check the acidity of solution. The pH will vary depending upon the plants which are grown. It's the pH is not proper then the plant can face poor productivity. The average pH range from 5.5 to 6.5 for the good productivity of plants.

IV. IMPORTANT ARTIFICIAL INTELLIGENCE TECHNIQUES IN AGRICULTURE

Machine learning is a subset of Artificial Intelligence (AI). The AI helps the computers in taken the decision on its own after getting trained for a required task. As human mind, thinks from its past experiences and takes decision, in the same way AI takes its decision based on the past data based on the algorithms. The machine learning algorithm can be used for controlling the plant growth using hydroponics by controlling the flow of nutrient solution. There are many algorithms in machine learning but the most popular once for machine learning are using Bayesian network and artificial neural network. In one of research paper, Bayesian network[20] algorithm for smart farming for controlling the parameters like of pH, water level and temperature changes and light intensity management in hydroponics. The datasets were gathered over for a month and analysis was done. In another research paper, applied artificial neural network[21] for the hydroponics data sets. It predicted accurately the pH and other parameters like of pH, water level and temperature changes and light intensity management for growth of plants. Either of the two algorithms can be used for accurate prediction of pH and other parameters for desired growth of plants. Appropriately controlling the Aeroponics condition is maybe one of the most testing undertakings the advanced producer must face. With a little develop room or a major nursery, it is hard to appropriately control factors, for example, temperature, moistness, pH and supplement focus, guaranteeing they are totally kept in close ranges with the best possible controlling activities continually being applied. Aeroponics crops are dynamic frameworks, with plants ceaselessly influencing their condition and requesting control activities [22] so as to keep conditions consistent. For instance plants will in general unfold water and ingest carbon dioxide during their light cycle; so as to keep dampness and carbon dioxide focus consistently you may need to turn on humidifiers, carbon dioxide generators, and so on. Realizing what move should be made isn't paltry and innocent control usage – like turning on humidifiers, AC frameworks, and so on when a few edges are reached – can cause issues where sensors battle one another (for instance a sensor attempting to increment encompassing moistness and another attempting to raise temperature) or even neglect to trigger. So as to give better control, scientists have made frameworks that depend on AI – frameworks that can gain from models – so as to realize what control activities are required and execute them so as to give perfect control to a hydroponic arrangement. An AI framework will have the option to envision things like the slack between turning an AC unit on and the temperature diminishing, so it will have the option to be both progressively productive and increasingly exact in the manner it controls your condition.
The drawbacks of algorithms, Bayesian network and artificial neural network algorithms couldn't produce appropriate action and control actions based on parameters trained for the hydroponics system. In order to overcome this deep neural network algorithm could able to appropriately take control action on real time basis. The combination of aeroponics technique interfaced with machine learning can make the yields better for the plants with less nutrients and water usage. The smart farming can still be enhanced by using the design AI- enabled edge computing [23] that can increase the speed and range of IoT applications that can used as interfaced in future. This computing decreases the unexpected failure for continuous monitoring at very low latency.

V. COMPARISON OF EXISTING TECHNIQUES OF FARMING WITHOUT SOIL

Table 2: Advantages, disadvantages, the future scope and the performance measures for existing literatures.

Paper	Technology/ Principle used	Advantages/ Disadvantages	Future scope	Performance measures
Paper[22]	1) Deep neural network algorithm as machine learning algorithm. 2) IoT for machine to machine interaction so that there is no human involvement.	Achieved a great accuracy in growth of plants. No human involvement in the system. The plants growth will be least effected by global warming More plants can't be grown in a single tank. The water consumed can be still reduced if aeroponics technology is used.	It could be extended to grow more hydroponics plants in different tanks. Hydroponics can be done on large scale. Can be developed with mobile application for controlling instead of Machine learning algorithms.	Temperature: 27°C to 31°C Humidity: 90% pH: 5.5 to 6.5
Paper[24]	Different methods of hydroponics like drip system, deep water method etc.	Hydroponics can be used for growing plants for supporting life on space also. This method can be used in places where gardening is not possible. People can grow their vegetables easily even if they are in crowded places. Pesticide and insecticides usage will be reduced and the soil will be in safe position.	It can be integrated with Machine learning for high accuracy. It can be applied for growing other plants also.	Temperature: 25°C to 30°C Humidity: 80% pH: 5.5 to 6.5
Paper[25]	Automatic aeroponics system using a mobile application, IoT devices with sensors and service platform.	Mobile application was developed with easy interface for farmers. Lowers farmers cost from ploughing the field, removal of weeds etc.	If mobile application gets hanged then farmers can't sort out the errors. Water loss in more compared to using sensors.	Temperature : 25°C to 30°C Humidity: 75% pH: 5 to 6
Paper[26]	Aeroponics is a blessing or a curse	Low production cost, zero pesticide usage, saves water in a huge quality and clean environment. Planting and harvesting can be done throughout the year.	Some training is required for system maintenance. Initial cost of system is high.	Temperature : 24°C to 30°C Humidity: 75% pH: 5 to 6.5
Paper[10]	Designed a control system to manage actuators like fan and mist maker. Sensor data is transmitted via internet.	Alternative method monitoring and controlling using wireless sensor and actuator network. This method has used solar panel for reducing power usage	Initial cost of system is high as includes solar panel and other wireless network.	pH value 5.5 – 6.5. Temperature:22°C to 28 °C Humidity -80%to90%
Paper[27]	Automatic hydroponic system integrated to agricultural curriculum	No creepy crawlies creatures and infection. Automatic system	Cost is high. If any failure occurs in system then a farmer can't able fix it.	pH: 5.8 and 6.5 Temperature: 22 °C to 28 °C Humidity–60%to 80%
Paper[28]	Automatic monitoring aeroponics irrigation system based on IoT and Raspberry Pi	Power is saved due to automatic control system. Closed system for water conservation. Easy harvesting. Reduced labour cost	Initial cost of investment is high.	Average temperature : 28.5°C pH: 6.2 – 6.7 Humidity–70%to 85%
Paper[29]	Cloud based technology for storage of data and shared with users	This method has generated fully functional system. Information can be shared with others via internet. Simple and cheap management system	Difficult to achieve ideal temperature and relative humidity. Water pump size must be larger for the sprinkling.	Temperature – 18.33°C to 26.67°C Humidity–50%to 80% pH:4,pH: 7 and pH 10

The paper[30] tells about the growth of plants is aeroponics is very healthier because of plants environment is clean. The growth of plant is faster in a more balanced way. The number of plants growing in a limited area can be increased as the fight for the basic parameters like water, nutrients etc can be eliminated. The potato growing in aeroponics [31] with high yields. The user can harvest any size of potato by controlling the input parameters like the nutrients, pH, and humidity etc. aeroponics technique has caliber to reduce the cost and increase the yields compared to hydroponics. The table 2 describes about the advantages, disadvantages and future scope about different methods used in existing literature. In order to overcome these disadvantages, integration of Aeroponics and machine learning strategies can be opted and the architecture is proposed below.

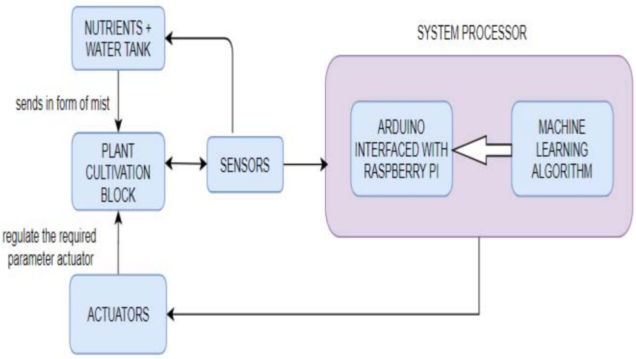

Fig. 2: Proposed architecture of aeroponics system

Figure 2 explains the proposed architecture of aeroponics system. The arduino is interfaced with Raspberry pi which is implemented with suitable machine learning algorithm. The sensors collect the data from the plant cultivation block and send it to the system processor. If there is any fluctuation in the input parameters with respect to the threshold then the system processor sends the signal to actuator a desired actuator, in order to maintain desired parameters. The system processor is implemented with machine learning algorithm which can lead to easy fault detection and automate the system without any human intervention. If there is conflict between sensors decision like a sensor attempting to increment encompassing moistness and another attempting to raise temperature, in that case AI frameworks can take over the correct decision for controlling of the human made environment for proper plant cultivation. The hardware components needed for the system implementation mainly consists of water level sensor for measuring the water levels, temperature sensor for temperature measurement, Light dependent resistor (LDR) to keep track of light falling on the system, LED bulbs for the light during night of desired intensity, humidity sensor for measuring amount of water content in the atmosphere of system, pH sensor for checking acidity of the nutrition tank, Temperature sensor for measuring the temperature of system , the carbon dioxide sensors sense the its content in the system. For example if the temperature of system increases then the actuator turns the coolant and regulates the temperature to a required level.

VI. CONCLUSION & FUTURE SCOPE

The main objective of this paper was to provide information about the automated controlling and monitoring in hydroponics and aeroponics techniques. In hydroponics, the cultivation is proper and due to the disadvantages as discussed in the paper, the aeroponics was born. From survey of literature, it's found that implementation of advanced tools can provide farmers an opportunity to monitor without any requirement of laboratory instruments and farmers can remotely control and monitor the entire system. The complicated controlling and monitoring manual process can be eliminated. Aeroponics with machine learning is interfaced then it requires less hand operated contribution, little domain knowledge of plants, and its environment for controlling the growth of plants. For the researchers in the agricultural field, especially those are working on the soil less Indoor Farming techniques for accurate growth of plants with limited utilization of water and nutrients. The comparison table provides the consolidated techniques for the indoor farming without soil. The researchers can use the data sheet as given paper to get the required input parameters range for the plant growth. Also the novel strategy is proposed which a combination of Aeroponics and machine is learning. This proposed system can achieve high yield of crops with limited use of nutrients and water usage. This model is developed has to be tested.

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