Hydroponics a Sustainable Agriculture Production System

Gokul Anand. K. R, Rajalakshmi. N. R, Karthik.S

Abstract: ***Agriculture stands as a center-piece in Indian economy. In spite of being important, it faces challenges from production to financial incompetence's. Indian agriculture is raged by several problems such as meager farm equipment's, lack in quality toolsets, unusual monsoons or outbreaks of pest. Our present day world emerges with innovative technologies in farming such as soil and moisture sensors devices, meteorological tracking systems, remote sensing through satellite imagery, autonomous rovers and drones, agri-genetics, RFID tracking devices and finally vertical farming technology to help us transform our challenges into opportunities. These technologies can help us to transform our Indian agriculture farming systems into be a sustainable one. Sustainability in agriculture is possible only, when we have a constant supply of natural resource such as sunlight, water, moist-air, soil, and organic manures rich in nutrients in its proportion. To achieve this system, we must develop a controlled environment to check all the parameters of natural resources and use them according to their needs and quantity. Hydroponics is promise ably one such sustainable method of cultivating plants comparing to traditional farming techniques. The uniqueness of the system is utilization of water to less than 10 %. Secondly, the hydroponic system yields more veggies and fruits in a short span of time. This is achieved by selecting proper grow bed such as alluvial soil balls, rock wool, charcoal and gravels. The medium is selected based on nutrient retention rate in the grow bed with respect to cultivation of veggies. Hence, hydroponics agriculture production system gives promising yield round the year. And also, this system is commercially scalable and adaptable by all sectors of people. We can either start as small green house system in home or to a highly productive industrial scale. The paper proposes one such home based hydroponics system for tomato plants. The system follows ebb-flow method in hydroponics cultivation with fine grained gravel stones as grow bed medium. To monitor the growth of tomato plants, the system is equipped with sensors. These sensors measure the growth rate with respect to nutrient supplies for tomato plants. It is done in a controlled physical environment through IoT enabled devices. Thus, ensuring its yield for a sustainable productivity.***

Keywords: Sustainable production, Hydroponics, Nutrient solution, IoT, Thingspeak

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I. INTRODUCTION

India is expected to reach world's highly populated country in forthcoming decades overtaking china with a growing population of about 1.37 billion. This human resource has helped us to build our economic growth of the country, projecting India as fifth largest one in Gross Domestic Product and third largest one in purchasing power. Agriculture is a good contributor for our Indian Economy**.** It accounts about 18 % of India's gross domestic product (GDP) and up to 50% work force of the countries. However, most of the Indian population is directly or indirectly contributing to agriculture. Directly refers to farming and indirectly is by agriculture based business sectors. Though agriculture sector serves good for our Indian economy, we are in demand to feed many mouths in the future. To meet this demand, India needs to move to increased agricultural yields or by importing its food requirements. Imports on food products would make the growth of Indian economy more costly. In day to day human consumption products, India exports rice, wheat, spice, and spice products and imports fresh veggies, fruits. To overcome this, an alternative farming techniques need to be adopted for growing veggies and fruits. One such promise able alternative farming technique is hydroponics method of cultivation [1].

In hydroponics system, plants could be grown by flooding their roots with the nutrient solution. In case like plant with thick stem is supported with mediums like alluvial soil balls or gravels. The nutrient solution is either prepared from natural by products or created artificially by blending micro and micro nutrients. [2]The plant is nurtured with nutrient solution which comprises of macro nutrients like N,K,P,Ca,S,Mg and micro nutrients such as Ni,Cu,Zn,Fe,B,Mn. The absorption of the nutrient concentrate is higher in hydroponics when compared to traditional system.

Commercial Hydroponics system is being established by techy-entrepreneurs across various cities in India [10]. It stretches from Herbivore farms from Mumbai to Jnga –fresh green in Shimla, Triton food works in Delhi, Nature's Miracle in Noida, LetcetraAgritech in Goa and Future Farms in Chennai [11]. The agri-entrepreneurs of hydroponics system state that it is most advantageous method in respect to its scaling nature, non-dependency of weather, minimal water utilization and zero pesticide-free yields to reach global standards [12].

II. RELATED WORKS

Hydroponics is established in different models like continual-flow system, Ebb & flow system, drip system and nutrient film technique.

The paper [3] "Nutrient Film Technique (NFT) for Commercial Production" by Stephanie et al., demonstrate NFT model prototype of hydroponics farming from concept to design.

The NFT system is costlier due to its installation process. In order to compensate the cost, it needs to be backed up with technology to make improved production from the system. In-door hydroponics is an idea of adding another feature to the cap. In this method, total light intensity, duration and color of LEDs is authorized by the cultivator. [4] Shreya et al., in their paper "IoT based Automated Hydroponics System" discuss about cost-efficient system by controlling it through internet of things. The authors of the paper introduces LED light source for hydroponics plants in indoor farming systems and in unusual climatic conditions. [5] Namagel et al., in their paper "IOT based hydroponics system with supplementary LED light for smart home farming of lettuce" has proved the provision to alter the light source with respect to plants growth rate. [6] Nathaphon et al., in their paper "Optimal Plant Growth in Smart Farm Hydroponics System using the Integration of "Wireless Sensor Networks into Internet of Things" spot out the automation of controlling devices like sensors and actuators in hydroponics system through WSN.

The Technology adopted in hydroponics system helps to measure intensity of light source, water utility, temperature and humidity and PH value of the nutrient water. [7] Charumathi et al., in their paper "Optimization and Control of Hydroponics Agriculture using IOT" excavates all the data from various sensors like light, humidity, PH value and temperature. This accumulated data is taken for generating intelligent decisions to enhance the growth rate by controlling the growth parameters. [8] Anuradha et al in their paper "Decision Support System for Smart Farming with Hydroponics Style" strongly suggests the importance of monitoring PH values and NPK values periodically. These monitoring data helps the user to take post operation decisions for building strong interactive IOT system through machine learning algorithms. [9] Raj Kumar et al., in the paper "A Novel Approach for Smart Hydroponic Farming Using IoT" coins user defined hydroponics farming system by Blynk App and instant data logging by Thinkspeak. The hydroponics farming could be commercially viable for profitable veggies such as Lettuce. The paper [13] "Design and Development of Solar Powered Smart Hydroponic Greenhouse" by Parth Varmora et al., quantifies a NFT design with solar powered function unit for reliable power source. Sustainable hydroponics system is technologically defined by decision making parameters. In the paper [14] "IOT based smart system to support agriculture parameters: A case study" by Abhijit et al., introduces Cuckoo search algorithm based farming conditions with cultivating parameters like temperature, PH value, moisture content. These data will help us to take precision of farming. Precise farming is the governing force for high expectation yields. The paper [15] "Intelligent monitoring and controlling system for hydroponics precision agriculture" by Herman and Nico Surantha pitches idea on precise control of water and fertilizer for lettuce plants. The data acquired is governed by cloud - based services. This method is stated in the paper [16] "Internet of things using Publish and Subscribe Method for cloud - based application to NFT-based hydroponics system" by Muhammad Agus Triawan et al. The next big thing in technology is Artificial intelligence. It stretches its roots in all potential sectors where intelligent decision making is a costlier one. The paper [17] "IOT based hydroponics system using deep neural network" by Manav Mehva et al., in their paper have broadly presented about the application of deep neural network in hydroponics method of cultivation and decision making on growth conditions through machine learning.

III. PROPOSED MODEL OF HYDROPONICS SYSTEM

The objective of this project is to sort out a hydroponics framework for tomato cultivation that is completely automated and supported through microcontroller board integrated with internet of things. This integration of hydroponics system with internet of things turns out to be a potential producer in business perspective. In recent days, the price tag of tomatoes varied from Rs. 25 to Rs. 45 due to phenomenal climatic changes for its cultivation. This can be controlled by making a sustainable production as a linear graph round the year through proposed cultivation method.

A. Tomato plant cultivation

Tomato plant is cultivated involves two time slots

- 90-120 days from the time of sowing
- 45-55 days from flowering period

B. The botanical characteristics of Tomato plants are:

- The root approaches a deep root-system that penetrates up to 50 cm or even more.
- The stem grows to a thickness of 2 to 4m in circumference.
- The plant is at its best for the temperature ranging from 21 to 24 ^{o}C.

C. Successful cultivation depends on following requirements

1. Temperature and light density:

Tomato plant requires a dry weather with relatively cool temperature, for a premium quality fruit and quantity yields.

- The defacto parameter that governs the growth cycle of tomato plants is change in temperature conditions.
- The tissues of plant would be damaged, when the temperature goes above 38^{o}C or below 10^{o}C.
- Intensity of light influences leaf's color, flowering state and fruit's color.

Table I. Temperature Conditions For The Growth Of Tomato Plants

Various stages in growth of Tomato plants	Optimum Temperature Range
Germination of Seed	16-29
Growth of Seedling	21-29
Flowering State	20-29
Development of Red color	20-29

2. Watering:

- Tomato plant is drone to drought. The yield downsizes considerably on deficiency in water even for a short period of time.

- Watering of tomato plant is mandatory on flowering period and occurrence of food.
- The quantity of water to be irrigated relays on soil type and also on climatic conditions.
- For a grown tomato plant, watering must be done 3 times per week.
- Under healthy circumstances, watering can be done once per week.
- Irregular supply of water creates disorders physiologically to plant resulting in reduction of fruit size.
- Tomato plant requires watering quantity of 20mm per week under healthy conditions and 70 mm per week under dry and hot conditions.

3. Soil:

Tomato plants grow well in nutrient rich soils that are having good water holding capacity and good aeration and added to this it, should be free from salts.

- The soil need to be 15 – 20 cm deep with good draining capability.
- For this in our proposed model, use ebb-flow system for deep rooting of plants and well-built draining system.
- Ebb & Flow System - It works by flooding tray of plant temporarily with water and nutrient solution. After absorption by the plants, excess water and nutrient solution are drained back in to the recycling reservoir. A submergible pump with timer settings is enabled to perform the in-flow and out-flow action.

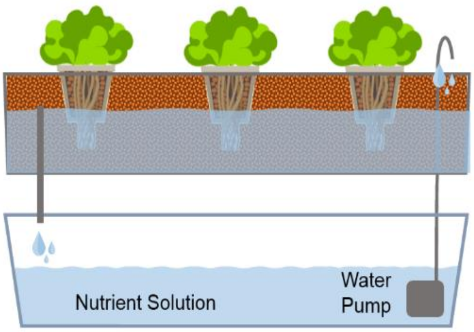

Fig.1. Ebb & Flow System (Source: www.leaffin.com)

4. pH value:

- Tomato plant grows healthy in soils with the pH value ranging from 5.5 to 6.8 along with sufficient micro and macro nutrients.

5. Irrigation:

- In traditional method, 60 % of tomato cultivation is through flood type irrigation. So, ebb-flow method of hydroponics system supports our traditional practices.

IV. PROPOSED MODEL SYSTEM ARCHITECTURE

Tomato belongs to warm – seasonal crop. The crop grows well with average temperature around 21°C to 29°C in a month.

- In summer, irrigating the plant must be done for every 5 - 7 days. To be cautious, the plant for a certain period in drought balanced suddenly by enormous watering leads to cracks in fruit.
- In winter, the plant needs irrigation for an interval of 10 to 15 days and it is sufficient for its growth. Excessive water and increase in humidity in the winter may lead to rotting of fruit.

The above stated cases in both summer and winter points out the importance of irrigating the plant with respect to temperature and humidity. The moisture content for the plant plays the crucial role in irrigation process. As upon irrigation, the moisture level changes for the plant.

In this hydroponics method, the nutrient derived from the manure is mixed with water and added to the plant in the form of fertigation. This fertigation has the potential to alter the moisture and pH value for the plant from the time of its irrigation. Our proposed model aims to build a solid method to support all parameters during irrigation process. The plant's height is propositionally measured with pH, moisture, temperature valves and irrigated accordingly.

A flow chart has been derived with the intention of dividing the grow cycle of the plant into two parts -Nurturing and Flowering time period of the plant

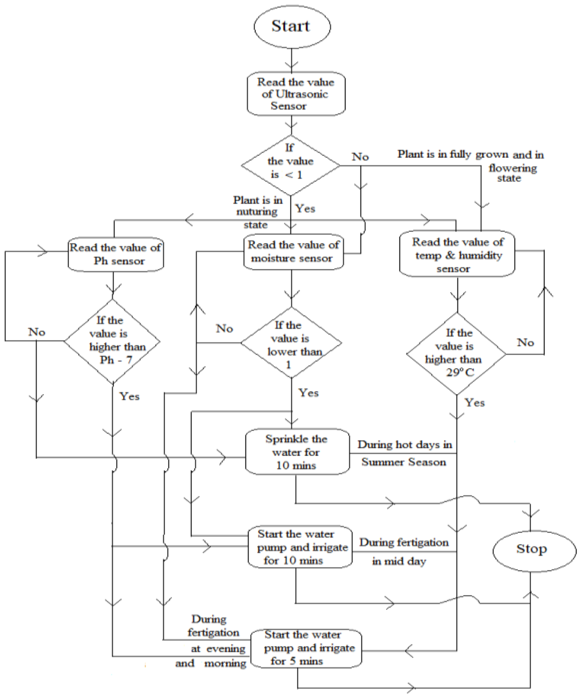

Fig.2. Flow Chart for Proposed Hydroponics model

The flowchart has following functional steps to support the proposed model.

Step1: Read the ultrasonic sensor value to measure the growth of the plant.

Step2: If the ultrasonic value is < 1, then plant is in nurturing state.

Step3: If the ultrasonic value is >1, then plant is in fully grown state.

Step 4: In nurturing State – Read pH value, Moisture value and Temperature & Humidity value.

Step 5: If pH value is > 7 (alkaline),
Moisture value is < 1,
Temperature is > 29°C, then
Start irrigating for 10 mins.

Step 6: If pH value is < 7 (acidic),
Moisture value is < 1,
Temperature is > 29 °C, then
Start sprinkling for 10 mins.

Step 7: If pH value is > 7 (alkaline),
Moisture value is >1,
Temperature is > 29°C, then
Start irrigating for 5 mins.

The step 5 shows the conditions that occur during fertigation process of a day. So, the irrigation lasts for 10 mins conditioning the grow bed. And step 6 shows the conditions that occur during hot climate in a day. So, the irrigation is through sprinkling. Step 7 shows the conditions that occur during warm climatic in a day. Thus, irrigating the grow bed for 5 mins.

The flow chart was converted to functional blocks (Fig.3) with the parameters given in the table below.

Table 2. List Of Parameters With Ranges

S.no	Parameters	Range
1.	Arduino Uno	5V Supply, 6 Analog Input Pins, 14 Digital I/O Pins, Flash Memory 32 KB (ATmega328P) of which 0.5 KB used by boot loader
2.	Relay Module	DC: 5V
3.	Solenoid valve	DC: 12V and 1/2" inch electric valve
4.	LCD Display	DC: 5V and 20x4 (2 Rows and 16 Characters Per Row)
5.	pH Sensor	DC: 9 V -1Amp, Measuring Range: 0-14pH
6.	Moisture Sensor	DC: 3.3V-5V Do: digital output interface (0 and 1) Ao: analog output interface
7.	Ultrasonic Sensor	DC : 5V- 15mA Max Range - 4m, Min Range - 2cm Measuring Angle - 15 degree
8.	Temperature and Humidity Sensor	DC : 3.3V- 5V Humidity Range: 0-50 Degrees Temperature Range: 0-50 Degrees
9.	Wi-Fi Module	ESP8266 - Arduino Compactable Serial Esp-01 Wi-Fi Wireless Transceiver Module
10.	Mini Motor Pump	DC : 3V - 9V Flow Rate : 80 ~ 120 L/H, Maximum Lift : 40 ~ 110 mm

The Functional Block Diagram is constructed with parameters mentioned in the table 2. with flow chart as model.

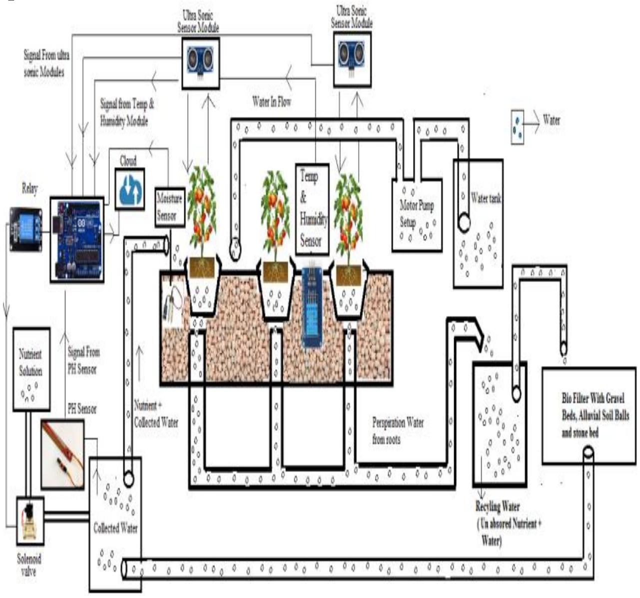

Fig.3. Functional Block Diagram of Proposed Model (Hydroponics system for Tomato Cultivation)

V. WORKING MODEL OF PROPOSED HYDROPONICS SYSTEM

The tomato sapling is transformed from the nursery to the hydroponics system- grow bed within 3 to 6 weeks.

It should be watered well before 12 to 14 hours to avoid damages caused to its roots. Seedlings of 15-25cm tall with 3-5 true leaves are most suitable for transplanting.

Fig.4. Tomato Sapling

The saplings of size 15 to 25 cm in growth with 3 to 5 good green leaves is ideal condition to transplanting to grow bed (Fig.4). Transfer of tomato saplings from nursery to grow bed need to be done during late afternoon or evening hours to avoid shock absorbed during transfer. Watering the saplings is essential after transplantation to grow bed.

A.Interfacing functional Blocks

1) Hardware Requirements:

- Arduino Uno interfacing - It is an ATmega328P microcontroller board with 6 - analog i/p and 14 digital i/o pins. The temperature, moisture, ultrasonic and PH - sensors are connected to analog i/p's and continuously monitored through LCD display. The LCD display and Relay modules are connected to Digital i/o pins. The Relay modules help us to easy switch between the mini motor pumps to pump up the water to grow bed and stop it, while instructed by the controller (Fig.5). The Sensor values displayed in LCD are transported to cloud through ESP8266 Wi-Fi module (Fig.6).

2) Software Requirements:

- ThingSpeak - It is open-source software from matlab for Internet of Things (IoT) applications and APIs for storing and retrieving data. It uses MQTT and HTTP protocol through the Internet or through a LAN for communicating with IOT devices. ThingSpeak helps us to create applications for sensors, to log in and out, to find location for tracking the status of applications and its updates.

Fig.5. Working Model of Proposed Hydroponics System

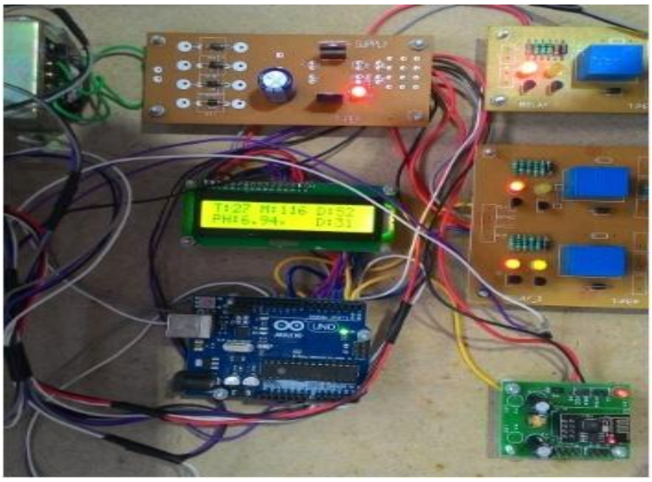

Fig.6. Hardware Structure of Working model

VI. RESULTS AND DISCUSSIONS

In the proposed hydroponics system, the initial conditions are measured after transporting the tomato sapling to the grow bed. The initial conditions are recorded through the sensors available in the system and the data generated are used to plot varies graphs with respect to the sensors. The study of graph helps to fix the conditions as ideal conditions for growth of tomato plant. The Fig.7 shows the ideal values of pH, Temperature and Moisture of the plant.

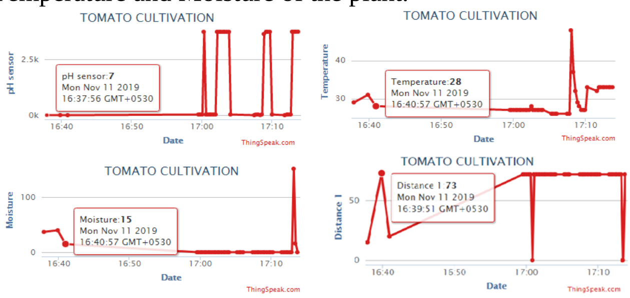

Fig.7. Ideal Growing Conditions for Tomato Plant

Now, the ideal condition is disturbed by increasing the temperature, fertigating the grow bed with liquid organic fertilizer (Panchagavyam). First of all, due to increase in temperature, the moisture content started to decrease drastically and nullifying it. Then, the fertigation system works to balance the moisture system. Now, the pH value shoots to12 that makes the environment highly basic. The Fig.8 shows the instable condition of the system through values of pH, Temperature and Moisture of the plant.

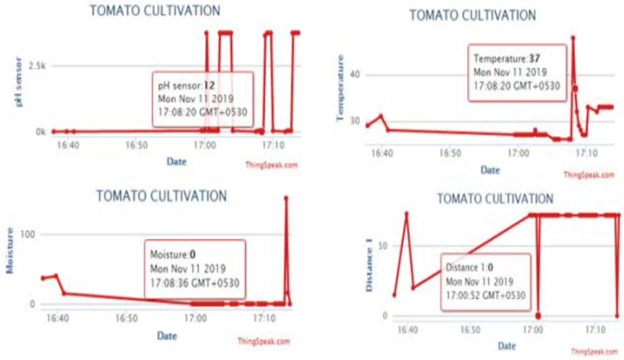

Fig.8. Conditions of instability in growth parameters for tomato plants

Now to restore this, the microcontroller system makes the motor pump to turn on the water from reserviour. This makes the grow bed to be filled with fresh water resulting in fall of pH drastically. The result of irrigating grow bed leads to overall increase in moisture content. The temperature becomes ideal after removing external disturbance. Fig. 9 shows the stablilized conditions of the tomata plant after irrigating it.

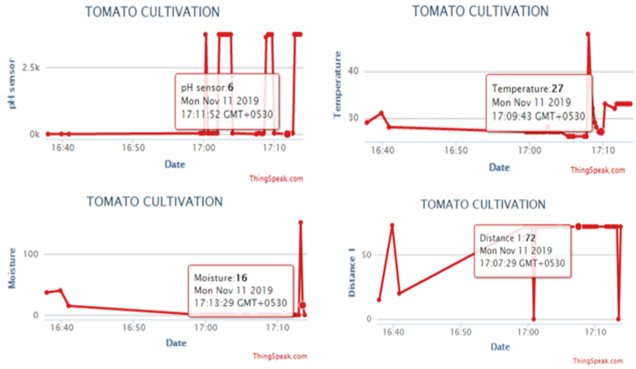

Fig.9. Conditions of stability in growth parameters for tomato plants after irrigation process

On the whole, the above results obtained from the graphs state that there is a unique captivity between the temperature and moisture level. This is addressed in the tabular column table 3. The Table 3 has sensor parameters mapped with respect to various growing conditions. From this table, we could conclude that for a tomato plant hydroponics system, the stable condition for its growth are temperature ranging from 27 to 28 °C and moisture from 15 to 16 respectively.

Table 3. Sensor Parameters With Various Growing Conditions

Sensor Parameters	Growing Conditions for Tomato Plants By proposed hydroponics system		
	Ideal Growing Conditions	Instable Growing Conditions	Stable Growing Conditions
pH	7	12	6
Temperature	28	37	27
Moisture	15	0	16
Distance	73	0*	72

Finally, a graph is derived exclusively between moisture and temperature. Fig.10 shows that whenever the temperature values are stable, the moisture content is always in its ideal state.

When, we abruptly increase the temperature by external disturbance, the moisture is also varied to counterbalance it. The graph shots out to peak value and stabled with respect to time.

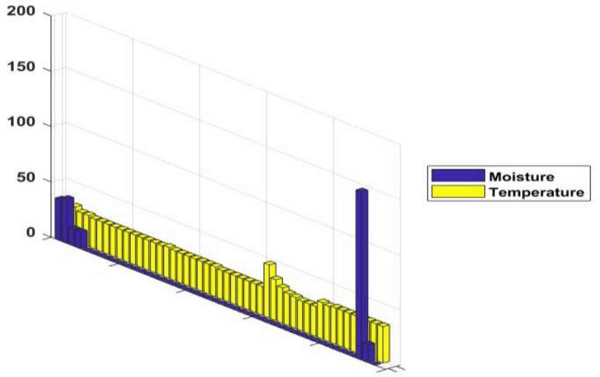

Fig.10. Graph obtained from Temperature and moisture data

VII. CONCLUSION & FUTURE WORKS

The proposed model was carried out as a pilot project to preciesly understand the growth environment for tomato plants through ebb-flow hydroponics method. Here, finely grained gravel stones that were filled in the ebb - flow system helped us to maintain a stable pH of 6-7 value. The recycled water is checked periodically to maintain the stable pH value. The organic liquid fertilizer (Panchagavyam) that is connected in bias with recycling water tank, helps to maintain stable pH level by converting alkaline recycled water to acidic one. And furthur, the observations from the data in table.3 gives a clarity on watering system for the plant. The observation says that the moisture content in ebb-flow grow bed and temperature of the environment must be in a balanced state for the growth of the plant. The flowering period as well as fruit set time period are crutical for good productivity of the plants. Since, watering is the only source of oxygenator for the root structure in plant physicology.

This pilot model gives a good exposure in hydroponics system for tomato plant. In futuristic works, we have planned to analysis the growth rate of root structure of the plant. As, the root structure is the main source of nutrient observer for the plants. The sensor values obtained would be applied with machine learning algorithms to make trial and learn from the results. This results would give precise changes that to be adopted during different phase periods in watering system for the tomato plants.

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Rajalakshmi.N.R is currently working as an Associate professor in Computer Science and Engineering, School of Computing at Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, India. She has done her doctorate in the field of Cloud Computing at Anna University in 2017, Chennai and Master degree in Software Engineering at Anna University in 2007. She has 16 years of teaching and research experience. Recently, She has been concerning in IoT, Machine Learning, Block Chain. Also , she published many papers in international journals and conferences.

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His research area includes development of optimization algorithm for sensor devices using wireless sensor networks for automotive vehicles. Currently, His research is towards IoT based smart grid implementation.