Autonomous Monitoring System for Indoor Herbaceous Plant Growth

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Abstract:-

Today a lot of agricultural sectors are using IoT technology for smart farming, or minimally invasive human involvement, in order to improve production, efficiency, and worldwide marketing, among other aspects of farming. Our economy's overall functioning depends heavily on agriculture, which is a sector that is just as conducive to automation application as industry. In today's society, severe and persistent illnesses are primarily treated using herbal medications. Similar to conventional treatment, herbal therapies have been used for a long time and have very few negative effects. It will therefore be more advantageous to cultivate the herbal plants in the best and most straightforward approach. This project suggests methods for growing herbal plants indoors as efficiently as possible using LED lighting. The plants are constantly observed by means of an automated system made up of sensors for temperature, humidity, and soil moisture. For this experiment, four herbs such as mint, holi basil, country borage, and keezhanelli are used. These herbs are cultivated in both natural light and under LED lighting, and they are constantly being observed by sensors that measure temperature, moisture, and humidity. AgriBot captured daily photos of the plant in order to track its growth and compare it to plants growing in the sun. Additionally, a convolutional neural network is used to examine the plants' growth rate, and the results are compared to that of herbaceous plants that are produced naturally. At 30◦C, 860 level of wetness, and 74 level of humidity on the seventh day, the plant cultivated under LEDs thrived nicely. When compared to other herbs, mint and country borage have grown significantly. Thus, precision agriculture combined with indoor farming produces a large output in a short amount of time.

Key words: - Herbaceous Plant, indoor farming, Agribot, Precision agriculture

1. Introduction:

Some of the most significant crops, including cereals, legumes, mint, holi basil, etc., are herbaceous plants [1]. They are utilized all over the world for a variety of purposes in the fields of agriculture, food, energy, pharmacology, and medicine. The production of herbaceous crops has advanced significantly in the previous few decades, mostly with the goal of raising yields. But the world's population is growing faster than ever before, and at the same time, arable land is disappearing, raising concerns about the need to develop more productive farming methods. However, further research is needed on a number of issues pertaining to how agronomic techniques affect quality attributes, as well as how to cultivate them in organic farming. According to the continual agricultural survey for the past eleven years, the Indian agriculture sector employs 50% of the labor force and contributes roughly

18% of the GDP of the nation. Techniques like indoor farming[2] have the ability to satisfy the high demands of product in the near future due to factors including the world's growing population, increased water demands, a growing demand for herbs, and frequent changes in climatic conditions. The climate of the farm can be adjusted by the indoor farmers to suit their needs. Crop contamination by pests is an issue that is easily managed and resolved. Indoor farming is an efficient technique to grow crops while conserving water because it uses less water. The primary benefit of this farming method is that farmers can produce more crops per acre than they could with conventional farming. Indoor farming, also referred to as indoor gardening, is the large- or small-scale cultivation of crops and herb plants indoors using hydroponics and artificial lighting. Artificial light is necessary for the herb plant to receive nutrients and for the plant to flourish. Although other plant varieties can also be grown using the same technique, fruits, vegetables, and herbs are often grown inside.

Since land is scarce for farming, indoor farming is becoming more and more common. Commercial indoor farming is used to grow fruits and vegetables for areas like cities that have high populations. Indoor farming has many advantages, one of which is that it requires less space to cultivate crops and can be easily run by one person on the whole. LEDs [3] are used in most types of Controlled Environment Agriculture (CEA) [4] to simulate solar power and enhance photosynthesis in plants. LEDs can be utilized even in greenhouse systems to battle the shorter days of winter or to increase the amount of light that crops receive in a given day. Growers may adjust the light intensity when utilizing artificial light, so they can vary the type and quantity of light that certain crops receive according on how much they require. It is also possible to control the color spectrum. Because plants cannot absorb green light, growers frequently remove it from the light spectrum, leaving just red and blue. This explains why indoor farms frequently have pink lighting.

An extensive range of herb plants may be grown indoors, year-round, in any environment due to grow lights. These growing lights are made specifically to replace sunshine, promoting photosynthesis and provide the ideal color spectrum for the growth and well-being of herbs. Many grow light varieties are available, each with unique advantages and features. Examples of these include fluorescent lights, high-pressure sodium (HPS), and light-emitting diodes (LED).

Farmers' supply chains are less risky when they practice indoor agriculture. There's a good probability that crops grown indoors in abandoned warehouses in urban areas are being eaten nearby. These goods might never reach the grocery store shelves and instead wind up in upscale eateries or neighborhood farmer's markets, which further reduces the danger to the food supply chain. Plants grown indoors [5] are also shielded from a variety of unfavorable external factors. For example, a significant portion of crops grown outside are lost annually as a result of storms, floods, or droughts. If those extreme weather events do not destroy the indoor farming facilities, then indoor gardening will make all of those extreme weather circumstances irrelevant because they will not change the indoor settings. Therefore, there shouldn't be too much concern about unfavorable outside weather if the indoor farming system was built in a stable manner.

2. Review of Literature

The tests with artificial lighting of vegetable seedlings using various types of lamps were proposed by Jadwiga Treder et al. [6] and were conducted on the tomato cultivar 'Debut' and the cucumber cultivar 'Kafkas'. The seedlings were first cultivated in growth compartments with regulated temperature, light levels, and photoperiod, and subsequently in a greenhouse. Two different types of LED lights with varying involvement from red and blue wavelength were utilized, together with 400 W HPS lamps, for plant lighting. Measurements of morphology (plant height, fresh weight, and leaf area), greenness (index SPAD) of leaves, and conductance of leaf stomata were applied. The findings show that different lighting setups had an impact on the quality and growth of the vegetable seedlings. Cucumber and tomato have distinct reactions to the various light spectra.

The relationship between LED energy consumption and plant growth in a small hydroponic plant cultivation system powered by sunlight was proposed by Yamaguchi, S. et al [7]. Such hydroponic plant growing systems need to function on an economical and effective basis. Three different conditions were used in three different experiments that used constant electrical energy consumption. These conditions included: low electric power and long lighting; medium electric power and medium lighting; and large electric power and short lighting. It was discovered that the first strategy produces outstanding lettuce growth after weighing the produced plants.

Red and blue light-emitting diodes (LEDs) were suggested by Sowbiya Muneer et al. [8] to help mitigate hyperhydricity in vitro-grown carnation genotypes. The three carnation genotypes—Purple Beauty, Inca Magic, and Green Beauty—were cultured in vitro in white fluorescent light (FL) under both normal and hyperhydric circumstances. Of the hyperhydric plants, half were grown under red and blue LEDs. It was found that red and blue LEDs reduced the oxidative stress caused by hyperhydricity in terms of the level of thiobarbituric acid reactive compounds (TBARS). Red and blue light LEDs maintained the anti-oxidative defense systems and thylakoid protein composition in carnation genotypes, thereby reducing hyperhydricity to control levels.

The dependence of lettuce plant growth, water use efficiency, chlorophyll fluorescence, and stomata features on light intensity was proposed by Parisa Ghorbanzade et al. [9]. While knowledge about photosynthesis and stomata's long-term responses to light intensity is scarce, they both actively react to brief variations in light intensity. The greatest difference in biomass gain was seen after 40 days of exposure to the light treatments. The beneficial effects of increased light intensity on leaf fresh and dry weights were time dependant. Higher light intensities, as opposed to lower light intensities, accelerated the development of the photosynthetic system in relation to the leaf developmental phases (in terms of an enhancement in the maximum quantum efficiency of photosystem II and non-photochemical quenching).

Plant development and photosynthetic properties of soybean seedlings under various LED illumination quality settings were proposed by Linzhi Fang et al. [10]. LEDs, or light-emitting diodes, have become a popular choice for light sources in controlled conditions for plant cultivation. Their work's goal was to use LEDs to study how soybean seedlings react to various blue and red photon flux ratios. During the day, solitary red plants accumulated higher levels of soluble sugar and starch. Altogether, the findings imply that, in contrast to red or blue-LED alone, a suitable mix of red and blue LEDs enhances soybean plant growth and photosynthetic efficiency.

The tomato crop was enhanced by the use of blue LED light as a stimulus and xerophytophysiology in plant production, as suggested by Huang-lian Xu et al [11]. Blue light activates the plant through the receptor protein, causing physiological and morphological changes, according to recent studies employing Arabidopsis. Finding out if the theory can be applied to the development of food crops is crucial. In the current study, tomato crop canopy was stimulated with blue light from LEDs for two hours after sunset in order to induce xerophyto physiological regulators. The experiment was carried out using a randomized split block design using the two cultivars as the primary block. The results showed that the tomato leaves under blue light treatment exhibited a higher leaf turgor potential and a lower osmotic potential in the symplasm at maximal turgor.

A survey of high-resolution image processing methods for tracking cereal crop growth was proposed by Sanaz Rasti et al. [12]. In this work, methods for obtaining important measures of cereal crop growth from high spatial resolution, usually proximal photos, are presented for image processing. Crop canopy cover, above-ground biomass, leaf area index (including green area index), chlorophyll content, and growth stage are the descriptive crop growth indicators taken into consideration. An overview of pertinent basic image processing techniques, such as camera kinds, color spaces, color indexes, and image segmentation, is included in the study. Automatic Tobacco Plant Detection in UAV Images using Deep Neural Networks was proposed by Zhun Fan et al. [13]. The management of tobacco planting depends heavily on the identification of tobacco plants. In their work, a novel deep neural network-based technique is suggested to identify tobacco plants in UAV-captured photos. Because of their exceedingly high spatial resolution (35 mm), these UAV images provide a very high degree of detail that can be used to construct automatic detection methods. The outcomes of the experiment demonstrate that the suggested algorithm does a good job of identifying tobacco plants in UAV photos.

Spiking Neural Networks for Crop Yield Estimation Based on Spatiotemporal Analysis of Image Time Series were proposed by Pritam Bose et al. [14]. This work proposes spiking neural networks (SNNs), which leverage the highly parallel and low-power-consuming neuro morphic hardware platforms for distant sensing spatiotemporal analysis of picture time series. To train an SNN to predict agricultural output promptly, the paper describes the construction and testing of a methodological framework that makes use of the spatial accumulation of time series of 250-m resolution data from the Moderate Resolution Imaging Spectro radiometer and historical crop yield data. Analyzing the ideal feature count to maximize the outcomes from our experimental data set is another aspect of the research project. Wireless sensor networks were suggested by A.M. Eshilalini et al. [15] as a means of IOT-enabled plant soil moisture monitoring. To monitor soil moisture, their work describes a wireless sensor network (WSN) connected to the Internet of Things. An IoT-based smart irrigation monitoring and controlling system was proposed by Shweta B. Saraf et al. [16]. With real-time data input, the system is built on the Internet of Things. The drip irrigation system is remotely monitored and controlled by a smart phone that makes use of a cloud-based wireless communication technology.

For chili plants, Maurf Harsosno et al. [17] suggested a smart IoT watering and monitoring system. Using a moisture sensor to measure the soil's present moisture content, the data is processed by an Arduino microcontroller. To determine the nutrients in the solution, this device additionally uses an EC sensor and a pH sensor. According to Mythili et al. [18], smart farming techniques and the use of sensors to track onion growth can produce the highest yields and healthiest onions. In addition to emphasizing the ideal watering time, this paper concentrated on offering the highest quality. They have also concentrated on charting the soil moisture level and lessening the farmers' effort.

This work uses an automated system [19] made up of an Agribot and a monitoring system to track the growth of herbaceous plants cultivated in LED lighting. CNN is used to examine and compare the plant's growth under LED lighting to that of plants grown in the sun.

3. Proposed Work

For indoor herbaceous cultivation, the suggested Agribot system with an LED lamp is utilized to monitor the plant's environmental conditions and promote the best possible growth level in the plants. The IoT-based smart agriculture monitoring system [24] and the deep learning [20, 21] techniques used for the development rate of plants under LED lamps are examined and contrasted with plants grown in direct sunlight.

The block diagram of the automation system is presented in Figure 1.

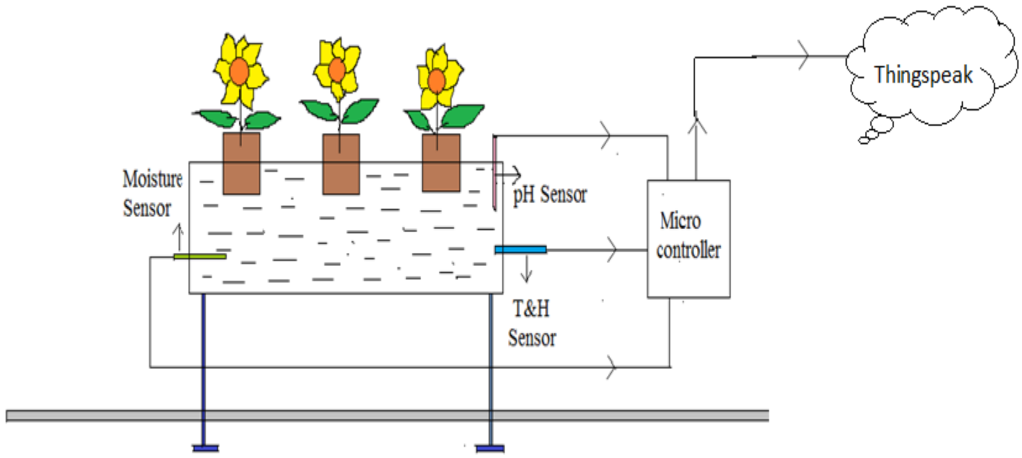

Figure 1. Automation of the proposed system

The herbaceous plant is taken to be grown under LED. Sensors such as temperature, soil moistures and humidity sensor are mounted on the plant bed to monitor the environmental conditions. The plant under LED lamp as real time setup is shown in figure 2.

Figure 2. Real-time setup of proposed system

Cultivating herb crops indoors on surfaces that are vertically inclined is known as indoor herb farming. Herbs come in many varieties that we can cultivate from seeds or even cuttings. In indoor farming, define hidden areas that are waiting to be discovered or create garden chambers using structures or columnar trees.

Certain indoor farms use natural sunlight and mostly solar heating during the day, much like greenhouses. There is also indoor farming that makes use of controls for artificial lighting, humidity, and heating. Planning is crucial when starting an indoor farming venture as a small to medium-sized enterprise. We must make sure that the products we generate are marketable and that the cost of manufacturing is reasonable. Choosing the appropriate plants is therefore the first step in making sure of this. Holy basil, mint, and country borage are used to examine how well the herbs thrive under LED lighting. The sensors installed on the plant bed, which is lit by an LED lamp, keep an eye on the environmental conditions of the plants. Information on the temperature, humidity, and moisture content of the herbaceous plant will be provided by this automation system. CNN compares the growth level of plants grown in the sun with those that were not by looking at the daily photos of the herbs.

3.1 **AgriBot for Indoor Farming**

An agricultural robot is a robot deployed for agricultural purposes. The main area of application of robots in agriculture today is at the monitoring stage. The proposed IoT-based robot will monitor the crop and also the environment around the crop. The proposed AgriBot consists of two modules, hardware, and software. The hardware system integrates with the camera (ESP32), Bluetooth module(HC-05), and DC motors. The ESP32 CAM Wi-Fi Module Bluetooth for Face Recognition has a very small camera module that can be operated by almost everyone. It Can operate independently as a minimum system with a 40 x 27 mm footprint. HC-05 is a Bluetooth system that works for wireless communication. The whole process of the robot is powered by the battery. The base frame has 4 wheels and all wheels are driven by a DC motor. The robot connects to the smartphone with Bluetooth. This Bluetooth system moves the robot back and forth. The camera attachment of this AgriBot will capture the current state of the plant with the help of Bluetooth and Wi-Fi. Figure 3 shows the hardware of the proposed AgriBot model.

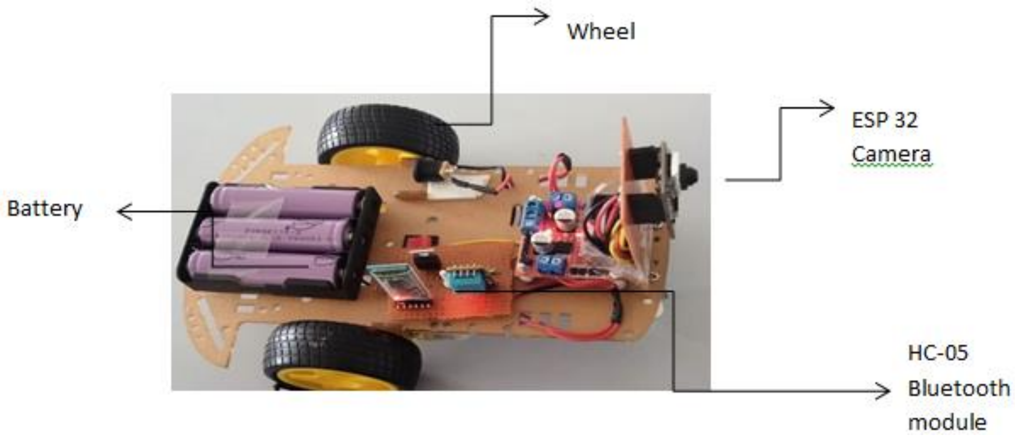

Figure 3. Hardware implementation of AgriBot

The software includes a system for moving wheels, taking photos, moving and testing the robot with the support of the Bluetooth APP. The command to operate via Bluetooth is shown in Table .1

Table 1. Command to operate vehicle

Command	**Definition**
*FF	Move forward
*LL	Move left
*BB	Move backward
*RR	Move right
*SS	Stop the Movement
*CC	Take picture

The benefits of automated agricultural robots include reducing human workload and improving monitoring and efficiency of agriculture. The AgriBot system mainly monitors the growth stage of the plant. So, it shows the destruction stage of the plant at the beginning and thus higher yields can be obtained.

3.2 Hardware Implementation

Developed hardware for automation and monitoring system which consists of temperature sensor, humidity sensor and soil moisture sensors [22] [23]. Hardware implementation of the monitoring model is shown in figure 4. At first the LDR senses the light intensity and the system turns on when the intensity exceeds the limit. When the temperature is on, it checks the temperature, soil moisture and humidity levels. All of these will make the appropriate decision when it is more or less than the defined amount. The amount of water required for the plant can be calculated by calculating the amount of heat and humidity so that the motor starts irrigating when the amount of heat is greater than the prescribed amount.

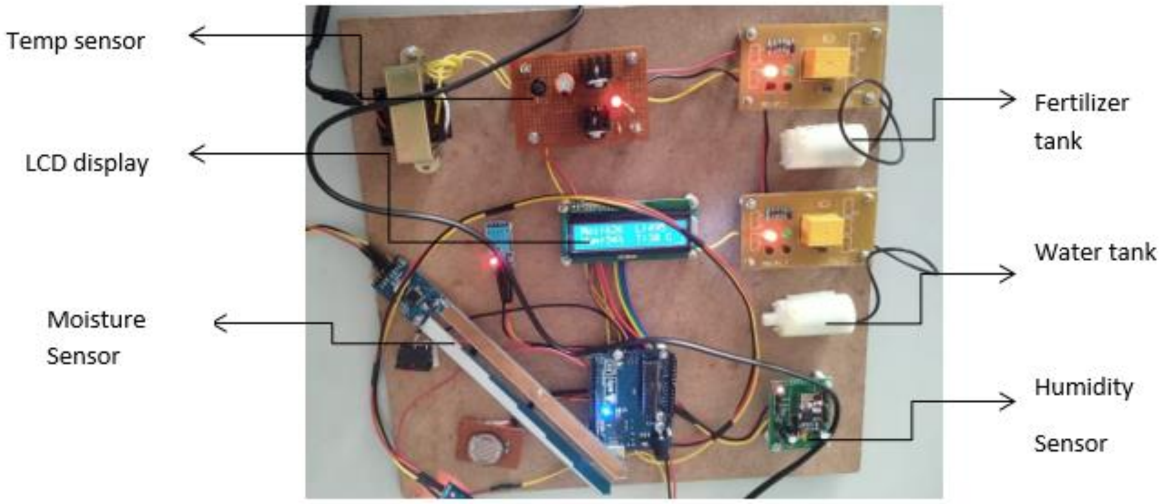

Figure 4. Hardwrae system of automation module

3.3 Real-time monitoring of the herbaceous plant

This automation system is used to monitor the environmental condition of the herbs plant bed which is grown under the LED lamp. This system consists of sensors such as soil moisture, humidity and temperature sensors [22]. The various results of the monitoring system will be sent to Thingspeak and a related graph will be obtained. All of these will make the appropriate decision when it is more or less than the defined amount. The amount of water required for the plant can be calculated by calculating the amount of heat and humidity.so the herbs will get better growth level when compared with the plant grown under the sunlight. This will reduce work load of the farmers and also reduce the occurrence of the errors. The values obtained from the sensors are send to the Thingspeak [23] for analyzing the data which is plotted in the graph for the days 1,3,5,7 and 9 (figure 5).

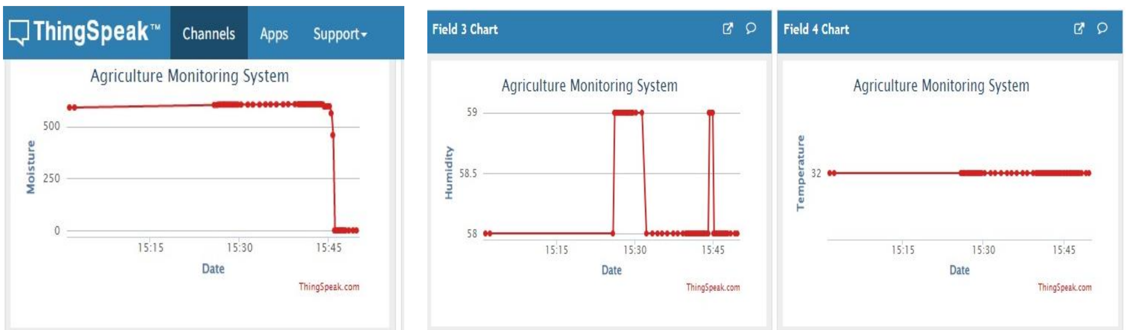

Figure 5.1 Graphical representation data for Day 1

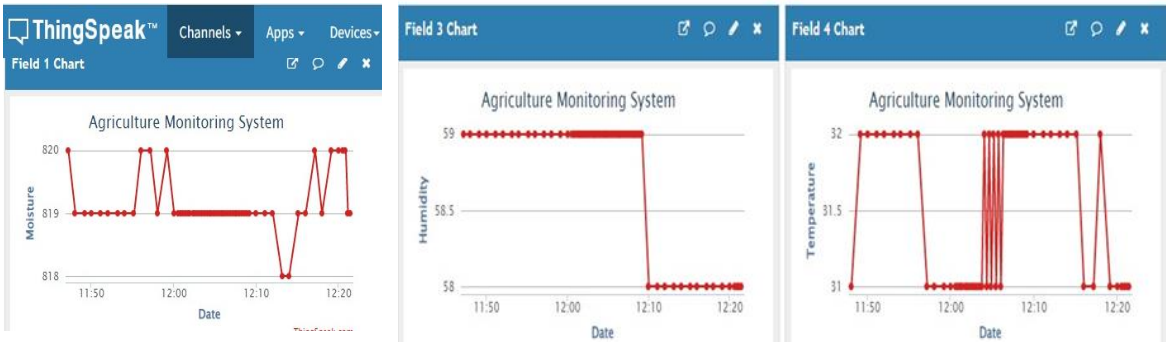

Figure 5.2 Graphical representation data for Day 3

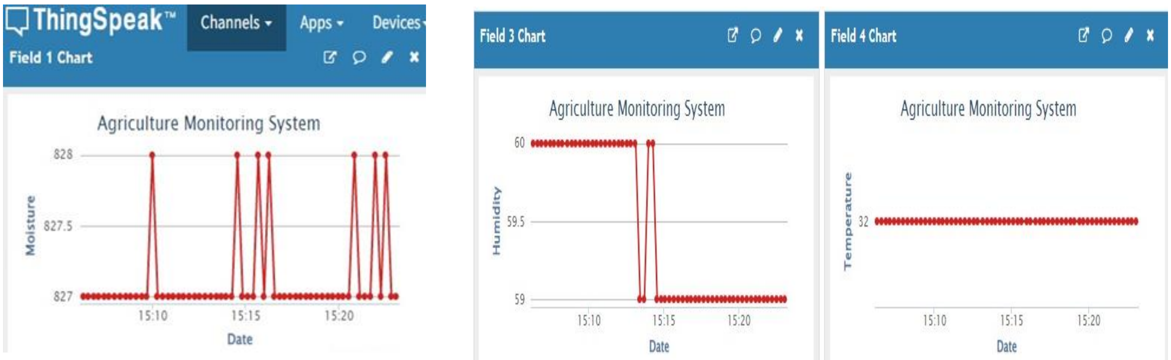

Figure 5.3 Graphical representation data for Day 5

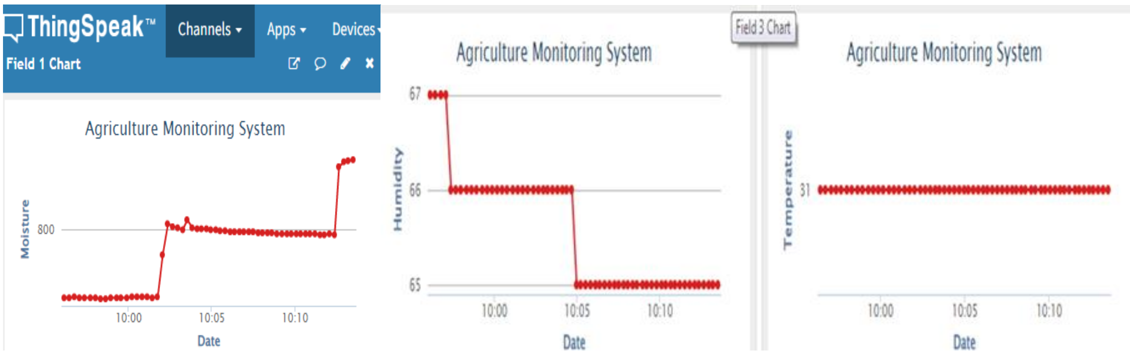

Figure 5.4 Graphical representation data for Day 7

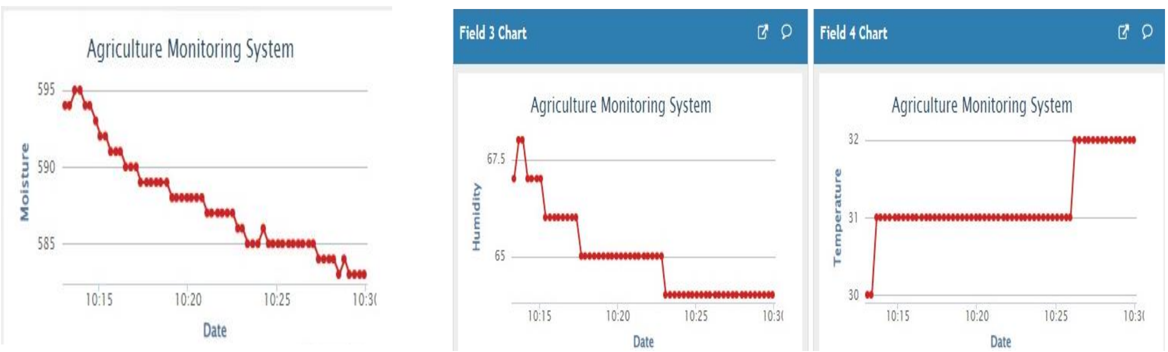

Figure 5.5 Graphical representation data for Day 9

3.4 Images of herbaceous plant under LED lamp

The pictures of the plants were taken daily by Agribot to analyze the growth level of the plant under LED lamp. The images from day 1 to day 9 are shown in figure 6 for the alternate days. It shows the plant grown very well under LED lamp. Due to this grow light, climate change conditions were not affecting the plant's growth and were also not affected by any diseases.

Figure 6.1 Images of herbs on day 1

Figure 6.2 Images of herbs on day 3

Figure 6.3 Images of herbs on day 5

Figure 6.4 Images of herbs on day 7

Figure 6.5 Images of herbs on day 9

Compared to other grow lights, LED lamps have an efficiency of up to 40%–60% higher when it comes to converting energy into useable light. LEDs' high efficiency makes it possible for them to consume less energy and produce less heat. While previous grow lights only convert roughly 20% to 40% of their energy into useful light, LED bulbs convert 40% to 60% of their energy into light, with the remaining energy being released as heat. Because LED grow lights produce less heat than other grow lights, they can be placed closer to plants. In order to achieve the best possible light penetration far into the canopy, this function also enables growers to position the lights closer to the plants. As a result, the plants developed at a healthy rate and did not contract any diseases.

4. Results and Discussion

The Autonomous monitoring system for indoor herbaceous farming under LED lamp was designed. This proposed system has Agribot and automation system with monitoring sensors. The herbaceous plant was grown under both LED lamp and sunlight. The plant grown under LED lamp was continuously monitoring by the automation system. The output of monitoring value is taken as a graph on Thingspeak. The average value of moisture, temperature and humidity is illustrated in the figure 7 as bar chart. The plant growth rate under LED lamp is given in table 2 for alternate days from day 1 to day 9.

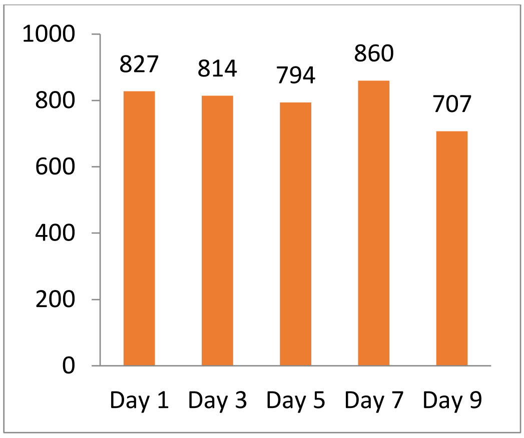

Figure 7.1 Average Moisture level of soil

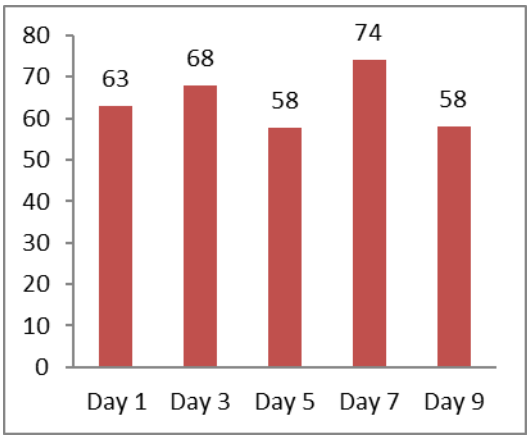

Figure 7.2 Average Humidity level of air

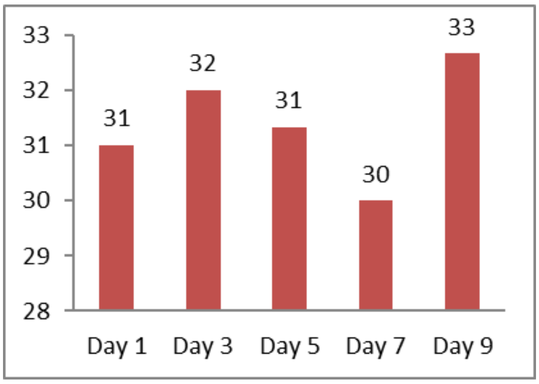

Figure 7.3 Average Temperature level of air

Table 2. Plant growth rate under LED lamp

Plant Name (LED)	Day 1			Day 3			Day 5			Day 7			Day 9		
	Actual Height of the plant in cm	Output of CNN		Actual Height of the plant in cm	Output of CNN		Actual Height of the plant in cm	Output of CNN		Actual Height of the plant in cm	Output of CNN		Actual Height of the plant in cm	Output of CNN	
		Pixels /cm	Height in cm		Pixels /cm	Height in cm		Pixels /cm	Height in cm		Pixels /cm	Height in cm		Pixels /cm	Height in cm
Mint	8.2	270	8.1	8.4	273	8.2	9.2	310	9.3	10.2	337	10.1	10.7	360	10.8
Holy Basil	8	264	7.9	8.2	277	8.3	8.5	287	8.6	9.2	303	9.1	9.5	320	9.6
Country Borage	8	263	7.9	8.1	273	8.2	8.9	297	8.8	9.8	323	9.7	10.3	340	10.2
Keezha Nelli	5	170	5.1	5	173	5.2	5.3	174	5.2	5.7	193	5.8	6.1	206	6.2

When compared to other dates, the seventh day is when herbal plants thrive the best. This is due to the fact that the temperature was low and the plant bed's humidity and soil moisture were both high on this particular day. When grown under an LED lamp rather than in the daylight, the herb plant grows more successfully. Mint and country borage, in particular, grow more readily than other herbs.

5. Conclusion

As a result, the suggested system concentrated on offering the best herbs that were produced under LED lights and lessening farmers' workload through the employment of an autonomous monitoring system. In this work CNN is used to analyze the plant's growth level. In order to monitor the plant's surroundings and assist to identify the ideal conditions for plant growth, a range of sensors are installed on the plant bed. The plant has grown admirably under the LED light. On the seventh day, mint and country borage show good development in comparison to the other plants under observation. In order to accomplish Precision Agriculture, this effort also provides information for the indoor farming movement based on automation and stored data. Further this work can be extended by using autonomous robot for taking decisions based on event of growth of the plants. This system can be improved as real time autonomous functioning system for plant cultivation.

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