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Smart Residential Multi Level Plantation System

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Abstract

The demand to supply ratio for plants such as basic vegetables or horticultural plants is often very high on the market, meaning demand is not met .This leads towards an unwanted burden on the market and a substantial rise in price. This resulted in developing a multi-level residential planting system. As the name suggests, the system will be built for residential purposes, mainly for growing plants (agricultural or horticultural) at home without any unnecessary burden on the user. This system will ensure an optimum, natural, and rapid rate of growth for various plants. This is achieved by tenaciously monitoring and controlling environmental factors using IoT devices. This control allows the plants to draw the essential nutrients as much as it can from the environment and provide the remaining by stimulating the environment. The prototype developed is controlling two factors i.e. light and water. Other factors like temperature can be seen on a display device and can be monitored. The multi-level system also inculcates the idea to optimize space so that more plants can be grown in less space in a user- friendly manner. With the help of this system a person can grow natural plants with ease and can in turn help in reducing the demand to supply ratio. The simulation and the prototype implementation prove that the user will invest minimum time in the process and will eliminate the tedious efforts to grow a plant and meet the demand.

Keywords: *Arduino Microcontroller, Coir, water control, temperature Control, Light intensity control, Android Studio, IOT, Multi- Level Plantation.*

1. Introduction

Agriculture plays a pivotal role in India's economy. It contributes about 16% of the total GDP and employs over 52% of the population [1]. As mentioned by the Ministry of Agriculture & Farmers Welfare of India, the agriculture sector in India is vulnerable to climate change. Every year due to changes in our atmosphere, the agriculture sector is facing a major loss. Even in the time of COVID-19, many farmers are witnessing difficulty in farming. Even the livelihood of the general public is disturbed due to breakdown in the supply chain of vegetables amid the pandemic lockdown. The Internet of Things (IoT) is a recent communication paradigm that envisions a near future, in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with one another and with the users, becoming an integral part of the Internet [2]. Need for the Internet of Things (IoT) in the sector of farming is now a requirement. Smart Farming is a development that emphasizes the use of information and communication technology in the cyber-physical

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farm management cycle. New technologies such as the Internet of Things and Cloud Computing are expected to leverage this development and introduce more robots and artificial intelligence in farming [3].

This multilevel plantation system is a solution for the farming and horticulture sector. According to R Bongiovanni & J Lowenberg-DeBoer, Precision Agriculture (PA) helps to manage the crop production inputs in an environmentally friendly way[4]. Precision farming helps to reduce the losses by targeting the causes of loss. Research by Abdelraouf Ramadan Eid says due to the differences in soil moisture and wetting pattern, crop yields may be different when the same quantity of water is applied under different irrigation frequencies[5]. In 1977, Passioura gave an equation to determine grain yield[6], and it is expressed as

$$\text{Yield} = ET*WUE*HI \qquad (1)$$

Where ET is seasonal evapotranspiration, WUE is water use efficiency for biomass products & HI is harvest index. This equation gives the value of WUE that is used to determine the irrigation frequency. Later on, many equations and theories developed over this equation to get the optimized irrigation frequency value. Beat Stauffe suggested that sprinkler irrigation is suitable for all kinds of soils [7]. Another parameter is different lights responsible for the quick growth of plants. Many factors affect this technique like plants to be grown, when to grow, height of plant, amount of light needed and spectrum of light required [8].

An array of light-emitting diodes (LEDs) that produce red radiation, supplemented with a photosynthetic photon flux (PPF) of 30 μmol·s-1·m-2 in the 400- to 500-nm spectral range from blue fluorescent lamps, was used effectively as a radiation source for growing plants[9]. NASA research findings say that LED lights are the best single source lights for growing plants on Earth as well as in space [10]. This factor has been used for choosing the right LED for our project. Studies by researchers say that an appropriate R: B ratio is important for indoor cultivation [11]. A study [12] says that not only the colour but the light quantity, quality & duration also affect the plant growth. In [13], it is suggested that LED lighting systems can provide precision delivery of photons and that they can be a more cost-effective option (if widely spaced benches were used) for supplemental greenhouse lighting.

Temperature & moisture values for setting the correct irrigation frequency and light are taken. The use of wireless sensors for precision farming is an ongoing study domain. Ahmad Sumarudin proposed the idea of e-agriculture by monitoring temperature, humidity, and moisture based on wireless sensor networks [14]. Zigbee-based agriculture monitoring system [15] serves as a reliable and efficient system for monitoring agricultural parameters. The corrective action can be taken. Wireless monitoring of the field not only allows the user to reduce the human power, but it also allows the user to see accurate changes in it. It is cheaper and consumes less power. Android Thing is an operating system developed by Google and it enables developers to create professional IoT applications using trusted platforms and Android. Android Things [16] is a modified version of the well-known Android used for plantation. This operating system has great potential because Android developers can easily switch to IoT and start developing new projects in a short time.

All the above methods have been studied and tested around the globe but an integration of all the methods has not been in such notice. The indoor plantation is the concept that has evolved due to this research. The proposed plantation system not only integrates all the

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above ideas but also gives a new vertical for plantation. It uses the sprinkler technique to minimize the water waste during the irrigation system by providing a required amount of water to the plants at certain intervals. In addition to temperature sensor, moisture sensor, and light sensor, the prototype incorporates Android Studio to establish a connection between android things and the nodes.

2. Multilevel Plantation system

The proposed system will tender towards the cause of maintaining an unseen balance between the supply and demand of agricultural or horticultural plants. A prototype of a multi-level residential planting system is developed. The essence of this work depends on the fact that the multi-level system is equipped with platforms having controlled parameters. These parameters can be adjusted or fine-tuned according to the type of plant that is being grown. This will ensure the optimum and natural growth of various plants. The parameters under our control will be humidity and light. Along with controlling such parameters, constant monitoring is also done through a mobile application that shows the moisture level, light intensity as well as the temperature in a given compartment. Implementing this concept, control over various environmental factors can be achieved. The multi-level system is used to optimize space so that more plants can be grown in less space.

Automatic water supply will be provided to the plants for maintaining their moisture content that can be easily set in the app. The water container is placed at the top compartment for the convenience of the user. The two compartments will be fitted with pipes and lights. Holes are provided in the pipes for a sprinkling effect which is easily achievable with a high power motor. The lights are also arranged in a manner to provide optimum lighting throughout the compartment. The intensity closest to the optimum intensity of light required will be provided by the lights. These too can be controlled by the app itself. It is often said that saving water is a vicarious deed. Keeping that in mind one-third of the compost is made with coir. Coir is essentially the fibers from the outer husk of the coconut. It is very well known for its water retention capacity. Therefore this arrangement is preferred to use minimum water and bring out the best results. In addition, water is sprinkled over the plants to reduce water loss.
This prototype will be able to be fastidious about the major parameters affecting the rate of plant growth thus helping us increase this rate. The overall block diagram of a smart residential multilevel plantation system is depicted in Fig.1. In summary, this prototype will be a catalyst to indoor plantation rather than making it a burden.

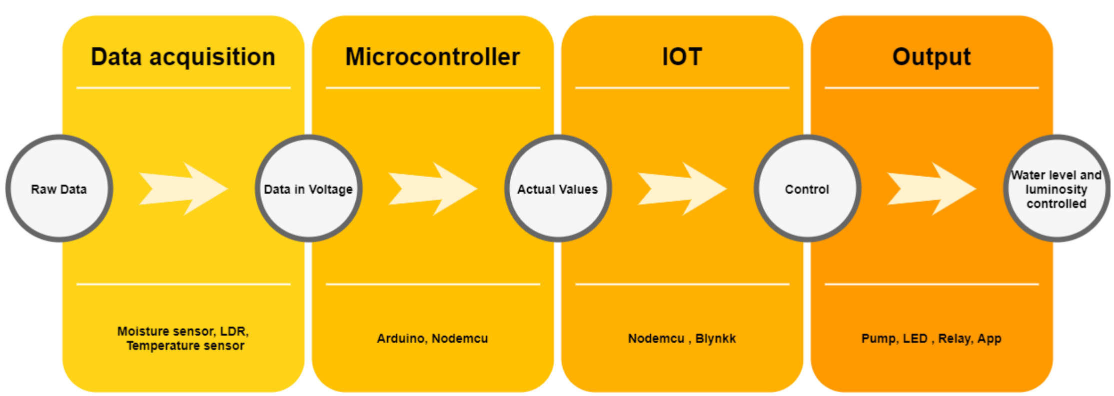

Fig.1 Representation of Multilevel Plantation System

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This project incorporates many electronic components (as depicted in Fig.1) whose details are mentioned below:-

a.Arduino Uno :- Microcontroller-based open-source electronic prototyping board which can be programmed on an Arduino software. Arduino UNO is the brain of this whole work. Using the microcontroller Atmega328P (Atmel company), Arduino does all the processing required to make this project work. The software of Arduino being in C++ is user friendly and helps us to program the board with relative ease. Arduino Uno operates at a voltage of +5 V and can be powered by an AC-DC adaptor or a battery.

b. Submersible Mini Water Pump :-A mini submersible water pump is used for pumping the water from the reservoir to the plants. It can operate within a range of 3-6 volts and can take up to 120 litres an hour consuming a meager 220 mA. Pipes are provided connecting the output of the motor to the plants.

c. Soil Moisture Sensor:- A soil moisture sensor is used to measure the moisture present in the soil. The sensor measures the volumetric water content by using other properties of the soil such as the electrical or dielectric constant. The soil resists the flow of electricity between the two electrodes and its sensitivity is used to determine the moisture content of the soil.

d. 9 V DC Battery :- A battery is used to supply 9 V DC to power the system. This battery is needed because the current output of the Arduino is not sufficient enough to drive the submersible water pump. Additional source is required and this 9V Dc battery can provide up to 500mA which is well enough for the pumps and also the LED to glow.

e. Relay: **-** A relay is basically a switch between the Arduino and the output devices like the pumps. The relay is needed to encompass multiple output devices and make them work in a programmed manner. Multi-Channel relay depending on the users need can be used. A two-channel relay can be used for two platform prototypes (for 2 pumps).

f. Temperature and humidity Sensor: **-** The DHT11 temperature and humidity sensor are used in this prototype to monitor the temperature and humidity in which the plants are growing. Working at a voltage level of (3.3-5)V, this highly calibrated sensor sends a digital output that can be converted to analog form using appropriate functions and can be displayed on the app.

e. LED-

Based on the LED reference data [17] given in Table 1, a multi-color LED system is preferred for the lighting system. This multi-colour LED system has a combination of red, blue, white, green light with varying intensity. The spectrum of lights will range between 460nm-700nm as referred from Fig 2.

g. LDR- Light Dependent Resistors (LDR) is used to detect the intensity of the light to switch on the LEDs accordingly. LDRs are made up of metal film contact and Cadmium Sulfide track which acts as a photoconductor having free electrons when illuminated. Hence, the presence of light decreases the resistance significantly to provide the output to the microcontroller. Resistance used for LDR is 1k ohm.

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Table 1: Effect of LED mixed light source on the color of pileus and the physical properties of stipe of oyster mushroom

Light source	Lightness of pileus	Properties of stipe		
		Hardness (kg/cm^2)	Brittleness (kg)	Springness (%)
Fluorescent Lamp	52.7[a]	4.0bc	48b	95.2c
Dark	-	-	-	-
Blue + White	49.5c	4.3ab	54a	96.4ab
Green + White	47.7d	4.6a	57a	96.5a
Blue + Green	50.8bc	3.2d	40c	95.2bc
Green + Red	51.2b	4.8a	56a	95.2bc

The intensity of radiation : 5umol/m^2/sec

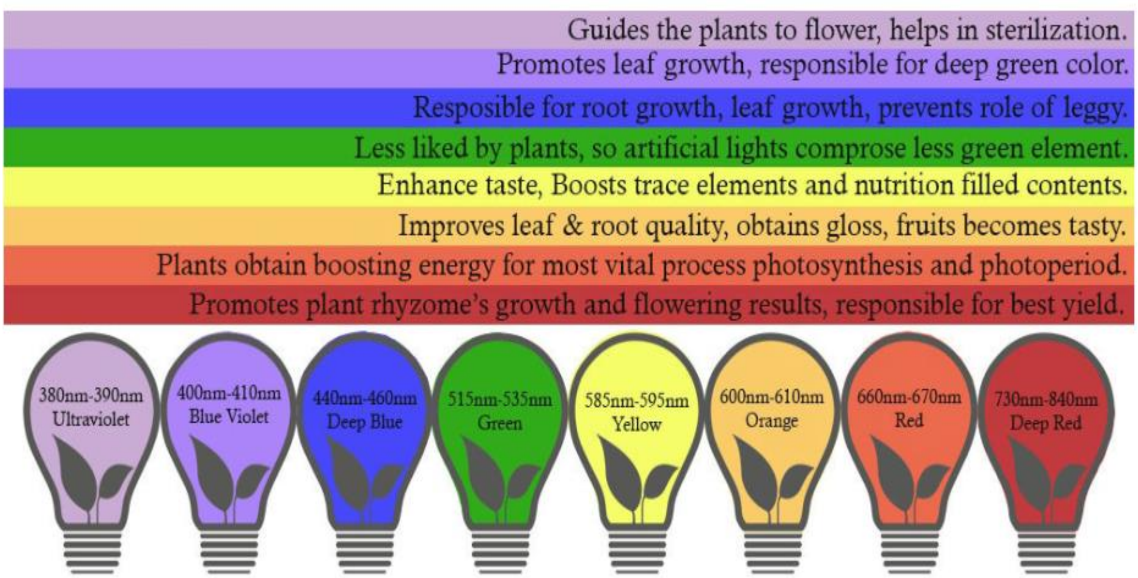

Fig 2 Light with their spectra and importance in plant growth [18]

h. Software- Android Studio is used to code the application which runs the NodeMcu and Arduino Board. To design the mobile application, Adobe XD is used which is the industry

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standard for designing applications. Fragments and RecyclerView are also employed inside the android studio application to obtain the tabs and cards view UI. Arduino is connected to the app with the help of Bluetooth to make it an IoT based project. The application uses Java language as it's the primary programming language. Kotlin can be used to make some design changes. The application has three major components in all the pages. Java is used for automation algorithm.

I. ESP8266 Nodemcu- A System On Chip called ESP8266 is used to provide networking between different sensors and the user. Nodemcu is the open-source software and hardware development environment which provides easy access to the chip by providing high-level language instructions. The IDE used for Nodemcu is the same as that of Arduino and can be programmed using C++ programming language. The operating voltage of Nodemcu is (3.3-4) V. Since Arudino uses 5V, the supply can be used in the input voltage (Vin) pin of Nodemcu when an USB is used. The user interface and IOT platform for Nodemcu are provided via blynk.

3. Simulation and implementation of the proposed work:

The implementation of smart residential multilevel plantation is illustrated in the flowchart [refer Fig.3] and the 3-D of the system is portrayed in Fig.4.

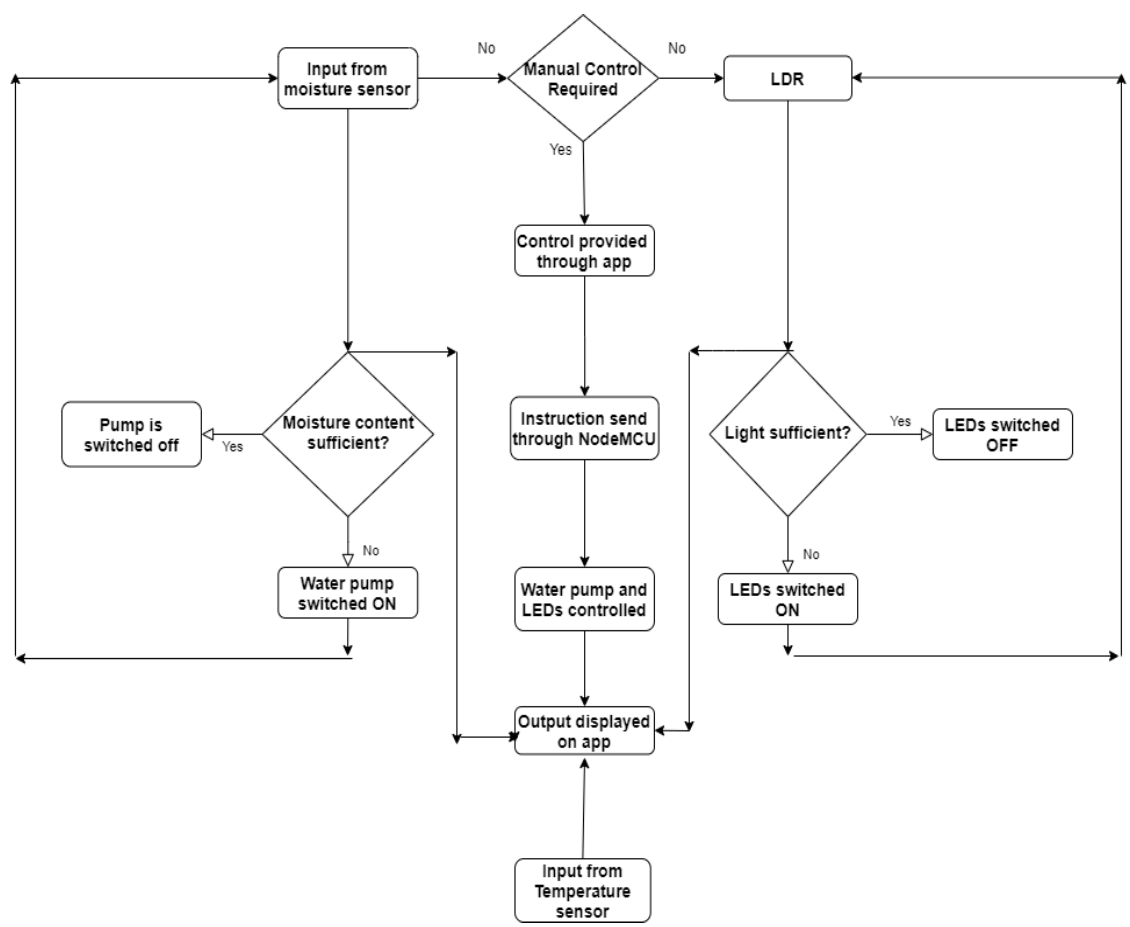

Fig.3 Workflow diagram of Multi-level plantation system

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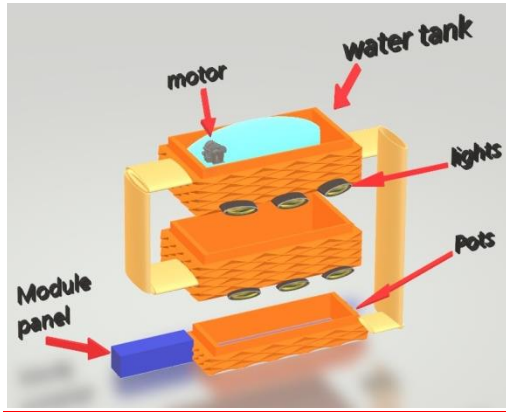
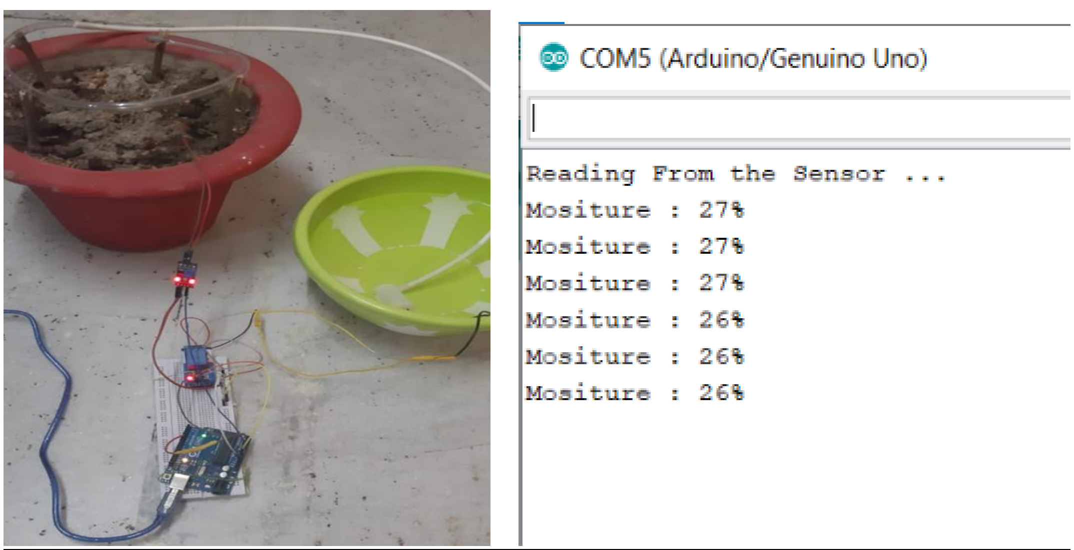


Fig 4 Multi-level residential plant -3D model

There are two modes of operation designed and are referred as Manual mode and automatic mode. In the Manual mode, the threshold value is replaced by the predefined value set by the user. The pump and LED will function according to the given value. All the outputs will be displayed on the app. In Automatic mode, the inputs from a single level are taken by the moisture sensor and the LDR. The output from the sensors is sent to the microcontroller to assess them and perform the necessary functions as per the program. The moisture sensor and LDR sensor have the threshold value set in this mode. The input value taken by the sensor is compared to the threshold value. If the moisture content is lower than the Preset values then the respective devices i.e. the pump or the LEDs are turned ON. After the predefined delay, the controller will repeat the process until the moisture goes back above its threshold value.



(a) (b)

Fig 5. Moisture sensor testing in one layer

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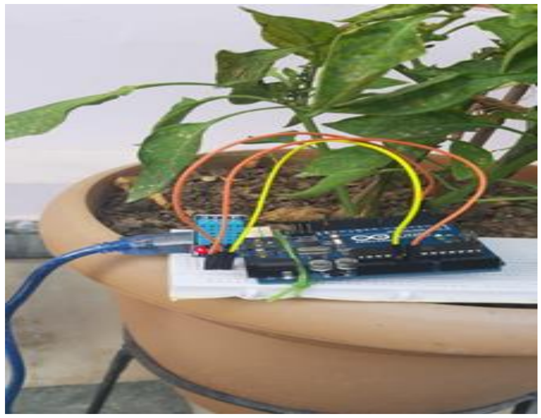

Fig 6. Temperature Sensor

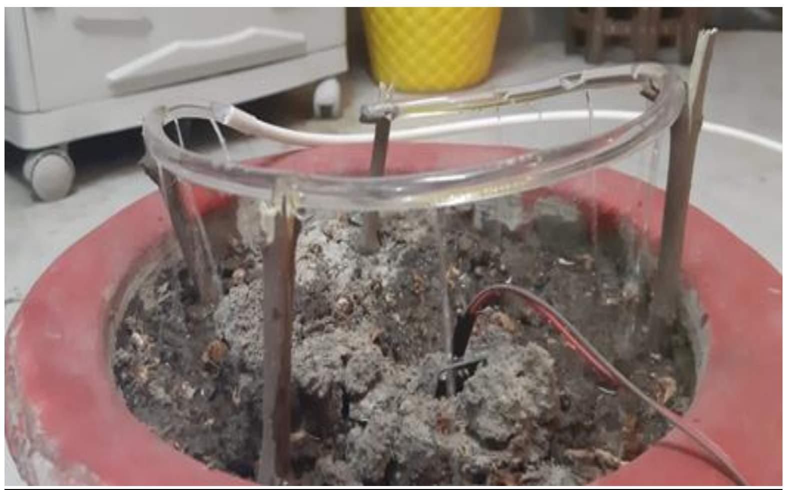

Fig 7. Motor pipes and sensors setup

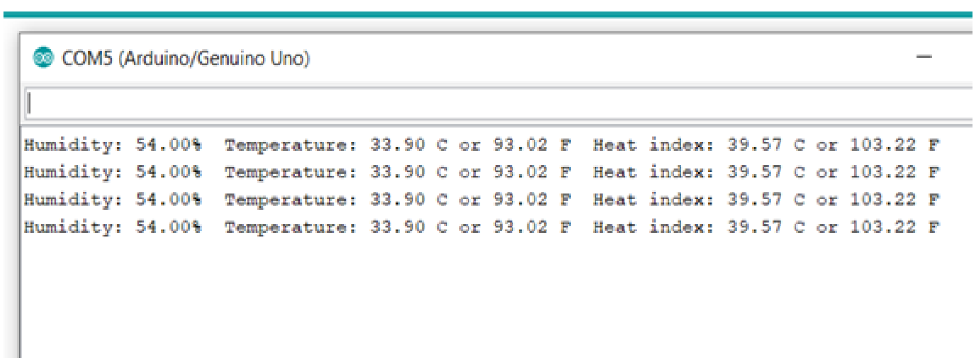

Fig 8. Output of temperature sensor on the serial monitor

3.1 Pseudocode: The pseudocode is developed by defining PINs for all the sensors on the Arduino IDE. Separate functions are created to get the output from the moisture sensor, LDR sensor, and temperature sensor. Analog read method is used in all the functions. The moisture sensors are shown in Fig.5(a). If the soil is drier, then the resistance of the sensor is more that draws more current. Raw output from the moisture sensor is mapped from 0 to 100. All the values are then printed to the serial monitor as depicted in Fig.5(b). For LDR

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sensors the raw values retrieved from the AnalogRead method are mapped from 0 to 100 to get the luminosity in percentage. Raw values from the temperature sensor as shown in Fig.6 are multiplied with 0.488215 to convert the voltage into its temperature equivalent. Similarly, the humidity, temperature and heat index values are transferred to the serial monitor as displayed in Fig.8.

3.2 Autonomous functioning: For the pump to function, a conditional statement is applied inside which the pump is switched on if the mapped output from the moisture sensor is less than 0(indicating the soil is dry). The pump is kept on for 1 second after which the moisture of the soil is checked again to keep the pump operating. Similarly, the mapped output from the LDR is checked and LEDs are switched on if the output is less than 25(out of 100).

3.3 IOT functioning: For IOT functioning, Blynk platform is used to connect Nodemcu and mobile applications to enable user input. First, ESP12-E module is installed from the Board manager in the Arduino IDE. Then, Blynk App is downloaded. After starting a new project, necessary control panels are added to the user interface after which an authentication code is generated and sent to the user mail. This is added to the code along with the wifi name and password. Virtual pins to operate the pump and led are defined at the beginning of the code, to connect them with the blynk app. BLYNK_WRITE() function is used outside the code which controls both LED and pump, to operate via the blynk app. Blynk.notify() function is used to mention the user when the pump or led are switched on.

3.4 Mobile App: The mobile app provides an option for the user to customize the temperature, moisture and light intensity settings. This is portrayed in Fig 9(a). Settings option is provided at on the top right corner. The menu item in the app helps to display the current measurement of the parameters as shown in Fig.9(b). An additional provision has also been given to edit the parameters. Fig 9(c) depicts the current values of the moisture intensity and temperature as 75%, 80% and 30°C. Navigating down a custom page is presented where the profile for different plants can be added. Further a pre-set page (refer Fig 9.(d)) is given to add a new profile according to user need.

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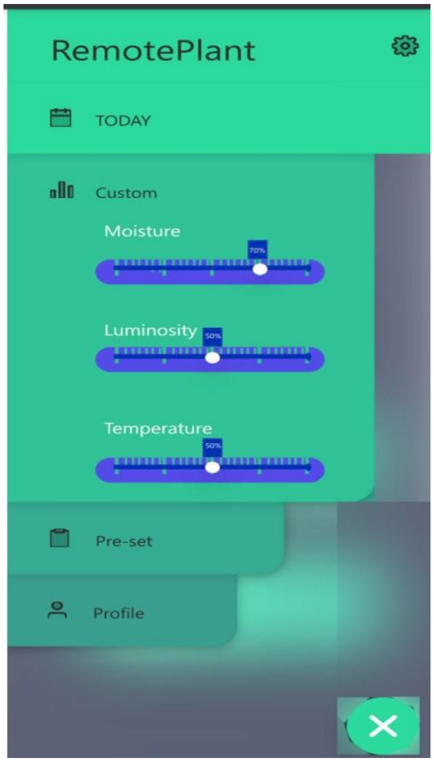
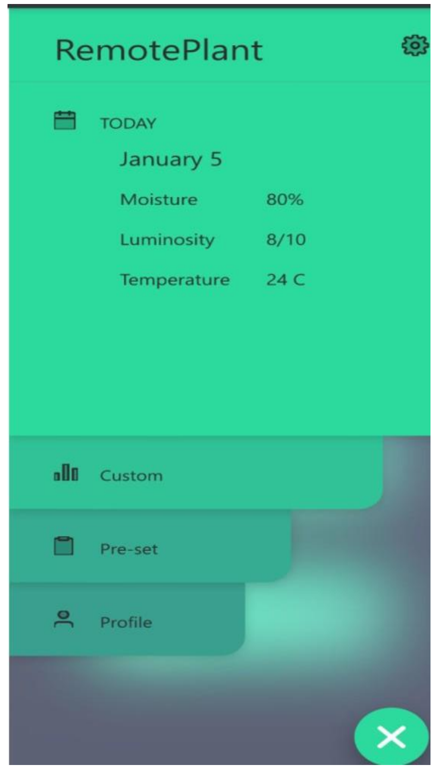
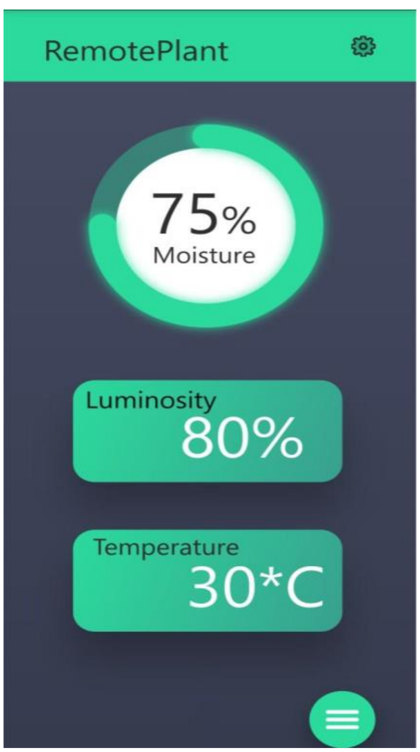


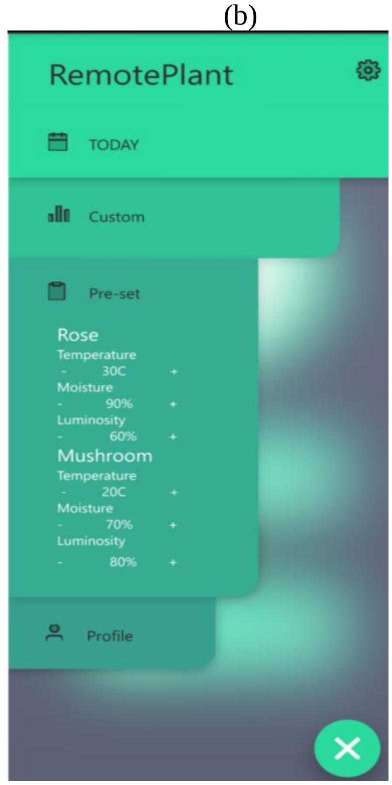
(a)



(b)



(c)



(d)

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Fig 9. App screen displays (a) a new profile or provides a facility for altering the current settings (b)Current status of the plant.(c) Moisture, Luminosity and temperature of the plant. (d)"pre-set" screen with pre-set values.

5. Conclusion: Conclusion drawn from the above results states that the moisture, temperature value of the soil has been successfully provided by this method. Thus the design, implementation and monitoring system of the prototype is given an optimized result. The data can be viewed in the app whenever the app is opened. The system can help to monitor real-time status of the plants and can be used in the market at primary level. This prototype can be made commercial ready with a more advanced IoT network like ZigBee. More features can be incorporated like temperature control systems and artificial intelligence (AI) for autonomous irrigation and other control settings. Structure can be developed to increase more levels of plantation. A cloud with a database of various plants and their growing characteristics can be made so that the system can suggest the user appropriate lighting, temperature, moisture, etc. LED grow lights can be used for better quality plants and further study on light spectra can be initiated.

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