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Smart Agricultural Monitoring System using IoT Application for Chili Plants

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ABSTRACT

The use of IoT applications for agricultural in Malaysia is still low. The farmers are mainly using the traditional method compared to modern agriculture by using advanced technology system like IoT application. However, the use of traditional agriculture requires a lot of work and use of labour. This will result their agricultural system become less efficient and quality of production becoming low. Thus, development of system for monitoring and automation are needed to help farmers to manage their agriculture. This paper focused on development of smart agriculture for monitoring and automation system on chili plants using IoT application. The system is developed using Arduino as microcontroller, soil moisture sensor, DHT11 sensor (temperature and humidity), ultrasonic sensor, servo motor, water pump and ESP8266 (Wi-Fi Module). The Wi-Fi module provides internet access to the local network which allows the system to connect to the system and the mobile phone. Soil moisture sensor used to measure the moisture of soil content. DHT11 sensor was used to measure the temperature and humidity of surrounding area of plants. Ultrasonic sensor was used to measure the height of plants. Servo motor is controlled by automation system via Remote XY Apps to provide the fertilizer to the plants. The water pump also can be controlled by the Remote XY apps as to water the plants. Then, data that was collected from the sensors was sent to user via Remote XY apps where user can control the system that is to turn on the servo motor and water pump to fertilize and water to the plants. Therefore, this system can help farmers to manage their agriculture efficiently and improve their quality and quantity of crops.

1. Introduction

Chili also known as Capsicum annum is a fruit type vegetable which is popular in Malaysian's Cuisine. Chili was originated from Mexico and South America but adopted to Malaysian tropical climate many decades ago [1]. About 14,560 hectares of chili was grown in Malaysia annually in major producing state such as Johor, Perak and Kelantan in commercial scale [2]. According to statistic of Malaysian Agriculture Department, the production of chili continues to increase. For instance, in 2017, the production of chili had increased by 9,832 metric tons that is 22% growth compared to

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2016. Besides, the total area of chili crop plantation has reached an area of 3,381 hectares which produced 43,738 metric tons of chili [3]. According to Haifa Group [4], the growth stage of chili plants can be classified into four stages; the first stage is the stage of vegetative growth that is from planting or seeding to the first flowering. The second stage is the period from flowering to fruit set, and the third stage is from fruit ripening to the first harvest. The last stage is the period from the first harvest to the last harvest. The duration of each stage may vary according to the growing method, characteristics of chili variety, and climatic conditions. The appropriate pH for chili cultivation ranges from 5.5 to 6.8 with an optimum pH of 6.0-6.5. While the optimal temperature for the growth of chili plants is 24°C-28°C [5].

The planting of chili plants required continuous monitoring of soil moisture and pH, soil nutrients, and temperature to ensure the plants can grow optimally [6]. The plants could easily wither if the plants got too much water [7]. On the other hand, chili plants should be watered thrice a day to avoid drought and they usually sacrificed time and energy to see the physical development of chili plants. Besides that, farmers faced problems managing their farm wisely because there is a lot of work to be done in the farm. As a result, a monitoring system is an essential tool to increase the chilli production [8]. IoT-based smart farming helps farmers to optimise water, fertiliser and pesticide inputs and improve crop yield, quality and productivity by monitoring various factors such as humidity, temperature, soil conditions and fertiliser and pesticide levels on their farms in real-time with the help of sensors and interconnectivity [9-11].

The main objective of this study is to design an IoT system for monitoring of chili plants. This project is focusing on developing wireless systems using Arduino, sensors and ESP8266 Wi-Fi Module. Data collected from sensors will be processed by the Arduino and send to the Remote XY application. Next, user can control and set the automation system to provide water and fertilizer via mobile phone.

Nayyar *et al.,* [12] proposed an IoT Based Smart Sensors Agriculture Stick for Live Temperature and Moisture Monitoring using Arduino, Cloud Computing & Solar Technology. This proposed system enables live monitoring of different agricultural parameters. The stick helps farmer acquire live data of temperature and soil moisture by positioning the stick in the field. Then, the live data feeds can be monitored on tablets and phones. Besides, the information produced by the sensors could be analysed and processed by the agricultural experts even in remote areas via cloud computing technologies.

Pusatkar *et al.,* [13] have proposed the Implementation of Wireless Sensor Network for Real Time Monitoring of Agriculture. This Wireless Sensor Network (WSN) helps in real time monitoring of the agricultural field. Various sensors are deployed in the field such like temperature sensor, humidity sensor, wind speed detection sensor, soil moisture sensor and wind direction sensor. The data collected from these sensors are connected to the ATMEGA 32A microcontroller. The alarm system will send alert to the farmer by using the Global system for Mobile (GSM).

A Low-Cost Smart Irrigation Control System has been proposed in [14]. In this paper, the author proposed a model where the flow and the direction of water is supervised and controlled. The system is developed with the help of soil moisture sensor and DHT11 sensor which sense the temperature and humidity. This system proposed a way to select the direction of water using electromagnetic valve. The pipe system is connected to the electromagnetic valve which changed the direction of the water automatically for the required area of the field. The valve is controlled by the Raspberry-Pi.

Rajakumar *et al.,* [15] proposed a Iot Based Smart Agricultural Monitoring System. Various sensors are deployed such as temperature sensor, moisture sensor, ultrasonic sensor and humidity sensor. The data collected from these sensors are connected to the Arduino UNO. ThingSpeak is added to the system which is an application in iPhone Operating System (iOS) that functions with

Arduino. The status of monitoring plant growth by using ultrasonic sensor will be sent to the mobile application via IOT module so that the values can be observed. Then, watering could be done automatically with a predefined time delay that controlled by Arduino.

Pawar *et al.,* [16] have proposed a Smart Irrigation System using IoT and Raspberry Pi. The proposed system used sensors such as soil moisture sensor, soil temperature sensor and ultrasonic sensor. The Raspberry Pi model is used to determine whether the soil moisture or soil temperature parameters have reached a predefined threshold level to turn on the irrigation system automatically. Besides, farmer can easily monitor in real time the actual situation of the field by using the webcam with suitable application on mobile phone.

An IoT Based Smart Agriculture Monitoring System is proposed in [17]. Various sensors were deployed such as temperature sensor, moisture sensor and PIR sensor. The data collected from these sensors were connected to the microcontroller (PIC16F877A). The received data is verified using a pre-determined threshold value. The system is set in to modes: manual and automatic. In manual mode, user has to switch ON and OFF the microcontroller by pressing the button in the Android Application. However, in the automatic mode, the microcontroller gets to switch ON and OFF automatically if the value exceeds the threshold point. Soon after the microcontroller has started, an alert is sent to the user through the GSM module. The data collected from the sensors could be viewed on the web page for detailed description of each value.

Kaburuan *et al.,* [18] proposed an IoT-based Monitoring System for Intelligence Indoor Micro-Climate Horticulture Farming in Indonesia. In this paper, the system used micro-climate monitoring systems based on IoT that suited with tropical Indonesian condition which is integrated with an automated intelligence system. An IoT system is designed for the electronic devices to monitor the condition of the soil, water, and air in the horticulture cultivation. Image capture equipment for plant cultivation also implemented. The monitoring result is sent to the database. This database is integrated with the Indonesia weather agency, Badan Meteorologi, Klimatologi & Geofisika (BMKG), for the daily weather and climate data at the farming location. This monitoring system will be useful for farmers in tracking crop performance based on farmers' behaviour from planting to harvest time. The collected monitoring data will be used for training a machine learning based technology for automated indoor micro-climate horticulture.

Karim *et al.,* [19] proposed a monitoring system using web of things in precision agriculture. The proposed system used Waspmote sensor (open-source wireless sensor). Then, each sensor node (wireless sensor node) is equipped with an ATMega 128 microcontroller. Next, each waspmote node is equipped with a soil moisture sensor and two electrodes incorporated in a gain above gypsum slice. It is buried in the ground to measure the soil water pressure which reflects the soil moisture conditions. Meshlium is a multi- protocol router that contains 5 wireless connection interfaces which are 2.4 GHz Wifi, 5 GHz Wifi, Blutooth, ZigBee and 3G/GPRS. This latest GPRS module is very user friendly for mobile applications. Meshlium a multi-protocol router of Libelium, that collects all data from the sensor nodes and stores them in a local database or exported to an external database.

Vani *et al.,* [20] proposed a Measurement and Monitoring of Soil Moisture using Cloud IoT and Android System. FC-28 soil moisture sensor is used to detect moisture of soil that present in the plant watered device. The output of FC-28 is in terms of analog voltage for measuring soil moisture. The sensor interfaced with CC3200 LaunchPad will be collecting the data from the sensor continuously. Using an on-chip Wi-Fi, the values from the sensor are uploaded into the Cloud (AT&T'sM2X Cloud technology). Farmers monitor and control their crops using Blynk mobile application for Android or iOS mobile devices. AT&T's M2X Cloud will show the chart of accessing data which is values of soil moisture data on M2X web page. These values will be uploaded continuously by connecting the internet with CC3200 LaunchPad and are downloaded every minute into Excel sheet2. Hence, farmer can track all the data collected from the sensor.

Pravin *et al.,* [21] proposed an Enhancement of Plant Monitoring Using IoT. This proposed system used soil monitoring sensor, light sensor and temperature sensor. The temperature sensor measures the temperature while the soil monitor sensor determines the water content in the soil. Then, the light sensor is used to measure the field light intensity. Different types of sensors are installed in the land for collecting different set of data that will help the farmers in predicting the growth of the crop. The information collected by the sensors will be passed to the Arduino and depends upon the data received, the corresponding action will be taken.

Rohadi *et al.,* [22] proposed a Raspberry Pi Based Farming Automation and Monitoring System using Automatic Weather System (AWS) (Case Study: Chili Plants). The system used temperature, air humidity, wind speed, and light intensity sensors. Temperature and humidity sensors are used to measure the temperature in the field to be worked on. The light intensity sensor is used to measure the intensity of sunlight in the field. Then, all measurements data will be stored into the database. The monitoring data will be compared with the data from the OpenWeatherMap API. The data is compared to check whether the data from the sensors are accurate while determining the weather in the area (on the land). After the data from the sensors and APIs have been analysed, then the watering pattern of chili will be determined in the arable land based on temperature, humidity, and sunlight intensity.

Kajol and Kashyap [23] proposed an Automated Agricultural Field Analysis and Monitoring System Using IoT. In this system, the moisture sensor is used to measure the moisture content from the soil at every 100 m distance and there is camera records the video. Frames from the video are chosen and processed using image processing algorithms to detect the pest. All the information from the sensor will be sent to SQLite database while the video from the camera will be sent to dropbox cloud storage. Then, the images stored in the dropbox will be retrieved to find the type of pesticides that will be used to prevent the pest in the crops. When all data are available in the cloud, farmer will get a detailed report with average moisture contents, pests attacking the particular crop, pesticide for that crop, seasonal crops, date and time of the report in the Android application. With this information, farmer will get to know about the field conditions and other information to help him in managing field effectively.

In summary, the works in [12-23] have developed the monitoring and controlling system for farming and agriculture using various method. The project that is proposed for this study is to monitor the chili plants using IoT. The system will be using Arduino as microcontroller, soil moisture sensor, DHT11 sensor and ultrasonic sensor. This study is different from the system that is developed in paper [22] with the addition of soil moisture sensor and ultrasonic sensor that will detect the moisture of the soil and measure the height of the plant respectively. Moreover, this system also has an automation system that can control the rate of fertilizer given to the chili plants and water pump to supply water to the chili plants by using Remote XY Apps. The added feature to the proposed work will ensure good plant growth and fruit formation to produce chili crops.

2. Methodology

There are several stages involved in the methodology which includes the Program Development, Interfacing of Hardware and Software, Function Evaluation, Troubleshooting and System Analysis. The output functions on the Remote XY Apps can be controlled using the mobile phone.

Figure 1 shows the block diagram of the system. Inputs for this system are soil moisture sensor module, temperature and humidity sensor module (DHT-11) and ultrasonic sensor (HCSR-04). Then, the data collected from the sensor will be sent to the Arduino. Arduino will switch on and off the water pump and servo motor to provide water and fertilizer respectively to the plant. Then, Arduino will provide the supply for all hardware connected to it and also control the input and output. Next, the data will be displayed on LCD and mobile phone that will be the output of the system.

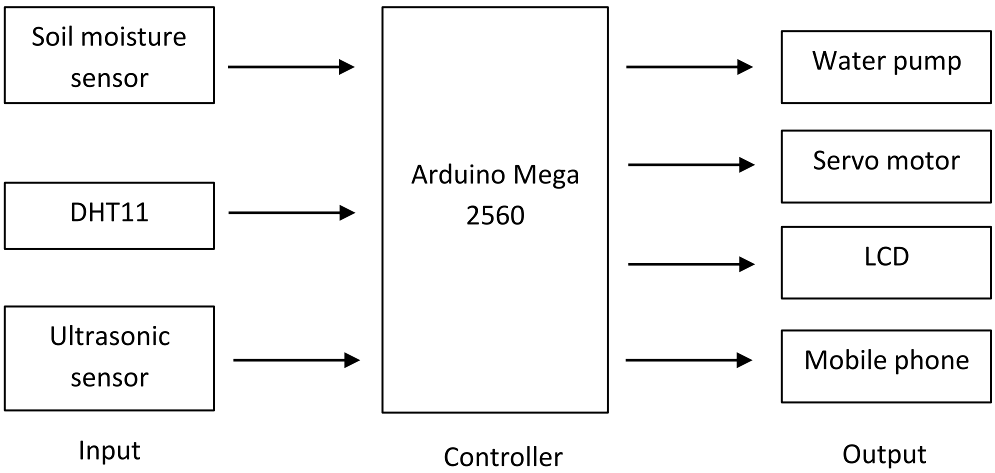

Fig. 1. Block Diagram of System

Figure 2 shows the architecture of the project. This system used soil moisture sensor, DHT11 sensor (temperature and humidity) and ultrasonic sensor. The data collected from the sensors will be processed by Arduino. Then, soil moisture sensor will detect the moisture content of the soil. The reading of the soil moisture will be displayed on LCD and send to user via Remote XY Apps. If the reading of soil moisture is less than 30%, the automation system will turn on the water pump automatically to provide water to the plants. Next, DHT11 sensor will detect the temperature and humidity of surrounding area and ultrasonic sensor is used to detect the height of the plant. Then, all the collected data from DHT11 sensor and ultrasonic sensor, the reading of temperature, humidity, and height of plants will be displayed on LCD and the data will be sent to user via Remote XY Apps. Besides, user can control the automation system that is by turning on the water sprinkler and fertilizer using Remote XY Apps to provide water and fertilizer to the plants respectively. If user wants to turn on the water sprinkler, water pump will be turn on for watering the plants.

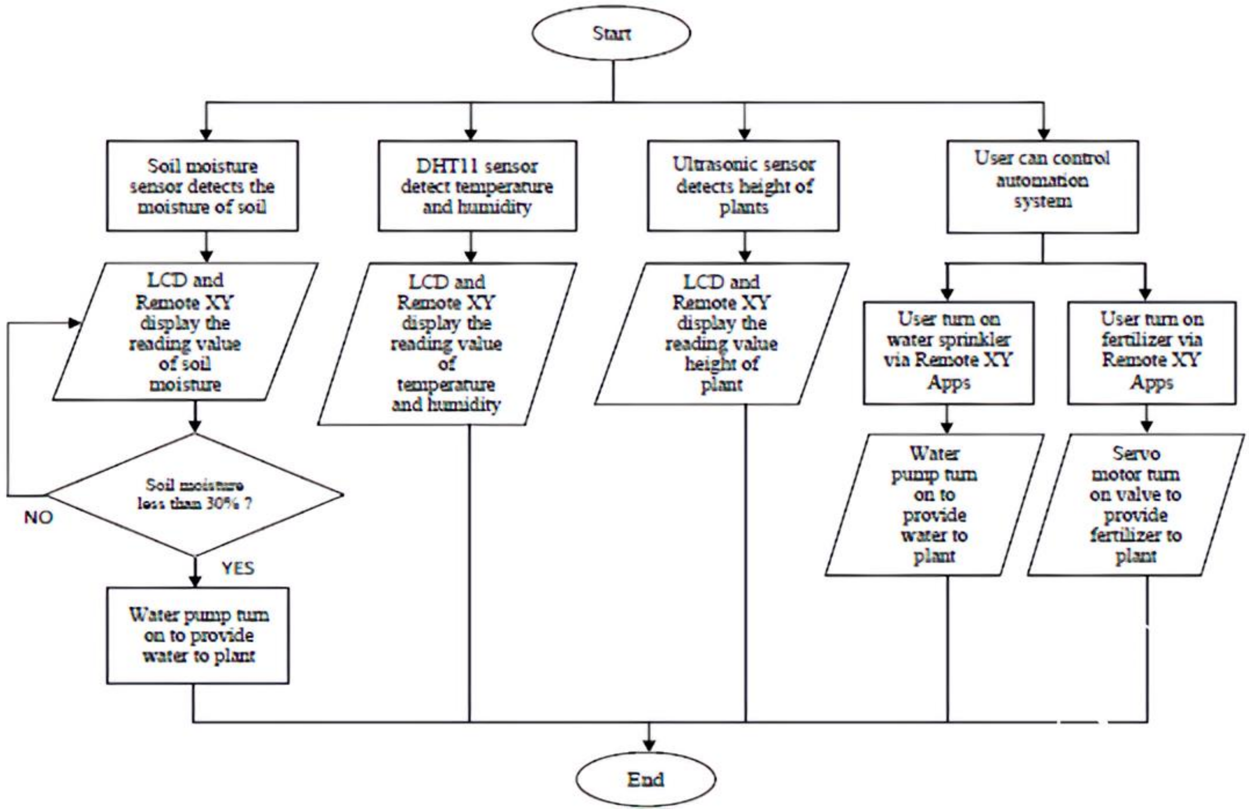

Fig. 2. Flowchart of Project

Next, if user wants to turn on the fertilizer, servo motor will turn on the valve of fertilizer to provide fertilizer to the plants. This automation system can be turned on based on the moisture of the soil and fertilizer needed for the plants.

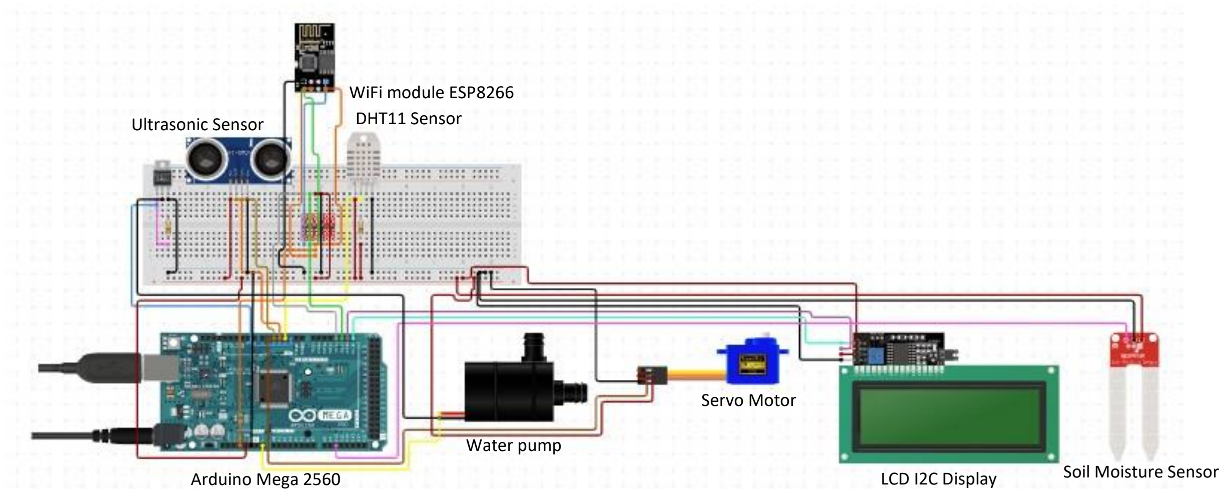

Fig. 3. Circuit Diagram

Table 1 shows the list and functionality of the hardware that are involved in the prototype development. Arduino Mega 2560 is the microcontroller for this prototype along with soil moisture sensor, DHT11 (temperature and humidity sensor) and ultrasonic sensor used for monitoring system of the plants. Water pump and servo motor used for automation system. Water pump and servo motor provide water and fertilizer automatically to the plants. Next, ESP8266 is used as the Wi- Fi module to connect Arduino Mega to the Wi-Fi network for sending the data to the Remote XY Apps.

Table 1
List of Hardware and Its Functionality

Hardware	Function
Arduino Mega 2560	Acts as microcontroller.
Soil Moisture Sensor	To measure the moisture content present in the soil.
DHT11 Sensor	To measure the temperature and humidity of surrounding area.
Ultrasonic Sensor	To measure the height of the plants.
LCD I2C	Display the current value from each sensor.
ESP8266 (Wi-Fi Module)	Send data to Remote XY Apps
Servo Motor	To turn on the valve of fertilizer to provide to the plant.
Water Pump	To provide water to the plants.

3. Results

In this section, the results obtained from the deployed system based on the output signal as well as the output displayed on the LCD and Remote XY Apps are discussed. This result consists of data from the monitoring and automation system. This chapter consists of the hardware system, software system and data displayed on LCD results respectively.

3.1 Hardware System Result

In this section, the hardware system result is discussed which is the development of monitoring and automation system. The result of this system will be displayed on the LCD.

Figure 4 shows the hardware prototype of this project. This hardware prototype consists of monitoring and automation system. For the monitoring system, Arduino as microcontroller processed all data collected from sensors such as soil moisture sensor, DHT11 sensor (temperature and humidity) and ultrasonic sensor. Then, the data collected was sent to the LCD display as well as to the mobile phone. User will receive all reading of data from all sensors via Remote XY Apps. For the automation system, user can control the servo motor and water pump using mobile phone via Remote XY Apps.

Fig. 4. Hardware prototype

Figure 5 shows the output reading of data collected from the sensors and current condition of water and fertilizer which were displayed on LCD. The reading for temperature is 29.00 Celsius, humidity is 65.00%, soil moisture is 50% and plant height is 15 cm. The LCD was also displaying the fertilizer and watering functions which were in off condition.

Fig. 5. Data reading display on LCD

Figure 6 user has turn on the fertilizer via Remote XY Apps. Therefore, this servo motor will be automatically turned on the valve of fertilizer to flow the fertilizer through the tube into the plant's polybag.

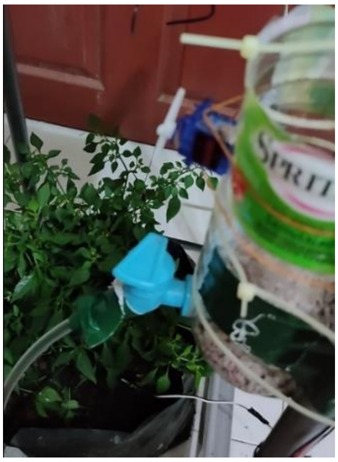

Fig. 6. Servo motor turn on the valve of fertilizer

Figure 7 user has turn on the water sprinkler via Remote XY Apps. Thus, water pump will be automatically turned on and flow the water through water sprinkler. Then, water sprinkler turns on and watering the plants. Besides, this water sprinkler will be automatically turn on when moisture reading obtained below 30%.

Fig. 7. Water sprinkler turned on for watering the plants

3.2 Software System Result

In this section, result displayed on the Remote XY Apps for monitoring system as well as automation system were discussed.

Figure 8 and 9 show the reading of data collected from the sensors and current condition of fertilizer and water sprinkler via Remote XY Apps. In Figure 8, the reading of temperature is 29.30 Celsius, humidity is 53.00%, soil moisture is 41% and plant of height is 19 cm. Then, the fertilizer function is in on condition which means that user has turned on the servo motor via Remote XY Apps. User can control and turn on the servo motor to provide fertilizer to the plants via Remote XY Apps.

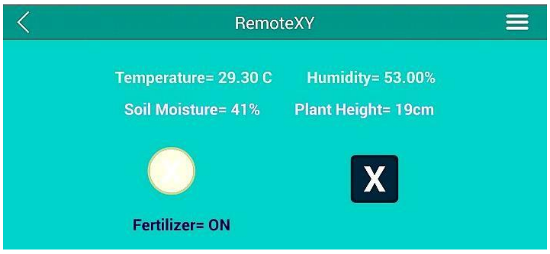

Fig. 8. Data Reading via Remote XY Apps

Next, Figure 9 shows the current condition of water sprinkler which is in on condition. User can turn on the water pump via Remote XY Apps. This water pump will automatically turn on when the soil moisture reading obtained is below 30%.

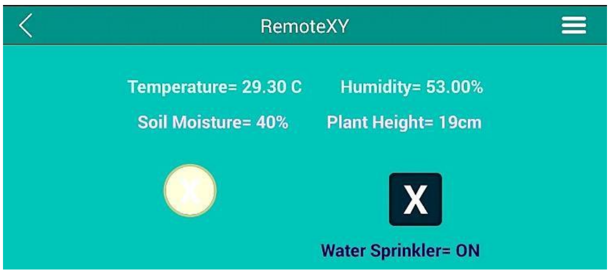

Fig. 9. Data Reading via Remote XY Apps

3.3 Data Display Result

In this section, the system was validated with the output graph and database of each sensor. These graphs and databases obtained by using PLX-DAQ software where this software provides the spreadsheet analysis of data collected from each sensor in Microsoft Excel. The result of graph and database obtained from each sensor are collected for one day.

Based on Figure 10, this is a graph and database of soil moisture percentage versus time which collected for one day (24 hours). The percentage of soil moisture starts to decrease from 12 am to 8 am which is from 45% to 31%. Then, the soil moisture content was steadily constant at 30% from 9 am to 3 pm. Next, the soil moisture increased at 4 pm which are 36% and then it decreased from 34% to 20% at 7 pm to 12 am respectively.

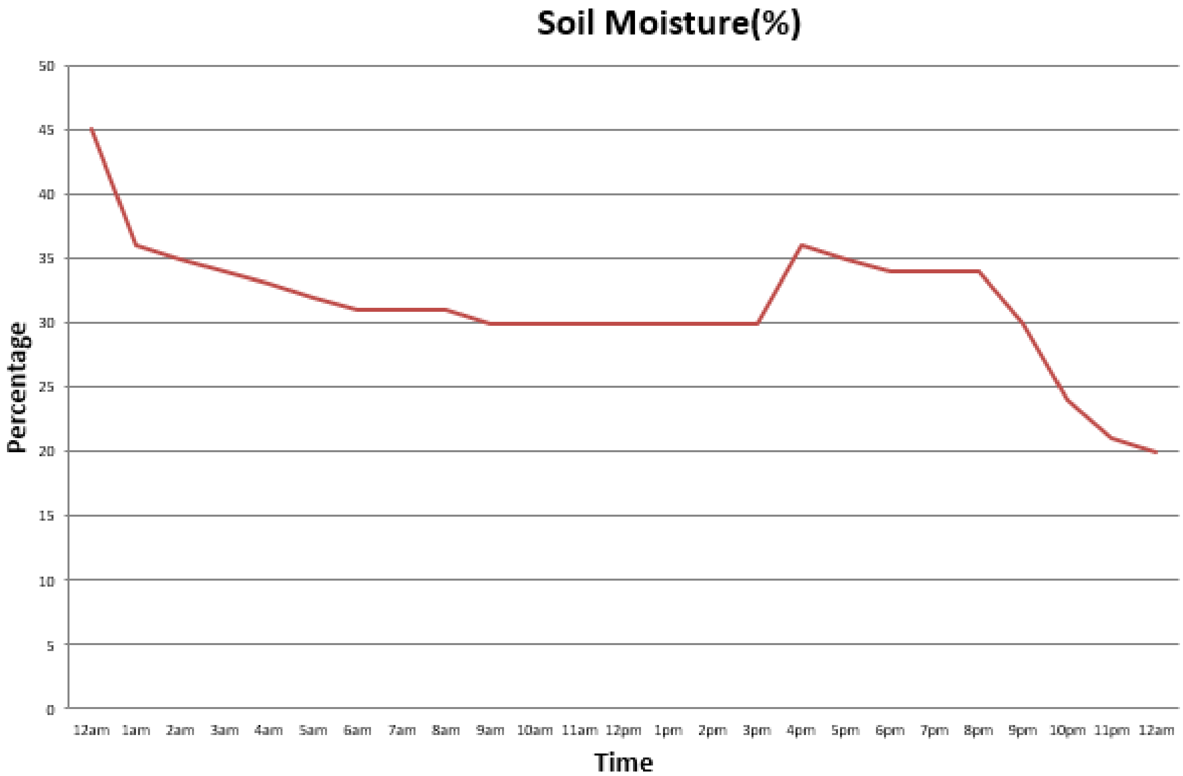

Fig. 10. Graph of Soil Moisture (Percentage vs Time)

In Figure 11 show the graph and database of temperature (Celsius vs Time) obtained in one day. The temperature of the surrounding area of the plants started to decrease from 12 am to 8 am which are 30.7°C to 29.6°C respectively. Then, the temperature started to increase from 30.1°C to 31.6°C at 10 am to 5 pm. Next, the temperature was decreasing from 31.4°C to 29.5°C at 6 pm to 12 am respectively.

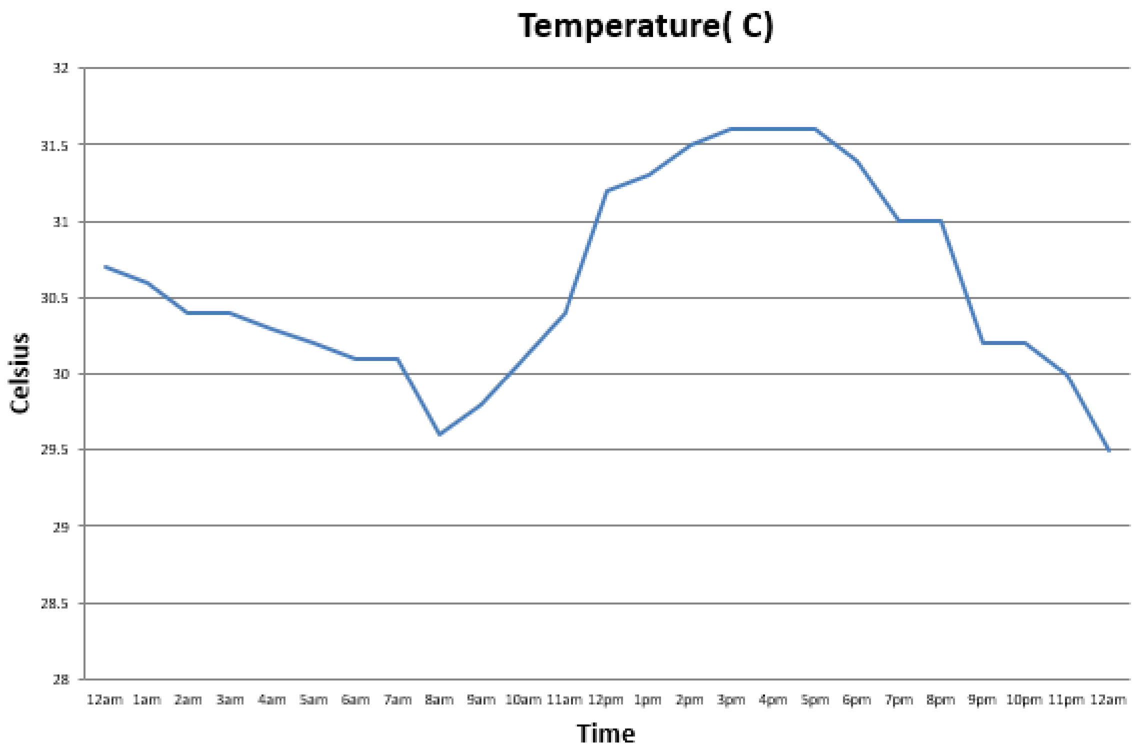

Fig. 11. Graph of Temperature (Celsius vs Time)

Based on Figure 12 shows the graph and database of humidity of surrounding area of plants in (Percentage vs Time) obtained in one day. The humidity from 12 am to 1 am is 55%. Then, the percentage of humidity is constant which is 56% from 2 am to 7 am. Next, the humidity value started to decrease and increase from morning to evening in the range between 49% to 52% at 8 am to 5 pm. After that, the humidity value increases and decreases back from evening to night in the range between 54% to 50% from 7 pm to 12 am. The humidity value increases and decreases in a certain period of time because the humidity is dependent on the temperature. When the humidity is high, the temperature will be low and when the humidity is low, the temperature will be high.

In Figure 13 shows the graph and database of plant height in (Centimeter vs Time) obtained in one day. Based on the graph, the plant height obtained at 12 am was 17 cm. Then, the plant height started to increase at 11 am where the height of the plant increases 1 cm where the new plant height obtained is 18 cm.

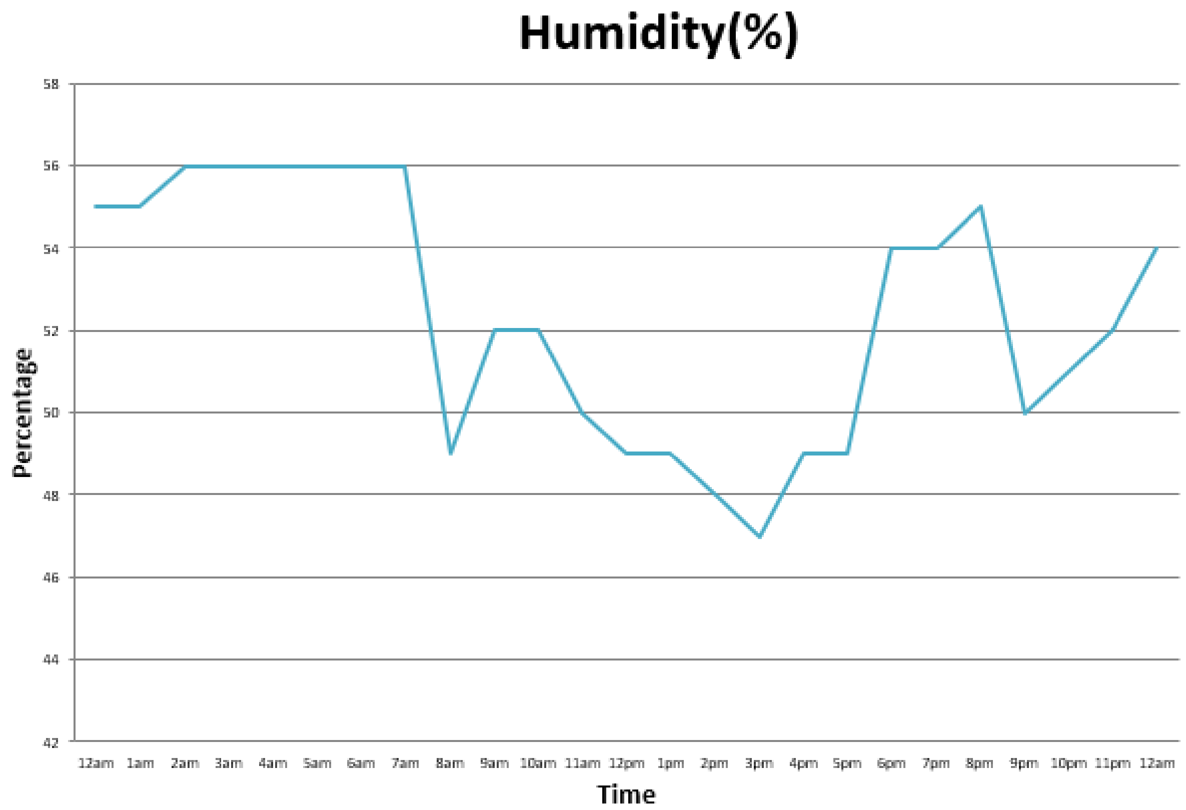

Fig. 12. Graph of Humidity (Percentage versus Time)

Fig. 13. Graph of Plant Height (Centimeter vs Time)

4. Conclusions

This system provides a solution for farmers to manage their agriculture by using advanced technology such as IoT application into their agricultural system. With the assistance of this technology, it can help farmers to manage their agriculture system more efficiently where farmers can monitor the crops by simply using a mobile phone via Remote XY Apps. Farmer can monitor their crops anytime and anywhere as long as there is internet access. Moreover, it can save farmer's time and farmer do not have to come to the farm every day to monitor the crops. Besides, farmer can control the automation system using mobile phone through Remote XY Apps. Farmer can provide fertilizer to the plants by clicking on button fertilizer via Remote XY Apps using mobile phone. Next, farmer also can water the plants by clicking on button water sprinkler via Remote XY Apps. Thus, this system is very convenient for farmers where farmers can only control the automation system by using mobile phone only if there is internet connection. Furthermore, it can improve the quality and quantity of crops and can increase the crop sales revenue.

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