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Development of Observation System Using Internet of Things for Growth Improvement in Indoor Farming of Apium Graveolens Var. Secalinum Alef

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ABSTRACT

This research was performed to develop an Internet of Things (IoT) monitoring system for growth condition of Apium Graveolens var. Secalinum Alef, then to determine the optimised lighting environment to optimise growth of Apium Graveolens var. Secalinum Alef. The experiment was conducted for 42 days, and the plants were grown hydroponically. Various data required to monitor the plants closely was collected daily using the developed IoT system and the data was relayed to the researcher using IoT. Based on the data collected from the experiment it is determined that the plants grown using the LED lighting system yielded more harvest compared to the plants grown using normal sunlight. The significant of this research is an IoT system to continuously monitor plant growth condition using an internet connected mobile device was developed, allowing farmers to obtain real time data of the growth conditions on their mobile devices, and it was determined that Apium Graveolens var. Secalinum Alef cultivation under LED artificial lighting performed better as compared to normal sunlight. The application of this IoT system can help farmers to lower their overhead costs and increase yields.

1. Introduction

Hydroponics is a farming technique that eliminates the need of soil to cultivate plants, where plants are grown using man-made or naturally available substrate and a nutrient solution is made available for the plants [1]. Issues faced by traditional agricultural cultivation techniques using soil that could lower crop yield are such as soilborne pests, diseases, poor soil quality can be averted using hydroponics [2].

Although there are countless advantages of hydroponic systems, there are also several drawbacks with this farming technique. Inadequate lighting is one major problem faced by growers when cultivating crops using hydroponics method. Good lighting is crucial as plants utilises light to generate energy, without proper lighting, the plants cannot produce energy required for growth. Plants of

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different species have varied lighting needs in terms of intensities, durations, and spectrums. Lighting needs of plants is also dependent on the type of plant and the stage of growth it's in. Another problem faced while using hydroponics planting technique could be nutrient deficiency caused by low performance of root system uptake due to unsatisfactory oxygen levels in the roots [3]. On top of all these, evapotranspiration, which is frequently known as the water loss by plants is higher in tropical areas as the solar irradiation and temperature is elevated, thus energy required for evaporation decreases [4]. With the factors described, it makes it harder for the grower to keep track of all the important information regarding the plants grown in a hydroponics system without the use of technology. Therefore, an Internet of Things (IoT) monitoring system is proposed to solve this problem.

IoT is used to robotize the course of information assortment from different boundaries identified with horticulture [3] and to control input boundary activities for hydroponic environment [4]. Studies have shown that the turn of events of plant production lines with light-controlled plant development framework empower exact control of explicit physiologies and development [5-7]. To handle the expanding difficulties of horticultural creation, the requirements for present day computerized advancements that screen consistently the actual climate is imperative to all the more likely comprehend the biological system. The significant issues in farming and resolved related issues like the accessibility of equipment, programming, strategies furthermore, instrument and techniques for information investigation (the parts in IOT) in agriculture [8].

There have been past developments of IoT based aquaculture model where the pH, water conductivity and water radiance are observed by utilizing sensors like pH, electrical conductivity, and light intensity (lumens), where data captured by sensors are conveyed off ARM 7 Microcontroller where continuous observing is done to identify the ideal development of plants [9]. There are also research team who developed a solar-powered IoT system to monitor plant growth [12]. Farmers oftentimes face continuous harm to crops and decline in amount and nature of plants due to climate change, thus a IoT based intelligent indoor micro-climate horticulture system was developed [10]. There is also past development in automated systems that adjust the concentration of nutrients available in irrigation water based on the evapotranspiration rates of cultivated crops [13].

The improvement of an observing framework that can assist farmers with developing harvests is significant. There is a need for a framework for checking the presentation of indoor miniature environment agriculture is introduced. Electronic sensors incorporated with an Internet-of-Things (IoT) board is deployed to screen the development of interaction, where sensors will pick up data that is gathered into a data set, allowing analysis to be performed.

Clever advancements like the Internet of Things (IoT) works with cultivating exercises and furthermore gives adaptable farm tasks. On the opposite side, cultivating has become achievable even in metropolitan regions, particularly assembling rooftops, open nurseries, and indoor horticulture. In this unique situation, monitoring system for farms are needed, fitting observing of homestead boundaries are currently crucial for useful cultivating in keen urban areas or provincial regions [11]. These days, we are seeing a gigantic organization of associated objects through the Internet of Things (IoT) in various fields. IoT can prompt an exceptionally powerful and critical commitment to the agrarian area's improvement. When these IoT sensors are set underneath the surface for water content and saltiness estimations, they should speak with the versatile administrator's base stations. Nonetheless, electromagnetic proliferation through soil is altogether different from proliferation through the air due to the dirt's permittivity and electrical conductivity [12].

The main aim of this research is to develop an IoT monitoring system that can relay real time data to an internet connected mobile device, compare the growth condition of Apium Graveolens var.

Secalinum Alef in indoor artificial lighting system and natural sunlight, then determine the most appropriate cultivating environment.

2. Methodology

This section details out the methodology of the development of IoT system for this research. The summary of the steps is as per illustrated in Figure 1 flowchart of experiment.

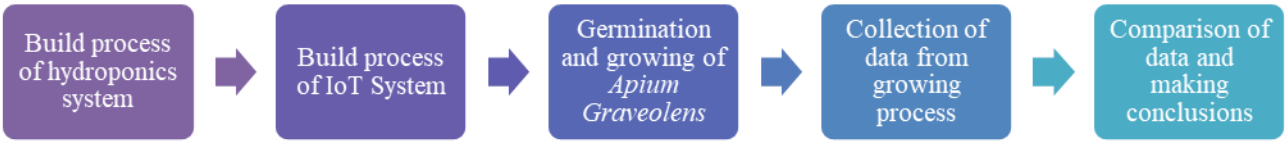

Fig. 1. Flowchart of experiment

The experiment will be conducted in a space dedicated for the cultivation of Apium Graveolens var. Secalinum Alef. Hydroponics systems were set up both under natural sunlight and artificial lighting locations where the plants will be cultivated hydroponically using no pesticide. The photoperiod was set to be 12 hours each day and 10 samples for each condition were considered in this research. Due to time constraint, no replication was performed. In the LED plant chamber, special formulation for fertilizer will need to be used because of lower temperature for growing conditions when compared to direct sunlight condition for growing [13].

The IoT observation system was developed and consists of data and humidity (DHT) sensor [14], light dependent resistor (LDR) sensor, moisture sensor, water pump, Relay 1 channel and ESP32 is used as the microcontroller. Internet connection is required for the system to use Internet of Things technology. The data received from the sensors will be transmitted to an app on the phone in real time which will provide information regarding the plant. The dashboard platform Blynk is used to display data with iOS and Android app available to control Arduino, Raspberry Pi and other microcontrollers supported over the internet [15]. It is a digital dashboard to build a graphic interface for the project by simply dragging and dropping widgets. Currently, Blynk supports most Arduino boards, Raspberry Pi models, the ESP8266, and a handful of other common microcontrollers and single-board computers, and more are being added over time. Arduino Wi-Fi and Ethernet shields are supported, though it can also control devices plugged into a computer's USB port as well. Figure 2 shows the schematic diagram of IoT observation system.

The seeds of Apium Graveolens var. Secalinum Alef. was germinated and grown hydroponically. One set of plants will be grown using normal sunlight and another set of plants will be grown using LED lights. There will be additional sensors introduced to record information for surrounding temperature, humidity, and CO_2. Light sensors will be utilized to distinguish the light intensities.

The plants will be grown hydroponically for 42 days at the targeted experiment site and data collection will be performed concurrently. The plant development estimations in this research will incorporate absolute yields such as fresh weight and dry weight. Whereas for actual physical measurements, length of stem and number of leaves will be recorded following 42 days of gathering.

The gathered data was relayed to an internet connected mobile device, then analysed and the conclusion of which environment is more optimised for the cultivation of Apium Graveolens Var. Secalinum Alef was determined. Figure 3 and Figure 4 show the set up and part of coding of IoT observation system respectively.

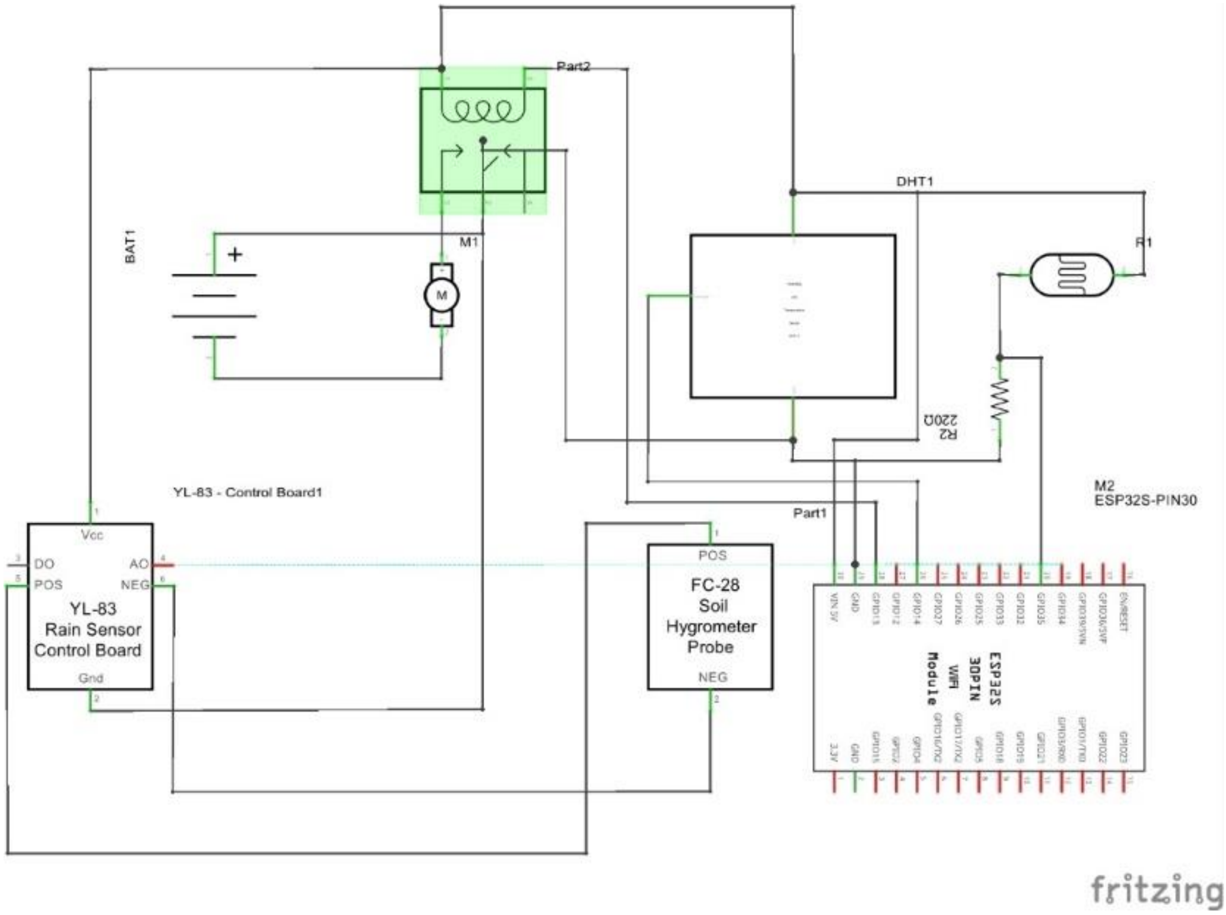

Fig. 2. Schematic diagram of IoT observation system

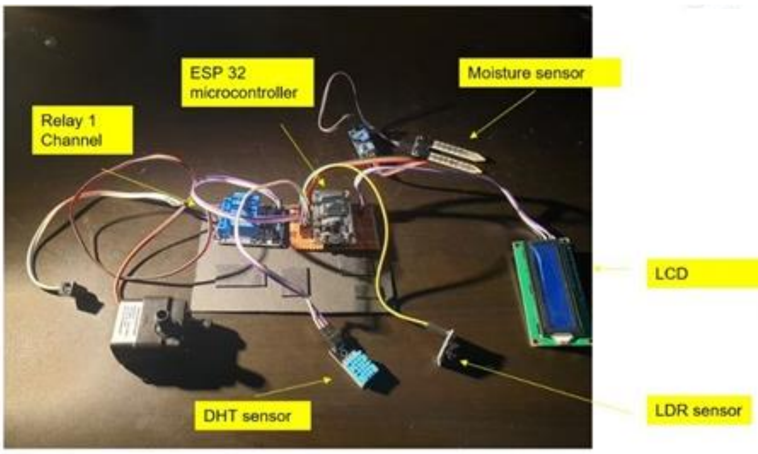

Fig. 3. Set up of IoT observation system

```
#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27,16,2);
#include "DHTesp.h"
#define DHTpin 14
DHTesp dht;

const int Soil = 34;
int sensorValue = 0;
int outputValue = 0;

const int ldrInPin = 35;
int sensorldr = 0;
int outputldr = 0;

char auth[] = "qX47zdUwSR1TrqAj6Id4hPAhkmXg2lrC";
char ssid[] = "IoT system";
char pass[] = "246813579";

int relay = 13;

int flag = 0;

void setup()
{
  Serial.begin(9600);
  lcd.begin();
  lcd.backlight();
  pinMode(relay,OUTPUT);
  digitalWrite(relay,HIGH);

  lcd.setCursor(0,0);
  lcd.print("Connecting Wifi");
  lcd.setCursor(0,1);
  lcd.print("-------------------");
  Blynk.begin(auth, ssid, pass);
  delay(2000);
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print(" Wifi Connected");
  lcd.setCursor(0,1);
  lcd.print("-------------------");
  delay(2000);
  lcd.clear();

  dht.setup(DHTpin, DHTesp::DHT11);
}
```

```
void loop()
{
  sensorValue = analogRead(Soil);
  outputValue = map(sensorValue, 0, 4093, 100, 0);

  sensorldr = analogRead(ldrInPin);
  outputldr = map(sensorldr, 0, 4093, 0, 100);

  Serial.print("sensor = ");
  Serial.print(sensorValue);
  Serial.print("\t output = ");
  Serial.println(outputValue);

  float humidity = dht.getHumidity();
  float temperature = dht.getTemperature();

  Serial.print(dht.getStatusString());
  Serial.print("\t");
  Serial.print(humidity, 1);
  Serial.print("\t\t");
  Serial.print(temperature, 1);
  Serial.print("\t\t");
  Serial.print(dht.toFahrenheit(temperature), 1);
  Serial.print("\t\t");
  Serial.print(dht.computeHeatIndex(temperature, humidity, false), 1);
  Serial.print("\t\t");
  Serial.println(dht.computeHeatIndex(dht.toFahrenheit(temperature), humidity, true), 1);

  lcd.setCursor(0,0);
  lcd.print("Soil:");
  lcd.print(outputValue);
  lcd.print(" ");

  lcd.setCursor(8,0);
  lcd.print("ldr:");
  lcd.print(outputldr);
  lcd.print(" ");

  lcd.setCursor(0,1);
  lcd.print("T:");
  lcd.print(temperature);
  lcd.print(" ");

  lcd.setCursor(8,1);
  lcd.print("H:");
  lcd.print(humidity);
  lcd.print(" ");

  Blynk.virtualWrite(V1,outputValue);
  Blynk.virtualWrite(V2,temperature);
  Blynk.virtualWrite(V3,humidity);
  Blynk.virtualWrite(V4,outputldr);

  if(outputValue < 20 && flag == 0)
  {
    digitalWrite(relay,LOW);
    flag = 1;
  }
  else if (outputValue > 20 && flag == 1)
  {
    digitalWrite(relay,HIGH);
    flag = 0;
  }

}
```

Fig. 4. Part of coding of IoT observation system

3. Results and Discussion

The development of IoT in agriculture operations has introduced the usage of sensors in each step of the farming procedure to precisely determine resources such as water, time and light required in cultivating vegetables. The developed IoT system for this research was able to collect data such as moisture, light intensity, temperature, and humidity utilising specialized sensors. These are among the important information needed to understand more about the plant growth conditions and is used to improve the microclimate for indoor farming. The sensors used in the IoT system are linked through cellular or network which is used to realize the real-time records from the sensors.

The comparison and discussion of results growth of plant for artificial lighting system and normal sunlight is found in sub-sections 3.1 until 3.4. Whereas the summary of discussion can be found in sub-section 3.5.

3.1 Moisture Levels

Graph from Figure 5 shows the water content of the planting medium, also known as the moisture content for both systems under LED lighting system and normal sunlight. The graphs presented were based on the data collected using the observation system. According to Figure 5, the highest moisture content for the plants grown using continuous LED lighting system was 37% and the lowest was 11%. Meanwhile for the plants grown using normal sunlight, the highest moisture content was 35% and the lowest was 10%. The plants grown using the LED lighting system demonstrated higher average moisture content. This phenomenon is plausible as sunlight shines brightly at the cultivation area, causing the planting medium to be heated up more as compared to cultivation under LED diodes that emit much less heat. The higher moisture content for system under LED lighting is due to the lower heat emission within the system, causing less evaporation of water which promotes better water retention in planting medium. This in end will cause in a reduction of water required for irrigation, saving valuable resources.

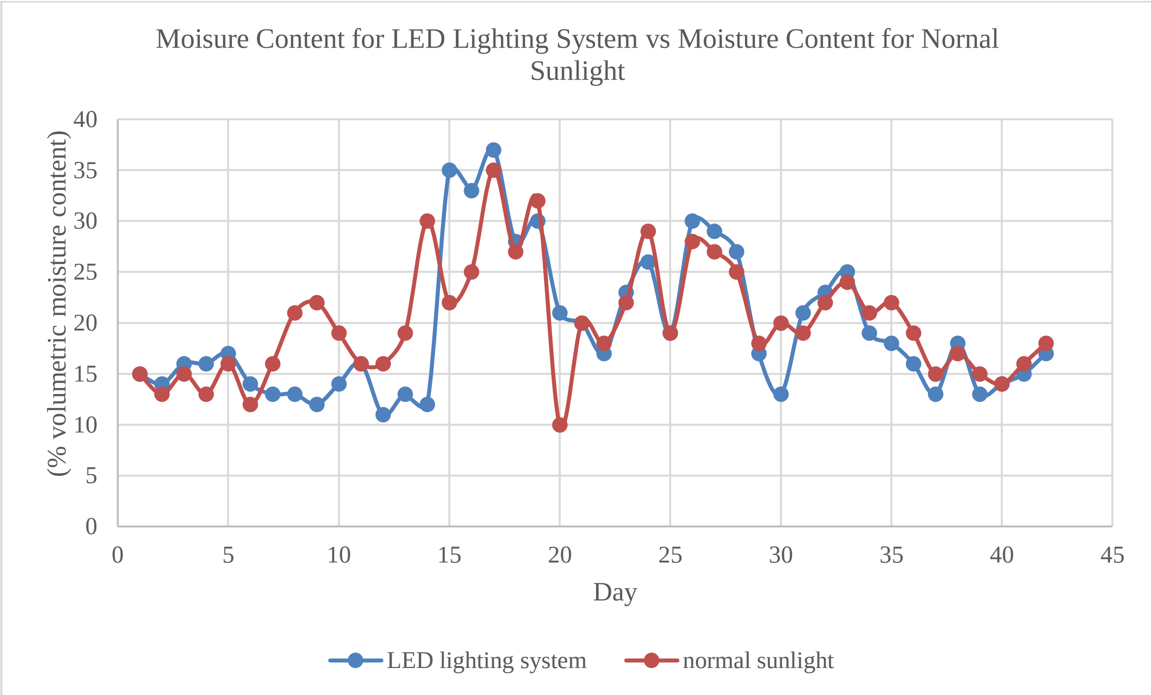

Fig. 5. Moisture content for LED lighting system and normal sunlight

3.2 Temperature

Temperature affects most plant processes such as photosynthesis, transpiration, respiration, germination, and flowering. As the temperature rises (up to a certain point), photosynthesis, transpiration, and respiration increase. In combination with the length of the day, temperature also influences the switch from vegetative (leaf) to reproductive (flowering) growth. Depending on the situation and the system, the effects of temperature can accelerate or slow down this transition.

Graph from Figure 6. shows the average daily ambient temperature of environment for LED lighting system and normal sunlight. This data was collected using the DHT sensor and the sensor was placed in such it avoids being exposed to light source to reduce heat absorption from light source which might cause false reading of the ambient temperature. While excluding the heat from light factor, it can be observed that both systems demonstrated similar ambient temperature at the cultivation area which was located within close proximity and the weather during the experimental period played a major role in this matter.

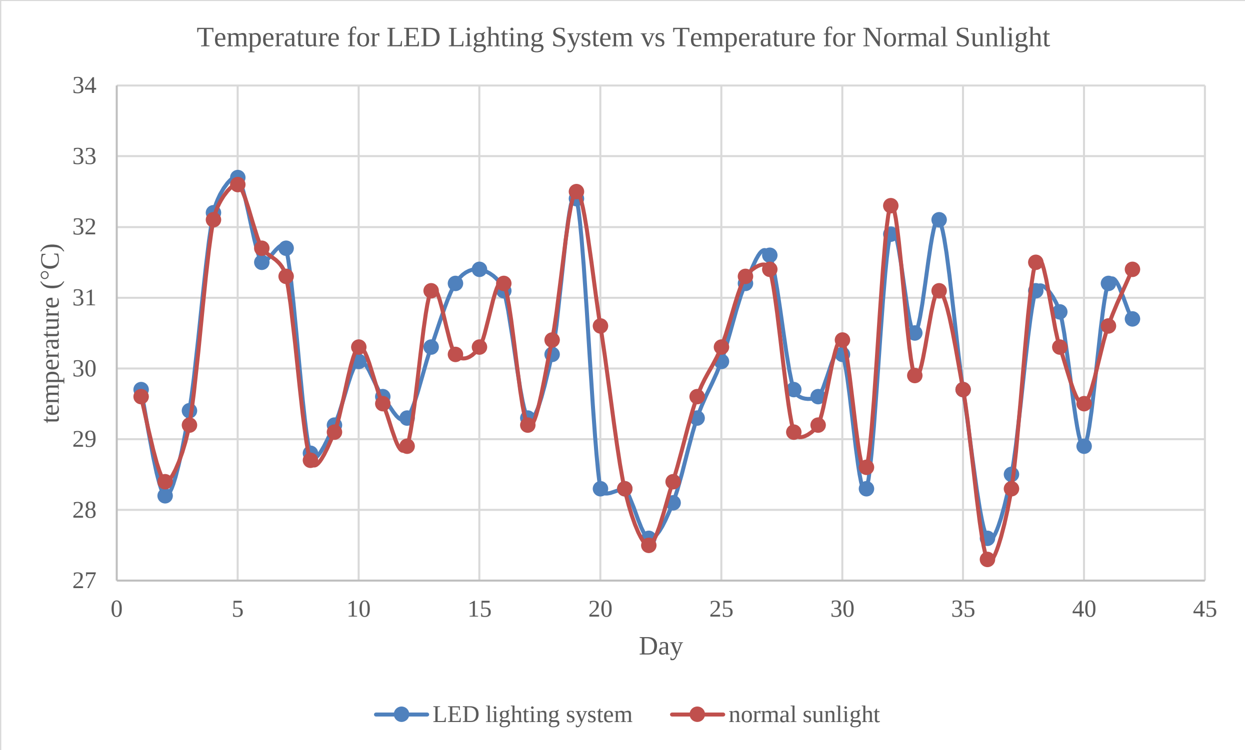

Fig. 6. Average daily ambient temperature of environment for LED lighting system and normal sunlight

3.3 Fresh Weight of Plants

It shall be noted that the researcher has no control over the seed quality and uniformity (sourced from single plant source with identical genes) utilised for this experiment, thus causing a possible variation in plant growth performance and quality.

Fresh weight is the weight recorded immediately after the plants are harvested. This variable contains the moisture contained in the product. Fresh weight helps to assess yield results before selling the product.

Graph as per Figure 7 illustrates the difference in fresh weight for plants using LED lighting system vs fresh weight for plants using normal sunlight. The highest value for fresh weight for plants using led lighting system was 7.9g and the lowest was 1.1g. The highest value of fresh weight for plants using normal sunlight was 5.4g and the lowest was 1.2g. Overall, based on the graph plotted, it shows that the average fresh weight for weight for plants using LED lighting system is higher compared to plants using normal sunlight. This demonstrated that the LED lighting system is more preferable by the cultivated plants, thus having better growth performance.

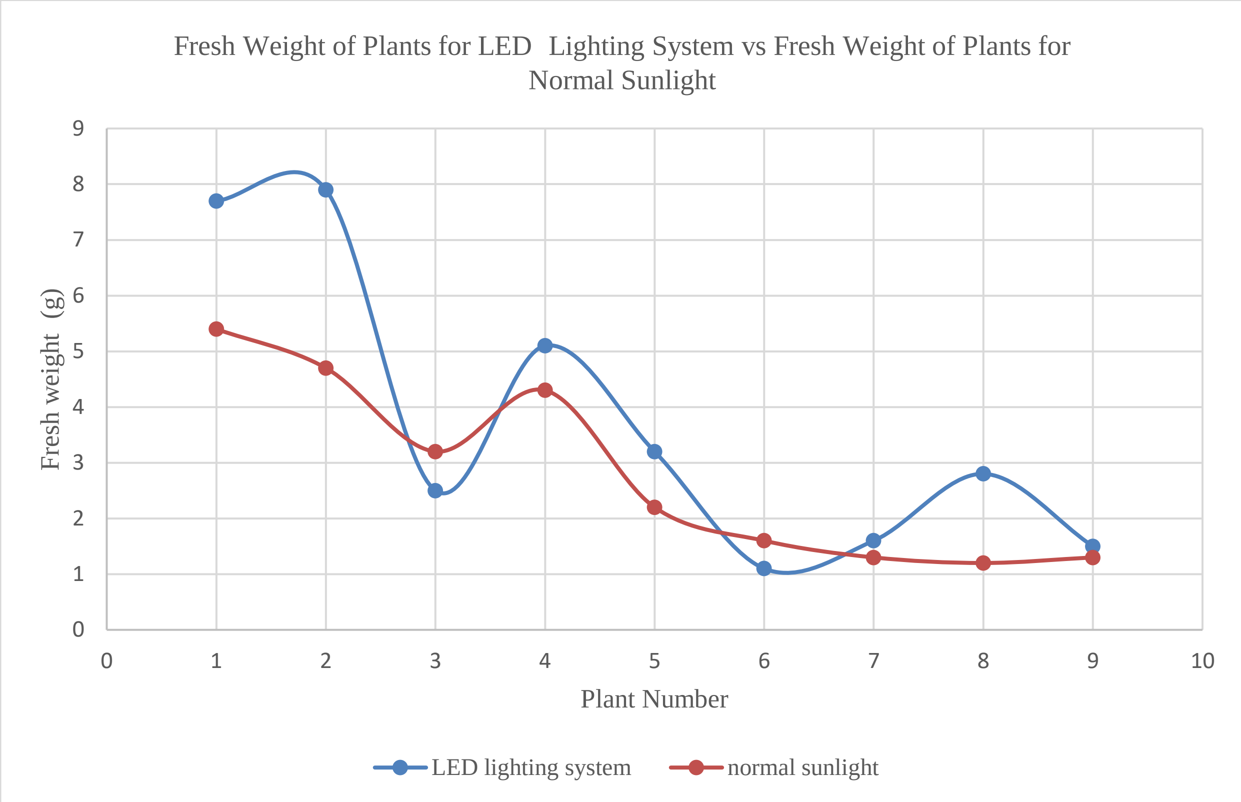

Fig. 7. Fresh weight of plants for LED lighting system vs fresh weight of plants for normal sunlight

3.4 Dry Weight of Plants

Dry weight, on the other hand, is defined as the weight recorded after the plant tissue has dried above ambient temperature, thereby removing water from the plant. Dry weight of plants provides an accurate measurement of biomass and eliminates fluctuations caused by water content. Dry weight makes it a useful and reliable tool for assessing plant performance, especially after applying treatments to improve yield and quality.

Graph as illustrated in Figure 8 shows the dry weight for plants using LED lighting system vs dry weight for plants using normal sunlight. The highest value for dry weight for plants using LED lighting system was 3.2 and the lowest was 0.4g. The highest value of fresh weight for plants using normal sunlight was 2.7g and the lowest was 0.3g. Overall, based on the graph plotted it shows that the average dry weight for weight for plants using LED lighting system is higher compared to plants using normal sunlight.

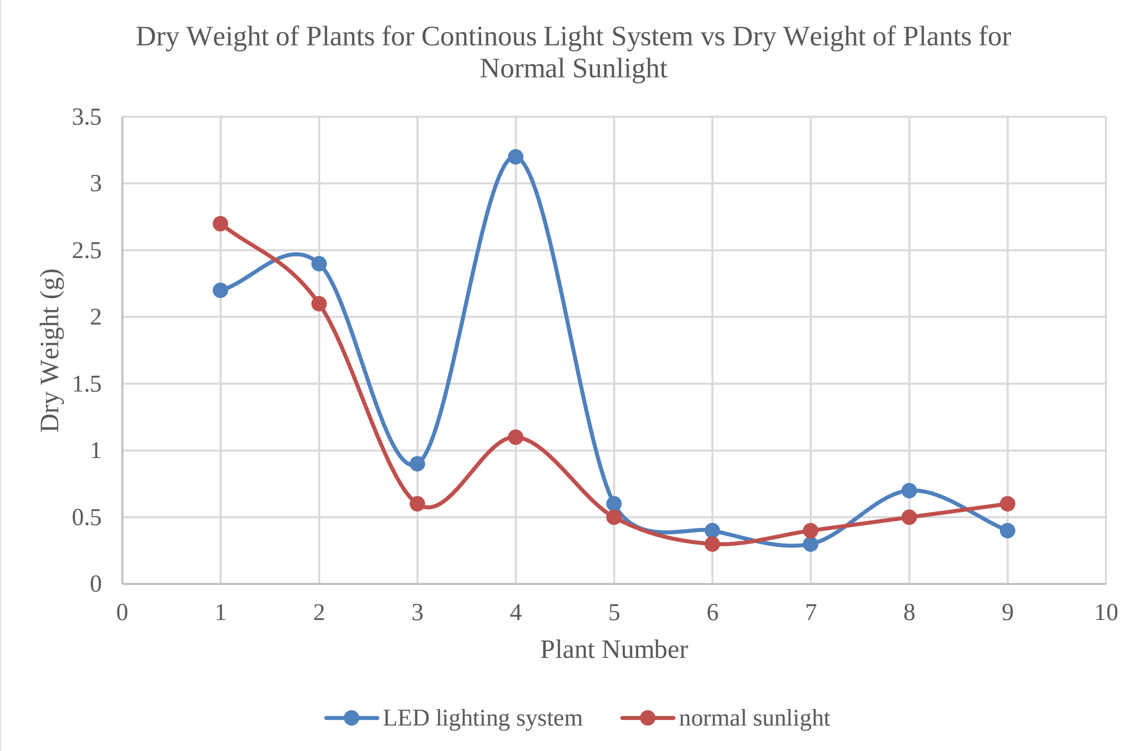

Fig. 8. Dry weight of plants for LED lighting system vs dry weight of plants for normal sunlight

3.5 Summary of Discussion

Based on the data collected from the experiment, which were the physical measurements of the plants after 6 weeks it is shown that the plants grown using the LED lighting system yielded more harvest compared to the plants grown using normal sunlight. This is supported by the data of fresh weight and dry weight collected for plants grown using the LED lighting system which were higher compared to the plants grown using normal sunlight. This is because indoor cultivation with LED lighting is superior to crop production that relies on older artificial light sources and can produce, in a sense, a richer yield than outdoor cultivation exposed to inconsistent sunlight and weather fluctuations. LED plant growth lighting provides operators with unprecedented control over all aspects of the plant environment. The LED lighting system can be configured to provide the optimum photosynthetic photon flux density. Photosynthetic Flux Density (PPFD) refers to the total amount of light that reaches the surface of a plant. Higher PPFD levels generally result in better plant quality and higher yields indoors. As LED lighting systems operate at lower physical temperatures than traditional indoor lighting, LED fixtures can be placed near the surface of the plant to produce these high PPFD values. Since LED lights are cold light, they can illuminate nearby plants without burning them, thus significantly improving space utilization photosynthesis, and plant growth.

4. Conclusions

An IoT system was successfully developed to monitor and relay the real time growth conditions of Apium Graveolens var. Secalinum Alef in indoor artificial lighting system and natural sunlight to an internet connected mobile device. Based on the experimental results, it was then determined the most appropriate cultivating environment to cultivate Apium Graveolens var. Secalinum Alef hydroponically is indoors under artificial lighting system using LED.

The application of this system can help farmers to better utilise resources, lower their overhead costs and increase yields as the optimum growth conditions was determined to be indoors under artificial lighting and can be monitored continuously by just using an internet connected mobile device. This allows the farmers to react quickly to adjust the needs of their cultivated corps by utilising real time data collected and relayed to them using the IoT system.

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