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Air Parameter Analysis for Precision Agriculture in Controlled Engineering

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Abstract: In a plant factory, an enclosed growing system, environmental parameters for the nutrients used are intentionally controlled, including temperature, carbon dioxide levels, humidity, light intensity, and humidity levels. The concept and objectives of this urban farming must be carried out under constant supervision, since this will affect the crop output. Unreliable patterns in variables have the drawback of ultimately causing the failure to achieve the objectives of the modern system. This study's objective is to analyze the data pattern recorded by IoT system that is installed to determine the accuracy of the sensors and look at the trends in the variables that impact temperature, humidity, and gas concentration in precision agricultural facilities. Data analysis techniques were used to get the data for the instruments used in this investigation. According to the data that were examined, the variables of temperature, relative humidity, and gas concentration within the plant factory were unstable at times for the crops development. The next goal is to determine whether both LEPF and AgroX system's sensor measure the selected parameter properly and able to provide reliable data for the variables.

Keywords: Plant factory, temperature, humidity, Co_2, O_2

1. Introduction

In this globalization area, both technologies and the number of human population might be over-rising. This has caused a concerning issue related to food security. This issue has led to an activity which is also a potential solution that is currently being practiced by people around the world called as *Urban Farming.* According to [1], the agriculture related activity is caused by severe food crisis, worsening poverty, agriculture market failure, political and economic challenges due to rapid growth of a country and government economic policies. There are two approaches to the problem of food security, which are static and dynamic security. For the first, static security refers to the particular value of national output excluding the value of output for food product exports. Next, dynamic security refers to the country's untapped potential production or the spare capacity of sources that might cover a food shortfall in the event of a crisis scenario [2].

1.1 Problem Statement

The upcoming scale of human population is concerning that it may lead to issues such as insufficient food supply. This also means that countries are heading to a whole modernization. The negative side of developing countries to modernization is more buildings and constructions will be considered. This may reduce the chances of natural food resources such as vegetables and any other plant to grow. With the technologies developing in the entire world, this issue can be combat. Plant factory is one of the alternative methods to combat food security issue that is currently concerning in most of the developed countries [2-6]. The problem with the usage of artificial technologies in plant

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factory may be different than how it grows naturally. In order to maintain the quality of the crops, the temperature reading, relative humidity, Co2 and O2 reading must be at a uniform range for the whole process. An advanced level of environmental control is essential for the appropriate growing conditions in order to control the productivity and maintain uniform quality of the crops. This paper will conduct and analyze the air parameter specifically to temperature, humidity, CO2 and O2 concentration per tier in plant factory and to compare the temperature and relative humidity reading pattern between systems installed in the plant factory [13-17].

1.2 Research Objectives

The main objectives of this study is:

I. To analyze temperature and humidity pattern for precision agriculture facility in controlled environment.
II. To analyze the CO2, O2 concentration by locating sensors at top, middle and lower rack.
III. To compare the internal temperature data collected by different systems installed in the plant factory.

1.3 Scope Of Research

The target for this research is using the data collected by sensors used in a precision agriculture facility to examine the air parameter concentration such as temperature, relative humidity, Co2 and O2 level collected by tier and the average air in the enclosed space.

I. Data collected experimentally at UTHM plant factory container.
II. Focusing on air parameter (temperature, relative humidity, CO2, O2) data collected for 12 hours within 3 days.

2. Literature Review

Many cities are recognising the importance public lands may serve as venues for urban farming as interest in establishing local food systems develops across the country. Parks, street medians and planting strips, parking lots, utility rights-of-way, vacant or underutilised lots, and the grounds around municipal buildings and public agencies all have the potential to support urban farming at various levels. As a result, several towns are enacting regulations that will allow and encourage the usage of these places. Cities and/or community organisations may perform inventories of public property as well as vacant or underutilised land to find places suited for agricultural activity. These lists include properties that are offered for short-term, long-term, or permanent rental. It is critical to provide financial and institutional support for public urban agricultural initiatives in addition to resolving concerns of land access and zoning rules [11-17].

2.1 Optimal Temperature in Plant Factory

Temperature plays an important role in order for crops to grow healthily. In an experiment of optimizing temperature for romaine lettuce *(Lactuca sativa L. car. Longifolia)*, where the crop is harvested in two different temperature day and night 20ºC/15ºC and 25ºC/18ºC, the difference in growth of the romine lettuce is noticeable. It is observed that higher temperature helps with the growth rate although it is not numerically expressed [7-12]. In another plant factory that compares the growth between butterhead and leaf lettuce, both crops grown under lower temperature than the range of 25ºC-30ºC, showed shortened in leaf lengths and leaf widths and less leaf numbers. The optimum day temperature for lettuce to grow was between 22ºC to 26ºC and the optimum night temperature was in between of 15ºC to 20ºC in order to reduce the visibility of tipburn.

2.2 Optimal Humidity in Plant Factory

To make photosynthesis possible, humidity is needed for evaporation which is a part of the transpiration process. Humidity levels nearby the plant are crucial for producing plants of a constant grade. In a closed factory, air conditioning is necessary to maintain the ambient temperature and relative humidity [15]. By inhibiting the uptake of water and nutrients, the relative humidity of the surrounding environment also has a direct impact on plant development. The relative humidity rises to a saturated level during transpiration. When there is insufficient airflow and excessive relative humidity, plants stop transpiring and absorbing nutrients from the soil or growth medium, which leads to progressive rotting in situations of prolonged humidity saturation. For improved development and glucosinolate accumulation, the preservation of the ideal relative humidity is crucial. According to some experts, the rate of photosynthesis is inversely correlated with relative humidity because a larger range of relative humidity reduces water stress in the leaves and boosts stomatal conductance [17].

2.3 Optimal Co2 and O2 in Plant Factory

The pace of photosynthetic growth, plant metabolism, and physiological and chemical defense are all impacted by CO_2 concentration. In addition to having less biomass, plants without CO_2 would also be weaker and of lesser quality.

CO_2 is immediately taken by plants since it serves as a crucial substrate for the process of photosynthesis. CO_2 has an impact on how plants transpire as well. According to a meta-analysis, different plant species might experience up to a 22% reduction in transpiration when CO_2 levels are high. Increased CO_2 levels aid in the photosynthesis of greater quantities of sugars and other essential elements. Additionally, higher CO_2 concentrations cause reduced decrease of the photosynthetic components, which raises the glucosinolate level.

3. Methodology

3.1 Plant Factory Specifications

The controlled environment took place in a cargo container with a total area of 76 m^2. This cargo container is 40 feet long, 8 feet wide and 9 feet tall. It has a matrix conversion of 12.2m (L) x 2.4m (W) x 2.6m (H). It is also has been upgraded with a 10cm width of insulation on the wall. This insulation prevents outside heat and temperature from entering through plant factory wall. The room has two growth racks and each racks composed of 3-tier growing beds. It is also equipped with air-conditioning system and ventilating fan as shown in fig.1.

(a) (b) (c)

Fig. 1 - (a) Container used as plant factory; (b) two racks with 3-tier growing beds; (c) air conditioning system with ventilating fan

3.2 Sensor Installation

Sensors are installed to measure internal temperature, internal relative humidity, temperature, CO_2 and O_2 concentration in the plant factory. The sensors are not wireless and it is connected to data loggers.

Table 1 - Sensor used in UTHM plant factory

Item	Measured Parameter	Sensor Model
1	Temperature (ºC)	SHT-30
2	Relative Humidity (%RH)	SHT-30
3	CO_2 (ppm)	SN-MG811
4	O_2 (%)	ME2-02

One sensor was placed on top of the plant factory ceiling to monitor interior temperature and humidity, while others were placed in the lower, middle, and top tiers to detect temperature, humidity, CO2, and O2. The installed sensors' locations are indicated below by red marks.

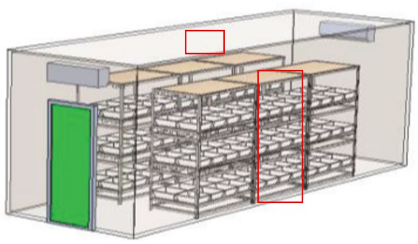
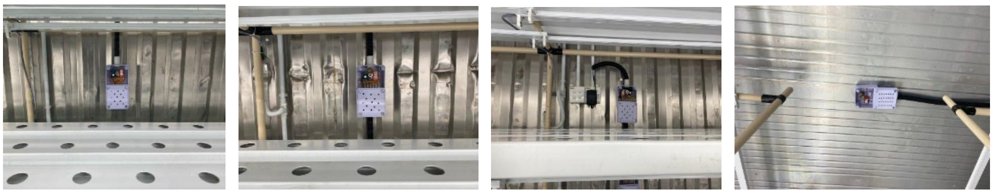


Fig. 2 - Position of installed sensor for LEPF system



(a) (b) (c) (d)

Fig. 3 - Sensors were deployed in the (a) lower tier; (b) middle tier; (c) upper tier; and (d) on top of the plant factory ceiling

3.3 Data Loggers

Data recorders and sensors are linked in the plant factory. The data measured is recorded using one of two types of data recorders. A LEPF system is used to capture data for interior temperature, relative humidity, CO2 and O2 levels. Throughout the whole cycle of the plant acquired using lepf-uthm.web.app/datalog, this system may produce data once per minute.

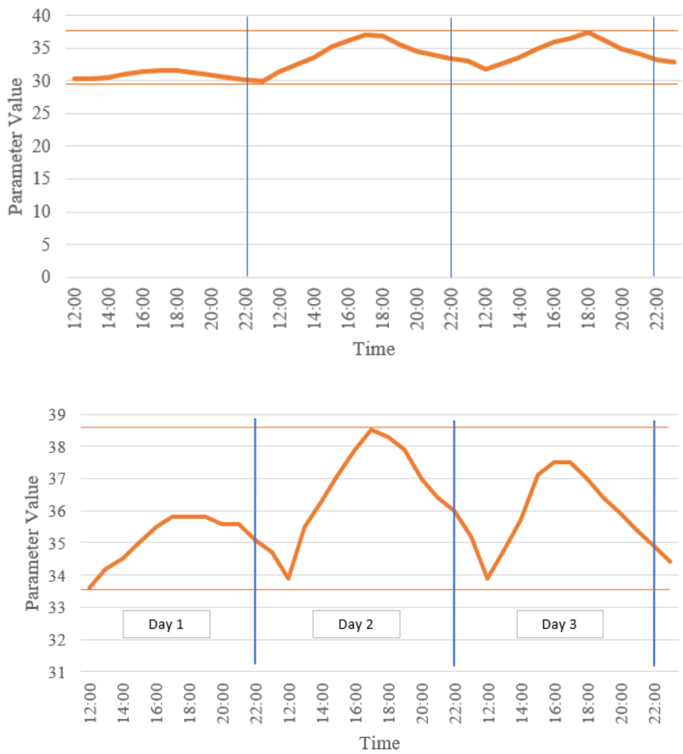
Fig. 4 - LEPF system display attached next to the racks

4. Parameters

4.1 Temperature

(a)

(b)



(c)

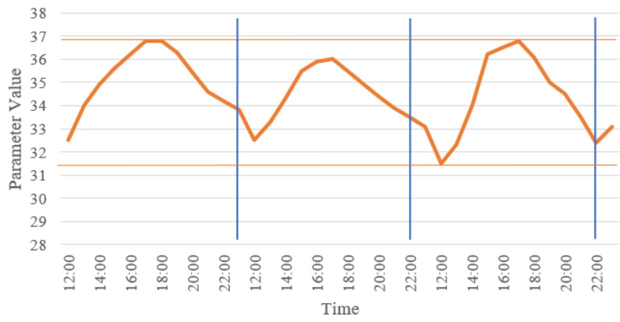


Fig. 5 - (a) Internal temperature of plant factory; (b) top tier temperature; (c) middle tier temperature (by 12-hour for 3 days)

The overall data in (a) then sorted to a 12-hour data for 3 days (1st of May to 3rd of May). Data recorded showed were from 12pm to 11pm. The data pattern shows that the temperature rise later after 12pm and reach its peak between 4pm to 6pm. However, the temperature on its peak hour of the 1st day of cycle is lower than the 2nd and 3rd day of the cycle. Graph (b) shows data pattern of top tier temperature on 1st of May to 3rd of May by 12-hours from 12pm to 11pm. On the first day of the cycle it shows that the temperature rises starting from 1pm and reach its peak in between 4pm to 6pm. Decreasing of the temperature can be seen in Fig. 5 (b). the pattern repeated on both 2nd and 3rd of May. Fig. 5 (C) show middle tier temperature distribution by 12-hour for 3 days. The pattern shows the pattern is almost uniform and repeated. This occurs due to a slowly rising temperature starting from 1pm and reach the peak in between 4pm to 6pm. It is then slowly decreasing as low as 37°C at 11pm. The pattern then repeated on 2nd and 3rd day.

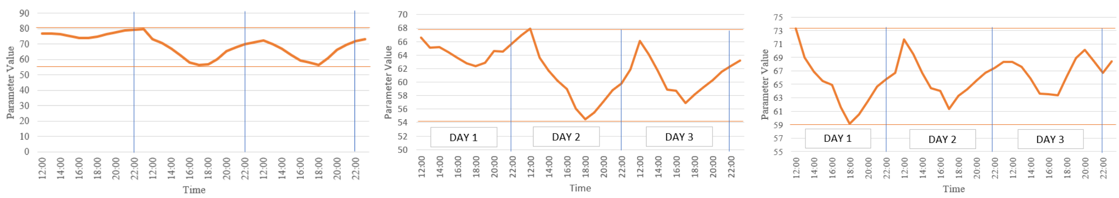
Table 2 - Descriptive statistic and regression analysis for temperature (by 12-hour for 3 days)

Item	Maximum	Minimum	Standard Deviation	R2	Mean
(a)	37.5 °C	28.1 °C	2.3703	0.2477	31.7877
(b)	38.5 °C	33.9 °C	1.2917	0.0203	35.8806
(c)	36.8°C	31.5 °C	1.4634	0.0009	34.6056

Table 3 - Descriptive statistic and regression analysis for temperature (by 12-hour for 3 days)

Item	**Maximum**	**Minimum**	**Standard Deviation**	**R2**	**Mean**
(a)	37.5 °C	28.1 °C	2.3703	0.2477	31.7877
(b)	38.5 °C	33.9 °C	1.2917	0.0203	35.8806
(c)	36.8°C	31.5 °C	1.4634	0.0009	34.6056

4.2 .1 Humidity



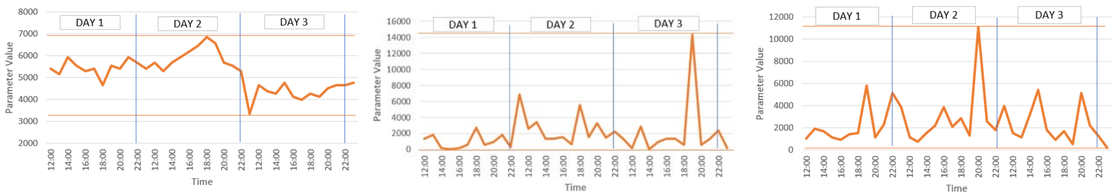
(a) (b) (c)

Fig. 6 - (a) Internal humidity of plant factory; (b) top tier humidity; (c) middle tier humidity (by 12-hour for 3 days)

Fig. 6 (a) displays the internal plant factory's 12-hour relative humidity over a period of three days. Only little percentage variations in relative humidity occurred on the first day of the trial. Between 4 and 6 p.m., there is a drop, and after that, an increase. On the second and third days, the trend persisted. However, between 4 and 6 pm, the percentage quickly decreased from 80 to 55.4%. The graph (b) shows chart pattern for top tier relative humidity of plant factory recorded by 12-hour for 3 days (1st of May to 3rd of May). On the first day, the humidity gradually drop during the day and slowly increasing as it reaches night time. However, the 2nd day experienced a rapid drop in relative humidity. The percentage is at ± 68% at 12pm as it rapidly drop as low as 54% at 6pm. As it almost reaches night time, the relative humidity gradually increasing up to ± 60%. Fig. 6 (c) displays the pattern of the middle tier relative humidity of the plant factory data set that was recorded by 12-hour for three days. The percentage on the first day of the analysis had a quick decline from 73 percent at 12pm to 59 percent at 6pm, in contrast to the trend of top tier relative humidity. As the hour went on, the proportion rose. The trend continued from the first day on the second and third days. On the second day, it barely decreased to 61% at 5 p.m.

Table 4 - Descriptive statistic and regression analysis for humidity (by 12-hour for 3 days)

Item	Maximum	Minimum	Standard Deviation	R2	Mean
(a)	80.4%RH	55.4%RH	2.3954	0.2467	31.7789
(b)	67.9%RH	54.5%RH	3.4531	0.0471	61.7222
(c)	73.3%RH	59.1%RH	3.0825	0.0311	65.9611



(a) (b) (c)

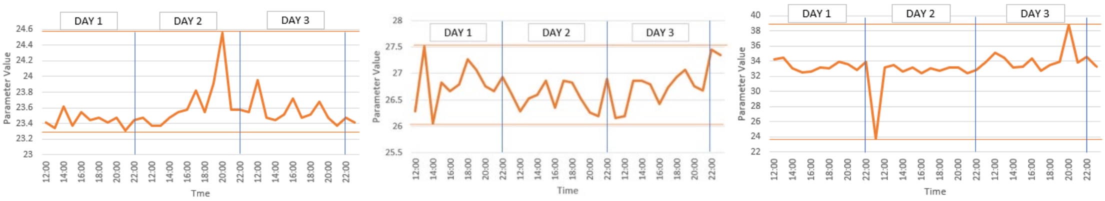
Fig. 7 - (a) Top tier CO_2; (b) middle tier CO_2; (c) lower tier CO_2 (by 12-hour for 3 days)

Fig. 7 (a) shows the pattern of the top tier of CO_2 concentration in the plant factory. Graph pattern shows no similarity in the trendline. The range of the CO_2 data for the 1st day is ± 4700ppm to 6000 ppm. CO_2 concentration drops under 5000ppm at 6.30pm and gradually increasing as it reaches night time. On the 2nd day, the concentration went up to 7000 at 6pm and experienced a major drop on the 3rd day where it is in the range between ±3300ppm to ±4800ppm. Graph (b) above shows the pattern line of middle tier CO_2 concentration in the plant factory by 12-hour for 3 days. The concentration is lower on the first day of the analysis than it is on the second and third days. It demonstrates that the first day's peak concentration does not exceed 3000ppm. Between 2 and 3 p.m., the concentration was as low as 0 ppm, and it progressively rose after that. On the second day, the pattern of focus is regular and repeats itself from 12 pm to 4 pm and 6 pm to 11 night. On the third day, however, the concentration value is extremely variable as it increased to a peak of over 14000 ppm before rapidly declining within an hour, from 6 to 8 p.m. Three days of analyses' worth of CO2 concentration data at the plant factory (c) lowest tier reveal a variety of patterns. From 12 p.m. to 6 p.m. on the first day, the concentration is less than 2000 ppm. From 6 to 7 o'clock, the concentration increased quickly, reaching 6000 ppm, and from 7 to 8 p.m., it dropped quickly, going from 6000 ppm to 1500 ppm. The second day has the greatest concentration of carbon dioxide, which increases quickly at 7 p.m. to around 11000 ppm before falling quickly at 8 p.m. to approximately 2200 ppm at 9 p.m. On the third day, the concentration pattern fluctuated steadily up and down, reaching a maximum of 5,900 ppm and a minimum of 0 ppm.

Table 5 - Descriptive statistic and regression analysis for CO_2 (by 12-hour for 3 days)

Item	Maximum	Minimum	Standard Deviation	R2	Mean
(a)	6832.03ppm	3351.56ppm	790.2045	0.0087	5192.057
(b)	14308.59ppm	0ppm	2746.577	0.0035	2167.12
(c)	11095.9ppm	225.567ppm	2087.43	0.0647	2491.89

4.2.2 Oxygen



(a) (b) (c)

Fig. 8 - (a) Top tier O_2; (b) middle tier O_2; (c) lower tier O_2 (by 12-hour for 3 days)

The graph (a) pattern showed in Fig. 8 is the concentration of oxygen (O_2) at top tier in the plant factory. The pattern of the concentration is vary for each day. On the 1st day, it can be seen that the concentration is at a steady range which is in between 23.2% to ±23.6%. Meanwhile on the second day, the concentration went high up to ±24.6% at 8pm and it drop rapidly at 9pm as low as ±23.6%. The 3rd day of the analysis showed a slow and consistent drop of the concentration. The graph pattern showed in fig.8 (b) is the concentration of oxygen (O_2) at middle tier of the rack in plant factory. The pattern of the concentration is almost uniform for each day. On the 1st day, it can be seen that the concentration is high at 1pm with a concentration of 27.50% and rapid drop occurred at 2pm to 26% which is the lowest concentration among the 3 days of analysis. Meanwhile on the second day, the concentration is at a steady range where it only in between of 26% to 27% from 12pm to 11pm. The 3rd day of the analysis showed a gradually and consistent increase of the concentration. The lower layer of the rack in the production plant is where the graph pattern in Fig. 8 (c) depicts the concentration of oxygen (O_2). On the first day, the concentration is almost steady with a range between ±34% to ±32%. However, the concentration fall rapidly to 24% and rises to ±33% after an hour. The third day of the analysis showed a concentration increase to ±39% at 8pm and gradually drop after half an hour

Table 6 - Descriptive statistic and regression analysis for CO_2 (by 12-hour for 3 days)

Item	Maximum	Minimum	Standard Deviation	R2	Mean
(a)	24.56%	23.30%	0.2266	0.0033	23.5485
(b)	27.50%	26.04%	0.3616	0.0471	26.7163
(c)	38.77%	23.78%	1.9749	0.0404	33.2988

4.2.3 Comparison Between LEPF and AgroX Datalog System

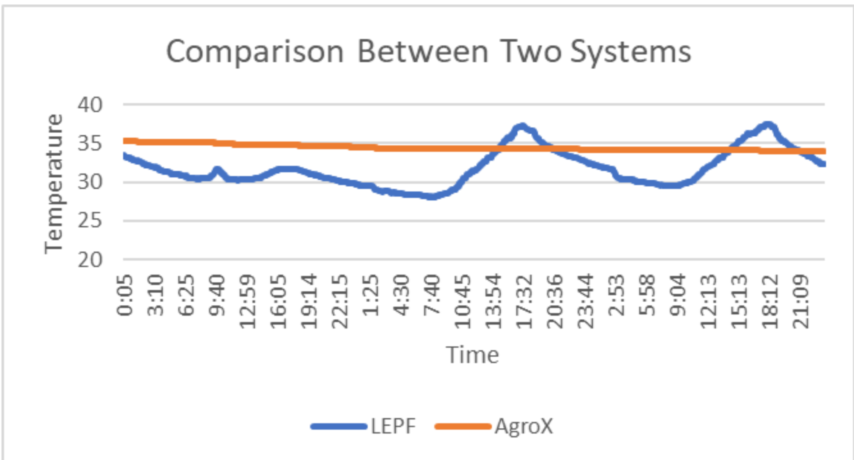


Fig. 9 - Difference of internal temperature data between LEPF and AgroX

The graph in fig. 9 demonstrates a significant variation in data reading. The AgroX system's line pattern is mostly stable, albeit deteriorating with time. However, the LEPF line pattern reveals a range of temperature data values. There are a number of possible causes for this. For instance, the placement of sensors used to gauge internal temperature is crucial. The main entrance is set distant from the air conditioning system, while LEPF system sensors are put close to it. Due to the sensor's sensitivity, the temperature will alter when individuals enter the factory. AgroX sensors are situated close to the air conditioning unit in the meanwhile. When there are heat contributors present, such as human presence or external heat from opening and closing the main entrance, this might result in a little variation in the temperature data. Additionally, the sensors' quality may have an impact on how the data is captured. For instance, a cheap sensor may be less sensitive and require regular calibration. The data that is captured could be affected by frequent sensor calibration. This is why some of the data acquired during the data collection for the study quickly dropped to zero.

5. Conclusion

In short, trends in all parameters of internal temperature, internal relative humidity for the whole container and for each tier of the racks CO_2 and O_2 concentration show acceptable results although there are varies in the line pattern. The study concludes that the objectives of analyzing and observing the temperature, humidity, CO_2 and O2 of precision farming facilities in a controlled environment have been fully achieved. After calculating the average value of the selected parameter from the collected data (variable and physical time graphs), you can determine the maximum and minimum values. However, the range of parameter value shows a distant number from the optimal parameters sets. The optimum range for temperature is around 20-30^{o}C, however the temperature range in the plant factory is in between 28.1-38.5^{o}C. There are few reasons why this happened. For instance, the usage of light bulb. In order to lower the temperature is to change the light equipment used. The external heat from the outside also contribute to the increasing internal temperature. Despite being distinct, temperature and humidity are connected. The formula describing the relationship between temperature and humidity simply states that they are inversely proportional. When the temperature rises, the relative humidity will fall, making the air drier; when the temperature falls, the air will get moist, making the relative humidity rise. This explains the decreasing trendline of humidity when the temperature is rising at the same time. a continuous air circulation system that uniformly distributes CO_2 over the plant canopy; alternatively, a higher CO_2 setting is advised. Thus, higher concentration of CO_2 may not affect the quality of the crops. Still, some data show unique value in terms of improvement. This paper is nearing the end. The research data from this study will serve as a reference for future research and other plant factories seeking improvements.

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