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Development of Control Program for Plant Growth Parameter Analysis in Lowland Tropical Greenhouse

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Abstract: The purpose of this project is to develop control system for environment parameter in the lowland tropical greenhouse using Microcontroller. The plant growth analysis covered both inside and outside greenhouse was presented. The controller was used to monitor the temperature, relative humidity and Vapor Pressure Deficit (VPD) in the planting of chili. The study of VPD is to show air moisture conditions for plant production while taking into account different temperature levels. The controller is used to maintain the ideal VPD inside the greenhouse where it has been done for an experimental greenhouse. The higher temperature inside greenhouse, during the day time, further proves the greenhouse effect. The ideal VPD is about to achieve at midnight where the temperature ranged between 19 and 23°C at relative humidity of 54 to 57%. PIC controller was successfully being used and interfacing with computer (read data). The ability of controlling the environment parameter such as temperature, relative humidity and VPD give great potential for the application of the greenhouse in agriculture plantation.

Key words: Lowland greenhouses, Vapor Pressure Deficit (VPD), plant growth analysis, microcontroller, agriculture, automation

INTRODUCTION

Greenhouse refers to a fully covered with a transparent material to provide a shelter for plant growth. Earth and heavens are the best example of ordinary greenhouse. In the righteous book, Al-Quran was stated that the earth is the chesterfield while the heaven is like the canopy for the purpose of human being sustenance (Ali, 1934). Plant cultivation in greenhouse is facing low risk of damaged by high rainfall, high temperature, high humidity, high wind speeds, insects and diseases compared to the conventional open field farming in the lowlands (Unkovich *et al*., 2009). Normally, outside greenhouse, the temperature, at day, is about 36°C and at night, is 26°C. However, the temperature can easily exceed 60°C and relative humidity can be less than 40% in extreme circumstances which crops are absolutely cannot survive in those extreme environment conditions (Ramin and Ismail, 2007). By controlling the temperature factor, the heat affluently effect the physically and chemical properties of plants the suitable for end user requirement (Saim *et al*., 2009). In order to study the effect for controlling the heat, an automatic control system has been practiced and installed in greenhouse by researcher several years ago (Elbatawi, 1998; Ramin and Ismail, 2007). Maximum yield and high quality of crop production will be achieved if a suitable environment controlled is maintained in the greenhouse during the cultivation period (Prenger and Ling, 2007). This was proven by a research which is being conducted on vegetables growing under a good internal environment control (Wan-Ishak *et al*., 2008).

The aim of this project is to develop an automatic temperature and relative humidity control system for lowland tropical greenhouse. The objectives of this experiment are: (1) to study lowland tropical greenhouse requirements; (2) to be able to monitor the growth of chili plant and (3) to evaluate performance of the developed system on the water requirement, temperature and humidity control in the greenhouse. Chili or hot pepper was chosen and planted in this project. Chili is one of the most important ingredient in a wide range of dishes prepared in Malaysia cuisine have chili as ingredient. Besides, chili is also used in many processing industrials such as chili course, dried pepper and pickled pepper.

The idea of growing plants in environmentally control areas had existed since Roman times from Roman emperor Tiberius. The first modern greenhouse was built in Italy in

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the thirteenth century and they were originally called botanical gardens. The concept of greenhouse along with the exotic plants soon spread to the Netherlands and then England. Experimentation with the design of greenhouse continue to advance and developed until today.

Nowadays, various designs and sizes of commercial glasshouse are available in market, such as greenhouse can be divided into glass greenhouse and plastic greenhouse (Krope *et al*., 2010). The glass was used for a greenhouse, normally, works as a selective transmission medium and its function to trap energy within greenhouse. Even though the commercial glass greenhouse can be installed with high technology production facilities for crops, but the initial cost and average cost per year is too high if compared to plastic greenhouse (Nelson, 2003). The attractive of plastic greenhouse is its low cost, light mass, able to absorb sufficient heat and lower tax liabilities.

MATERIALS AND METHODS

The study was conducted in 10×4 m lowland tropical greenhouse fully covered with polyethylene film at Institute Teknologi Maju (ITMA) Universiti Putra Malaysia. To validate the system performance, a number of experiments were carried out during February 2010. In this project, 27 Chili Kulai were planted using fertigation system in Polybags in greenhouse and 3 Chili Kulai were planted in an open field beside the greenhouse as a control experiment. The plants were placed in 6×3 m area with a total of 27 polybags with 9 polybags for each row in greenhouse. Figure 1a and b show the inside and outside greenhouse structure for this project.

Plants were grown in an automatic control system lowland tropical greenhouse with mechanically ventilated and cooling system using circulation swamp cooler, vent and fogger which provides control of temperature and relative humidity. Fertigation system was used to provide water and nutrient for crops. Figure 2 shows the equipment used for controlling the environment parameter in greenhouse. Through this fertigation system, the water with sufficient nutrient solution will supply directly to plant root zone. Sufficient water and fertilizer were supplied to the crops automatically by using timer clock daily. The temperature and relative humidity were recorded and saved in EEPROM every half an hour. Figure 3 shows the flow chart of the program used to control the system.

Equipments: The data from temperature and humidity sensors were sent to PIC controller as input signal and were then converted to digital form through internal Analog to Digital Convertor (ADC) inside the controller. Output signals were then sent to activate actuators during the automation.

Figure 4 shows the block diagram of overall processing in this research. In this project, data from temperature and relative humidity sent to PIC via I/O pins as input for controller. Pins a_0 and c_0 were used as temperature and relative humidity input signals while pins of PORT B were used as output for LCD display on training kit. Pins a_1, a_2 and a_3 of PORT C were used as output for activate actuators in greenhouse.

Development of Graphical user Interface (GUI): A Graphical User Interface (GUI) was developed for the system check-list for actuators according to the temperature and relative humidity recorded in real time inside the greenhouse. User will get the optimum temperature, relative humidity and VPD values according

Fig. 1: (a, b) Greenhouse structure for this project

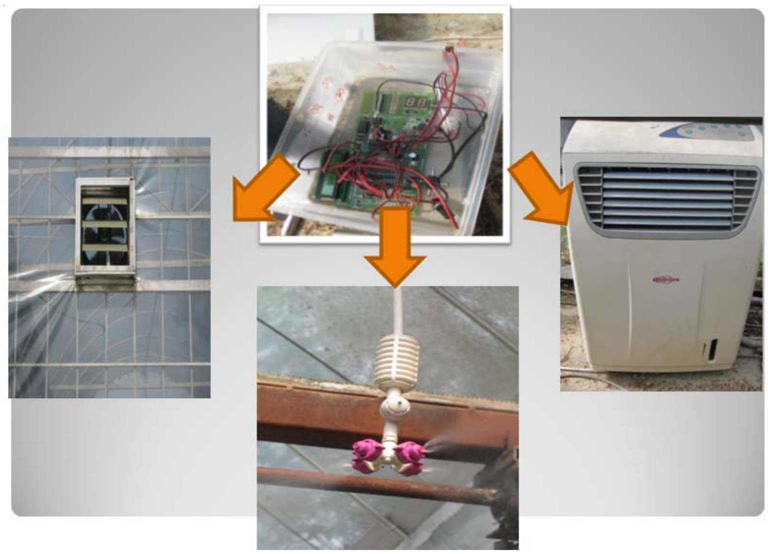

Fig. 2: Microcontroller (top) for controlling the vent and fogger, Fertigation system and circulation swamp cooler (from left) used for this project

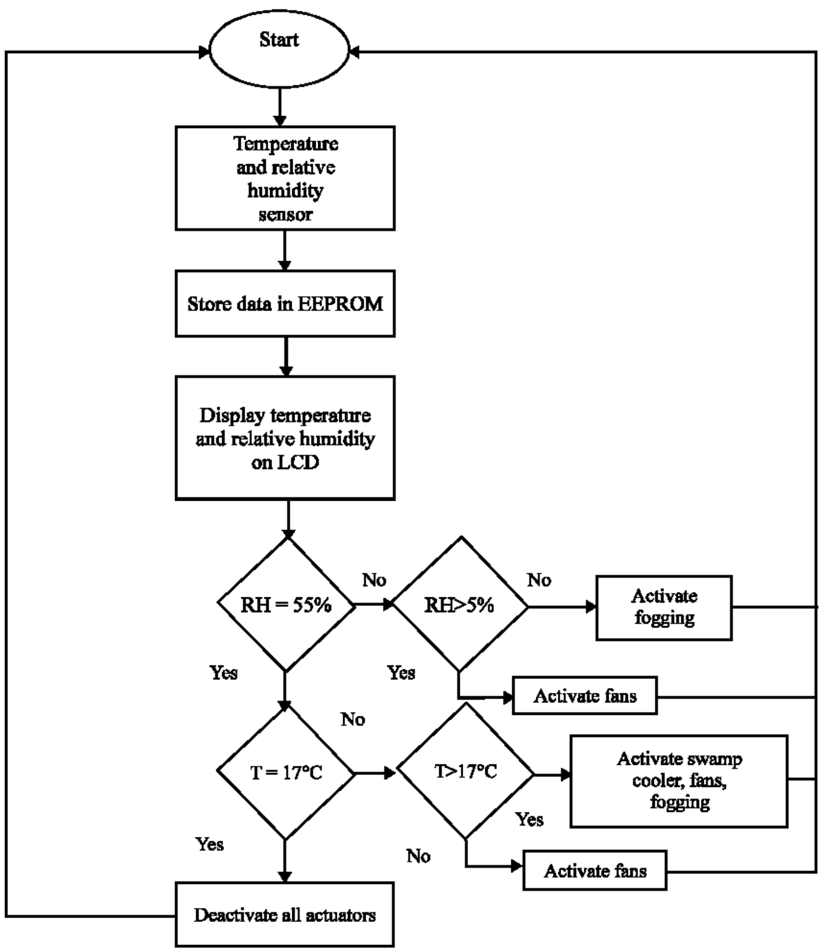

Fig. 3: Flow chart of the program used to control the system

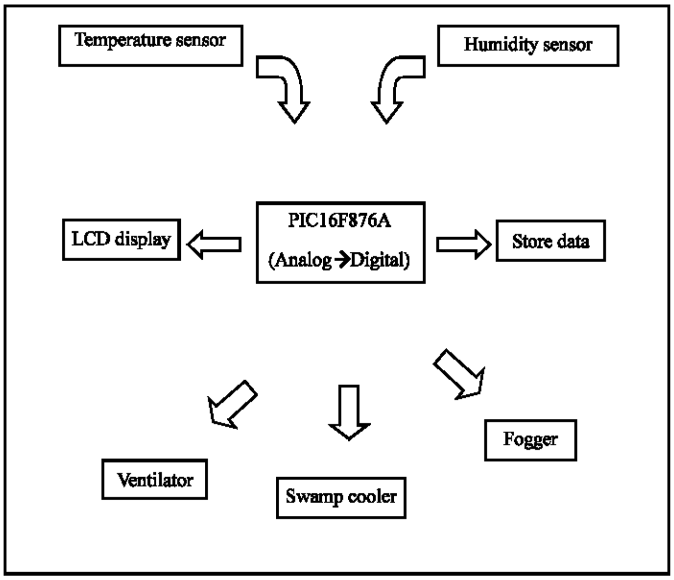

Fig. 4: Block diagram of overall processing

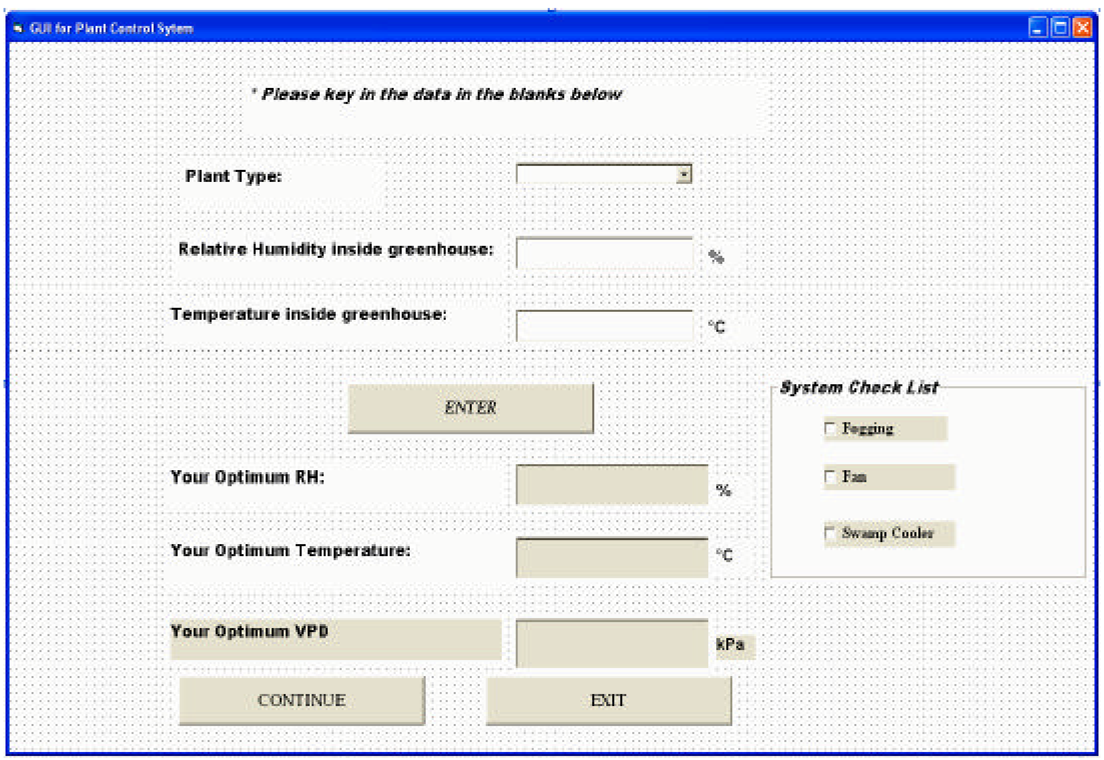

Fig. 5: Graphical user interface for plant control system

to plant type cultivated. Figure 5 shows GUI for plant control system. This GUI can be used for other crops in further study. Visual Basic programming software was used to develop GUI for this project which capability with rapid development in the concept of agriculture automation software (Hudzari *et al*., 2010).

RESULTS AND DISCUSSION

The data of temperature and relative humidity inside and outside greenhouse were captured are recorded during planting period of the experiment. Vapour Pressue Delicit (VPD) calculator which was available at www.autogrow.com was used to calculate VPD based on the data captured. The examples of graph for temperature, relative humidity and VPD versus time are shown in Fig. 6a-c for the open field planting and Fig. 7a-c for the greenhouse planting. Every first data started to be captured at 12.30 a.m. midnight and capturing process will be every 30 min interval. Figure 6 shows that temperature and VPD increase gradually since MINS 600 and decrease slowly after MINS 1000. From the VPD graph, we could see there is a high peak at MINS 800 MINS 1000, because it is in the middle of the day (Sunny Day). Razali *et al.* (2008) also mentioned that the sunny day had highest intensity of sunlight which affected the optical properties of the fruit. Relative Humidity (RH) was low due to the hot weather. The high temperature and low RH, as a result, had lead to high VPD value which is higher than the ideal VPD value for plants. The VPD can increase up to 2.81 kPa in open field.

Inside greenhouse: Figure 7 shows that temperature and VPD increase gradually since, MINS 400 and decrease slowly after MINS 800. From the VPD graph, we could see there is a high peak at MINS 700 MINS 900, because it is in the middle of the day (Sunny Day). RH was low due to the hot weather. The high temperature and low RH, as a result, had lead to high VPD value which is higher than the ideal VPD value for plants. The VPD can increase up to 3.20 kPa inside greenhouse in the day time for night time, the VPD is around the 0.96 kPa in the midnight.

Analysis of the VPD: The highest temperature inside and outside the greenhouse does not have much difference. This is because of the successful function of the controller inside greenhouse. When RH is lower than 55%, the fogger will release mist to lower the temperature in the greenhouse. The mist will increase RH and at the same time, it will lower down the temperature. Even though the temperature can be controlled, but it is very difficult reach the optimal temperature. The heat captured by the greenhouse via radiation is hard to dissipate in the condition of low efficiency of ventilation system. Therefore, in the day time, RH will be low although the fogging was on, as the mist was evaporated to cool down the greenhouse (lowering the temperature). With the low RH, it will increase the crop transpiration (Henry *et al.*, 2005).

In the night time, the temperature will be decreased gradually and as a result, RH will be increased gradually.

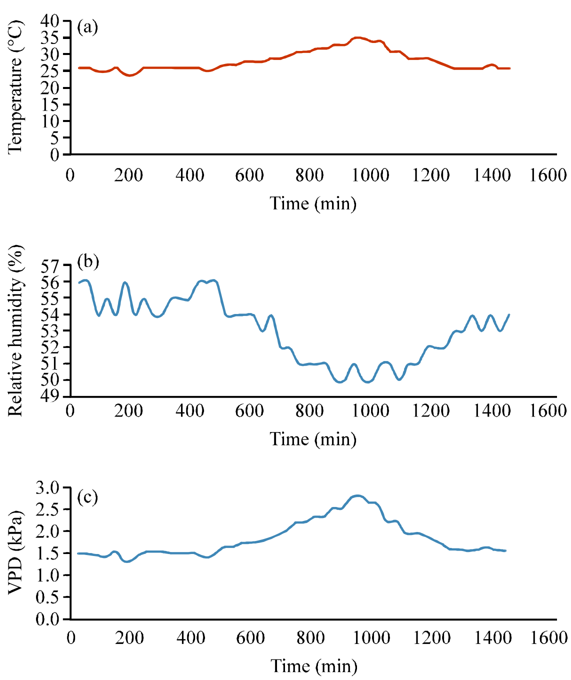

Fig. 6: The graph of (a) Temperature, (b) RH and (c) VPD versus time of open field data

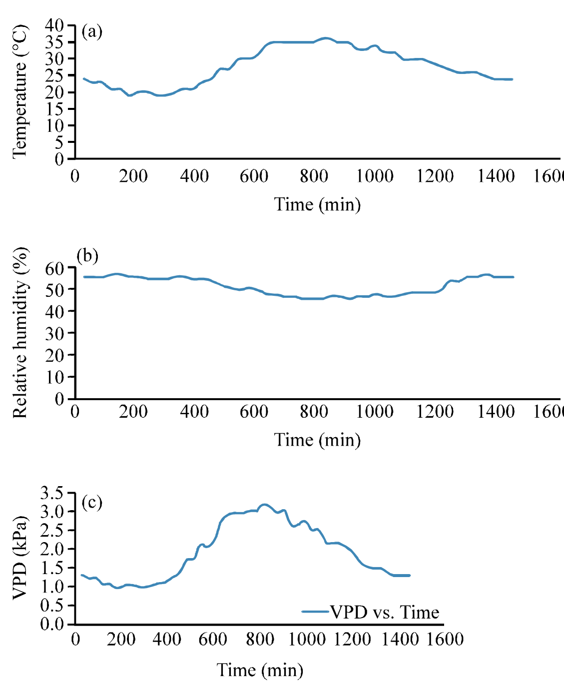

Fig. 7: The graph of (a) Temperature, (b) RH and (c) VPD versus time inside greenhouse

Table 1: Chili growth at open field

Month	Stage	Height average (cm)	Leaves width (cm)	No. of flower Min	No. of flower Max	No. of fruit Min	No. of fruit Max
1	Seedling	-	-	-	-	-	-
2	Vegetative	29	4	-	-	-	-
3	Flowering and fruiting	34	5	6	11	3	7

Table 2: Chili growth inside greenhouse

Month	Stage	Height average (cm)	Leaves width (cm)	No. of flower Min	No. of flower Max	No. of fruit Min	No. of fruit Max
1	Seedling	-	-	-	-	-	-
2	Vegetative	33	4	2	12	-	-
3	Flowering and fruiting	49	5	18	34	0	2

So, if the RH is higher than 55%, the fogging system will be stopped. So, it has been proven the control system works if it is in the normal condition.

The main constraint in this experiment is the RH inside greenhouse is still low even though the ventilation fans and fogging are on. This only can be solved by increasing the number of ventilator and number of fogger.

Analysis of plant growth: Table 1 and 2 show the parameters of plant growth inside and outside greenhouse, respectively. Those data were recorded according to plant growth stages. At start, the plants experienced the transplanting shock when they were transplanted into a bigger polybags. However, after a few weeks adaptation, plants growths were found healthy. This can be shown in the Table 1, where there is no any flower and fruit obtain in vegetative stage. However, in the flowering stage, the maximum number of flowers obtain in open field is 11, this might due to the plants were widely exposed to environment condition where most of the flowers falls down due to heavy raining. After 3 months, during the fruiting stage, there were only two plants fruiting where 7 chilies were yield. Figure 8a and b show the chilies yield in the open field condition.

The average height of plants in vegetative stage inside greenhouse is much higher than the average height of plants in open field. This is because the plants are growing under a shelter (greenhouse) and water was supplied by fertigation system automatically (Krope *et al*., 2010). The plants in open field are watered manually and exposed to natural environment.

The chili yield in the open field is higher compare to greenhouse although the number of flowering inside greenhouse is higher than the plants in the open field. It is believed that process of fertilization was not successful due to low pollinators such as insects or wind inside greenhouse. If the problem is served by solution, the yield of the chilies inside the greenhouse will be higher. Figure 9a and b show the chilies yield inside greenhouse.

Fig. 8: Chilies yield at open field plantation

Fig. 9: Chilies yield inside greenhouse

CONCLUSION

The total number of flowers inside greenhouse is higher compare to open field. Thus, if the environment in the greenhouse can be efficiently and effectively controlled, the yield will be higher. Otherwise the VPD is not successfully maintained around the ideal value during the whole process as it is difficult to increase the humidity inside greenhouse gradually under hot weather. The higher temperature inside greenhouse, during the day time, further proves the greenhouse effect. The ideal VPD is about to achieve at midnight where the temperature ranged between 19 and 23°C at relative humidity of 54 to 57%. This shows that the data acquisition system able to work efficiently under normal condition. A data acquisition system to control the environment parameter inside greenhouse was successfully developed and able to record the data. The data acquisition system is able to monitor the growth plants via the control system. PIC controller was successfully being used and interfacing with computer (read data). The ability of controlling the environment parameter such as temperature, relative humidity and Vapor Pressure Deficit (VPD) give great potential for the application of the greenhouse in agriculture plantation. Making closed loop feedback sensory system, the actual effect of the plant as the output can be monitor and adjust.

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