Control of Plant Growth by Monitoring Soil Moisture, Temperature and Humidity in Dry Climate

N K Madzhi¹,2 and M A Nor Akhsan¹

¹Department of Electrical Engineering, School of Engineering, Universiti Teknologi Mara Shah Alam Selangor, Malaysia
²Corresponding author’s e-mail: ninak654@uitm.edu.my

Abstract. Monitoring of environment parameter such as soil moisture, temperature and humidity are important parts of plant growth. This paper focused on the development of an instrumentation system and analysis on the effect of the water volume to the soil moisture, effect rate of soil moisture, temperature and humidity for an indoor greenhouse. Data were collected through two experiment. First experiment focused on effect volume of water to soil moisture. Soil hygrometer sensor used to measure soil moisture in real time. Five bottles contained different volume of water poured into soil which the soil is fixed to 200gram. Three different rate of soil moisture applied to plant and the data were analysed to determined relationship between soil moisture to the plant growth. It can be concluded that the rate of soil moisture does have effect on the stem diameter and leaves length based on the observations of the plant growth for three weeks.

1. Introduction
Indoor Greenhouse System creates an artificial garden in the house. It can prevent disease, insect pest of breeding, reduce the dosage of pesticide, pollution and climate change [1-3]. According to Ibrahim Al-Adwan [4], the environment inside the greenhouse will affect the quality of the plants. Unlike outdoor greenhouse, monitoring environment parameter such as soil moisture, temperature and humidity inside indoor greenhouse are easier because of rate of change of these parameters are low.

The important parameter which needs to be monitored to produce a quality plan is soil moisture. Inefficient use of water will result in a waste of water supply [5]. If too little watering a plant, it will cause uneven water in soil. Prevention of overwatering is an aspect that can improve water usage efficiency and pest prevention. For example, a recent study from Slatyer reported that larvae of shore fly can be reduced if the soil moisture level is maintained around 30%. Similar approach can also reduce root zone diseases such as Pythium [6].

Delivering water to plants at the right time and right quantity is a key to effective and efficient irrigation. Knowing when and how much to water is two important aspects of irrigation. To do this, sensors is needed to determine when plants may need water. Water is absorbed by the root system and lost through transpiring leaves. Evaporation from the leaves is the driving force for transfer of water across the plant and only a small proportion of the uptake water is used for growth. It was calculated that the water lost per day by transpiration from some plants is equal to twice the weight of the plant. The rate of water lost depends on the condition of soil, air flow, relative humidity in air and the temperature of the environment. Loss of water from the soil by means of drainage is quite common during the dry season [5-6].

In this system, commercialized soil hygrometer sensor is used to monitored soil moisture. This sensor consists of two probes which are used to measure the volumetric content of water. The two probes
allow the current to pass through the soil and then it gets the resistance value to measure the moisture value. When there is more water, the soil will conduct more electricity which means that there will be less resistance. Therefore, the moisture level will be higher. Dry soil conducts electricity poorly, so when there will be less water, then the soil will conduct less electricity which means that there will be more resistance. Therefore, the moisture level will be lower [7].

Another major factor influencing plant growth and healthy is the temperature [8], too cold or too hot temperature will result in unhealthy plants. Temperature influences most plant development process including photosynthesis, transpiration, absorption, respiration and flowering. In general, growth is promoted when the temperature rises and inhibited when temperature falls. The growth rate of a plant will not continue to increase with the increasing of temperature. Each species of plant has a different temperature range in which they can grow [8-9].

Humidity is important to plants because it partly controls the moisture loss from the plant. The leaves of plants have tiny pores, CO2 enters the plants through these pores, and oxygen and water leave through them. Transpiration rates decrease proportionally to the amount of humidity in the air. This is because water diffuses from areas of higher concentration to areas of lower concentration. Due to this phenomenon, plants growing in a dry room will most likely lose its moisture overtime. The damage can be even more severe when the difference in humidity is large. Plants stressed in this way frequently shed flower buds or flowers die soon after opening. High humidity can also affect the development of plant. Under very humid environments, fungal diseases most likely to spread, on top of that air becomes saturated with water vapour which ultimately restricts transpiration [10]. Monitoring these two parameters which is temperature and humidity need an accurate sensor. Study by Diaa Mehdi Faris suggested to use DHT11 temperature and humidity sensor where this component is cheap, reliable and easy to use. Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. [11].

Monitoring of the crops exposure from excess cold or heat and unwanted pests nowadays can be done via an intelligent environment monitoring and control system based on Arduino UNO board for a small-scale agriculture namely greenhouse. The system user can monitor and control the greenhouse climate conditions remotely via web interface/mobile applications and GSM in a real-time manner [12-14]. The Arduino was said for interfacing all the sensors and integrates the results of each sensor. The sensors that connected to the Arduino should be programmed and the code was embedded in the Arduino [12].

To grow plants inside indoor greenhouse effectively, some parameters need to be monitor. Soil moisture, temperature and humidity are parameters that will affect a plant if too much or too low inside greenhouse. For example, as mention in introduction, too little watering a plant, it causes uneven water to soil and stunted growth of plant. But if too much water it causes root zone diseases such as Pythium and waste the water. Knowing when and quantity of the water needed to watering plant is also problem if soil moisture not to be monitor. By creating indoor greenhouse system equipped with soil moisture and DHT11 sensor will help to growth plant with a great quality.

In this work, two experiments were conducted to analyse the effect of water volume to soil moisture and relationship between rates of soil moisture to the plant growth. These experiments were done in AGROSEN lab at FKE, UiTM Shah Alam using Basil plant since it is the most suitable indoor plant to observe on the growth of its stem and leaves. Soil hygrometer and DHT11 temperature and humidity sensor were placed inside indoor greenhouse to senses change of parameters which is soil moisture, temperature and humidity.

The limitation of this study is the system cannot control the parameters which is temperature and humidity inside indoor greenhouse because the system did not have control element. If temperature and humidity are too low or too high it will affect plant growth.

2. Materials and Method

Figure 1 shows the basic block diagram of the system. The soil hygrometer sensor as shown in Figure 2 was inserted into the soil and the change of the moisture in the soil caused the resistance value varies and display the voltage output. The resistance measured decreased because of the increase of moisture and as resulted the voltage drop. DHT11 temperature and humidity sensor were placed inside indoor
greenhouse to monitor the surrounding temperature and humidity. The processor used in this word was an Arduino UNO whereby it interpreted the data from these input sensors send the output to display in the serial monitor. Serial monitor became the output device that displayed soil moisture, temperature and humidity reading.

2.1. Overall function of the system

Figure 3 shows the overall function of the system. The system starts by the sensors placement inside the indoor greenhouse. Soil hygrometer sensor was inserted into the soil and the DHT11 sensors mounted at the pillar of the greenhouse. These sensors measured the changes of parameters or values of soil moisture, temperature and humidity and the data displayed at the serial monitor.

![Figure 1. Block diagram of the system.](image1)

![Figure 2. Soil hygrometer and DHT11 sensor.](image2)

![Figure 3. Flowchart of the system.](image3)
2.2. Data collection
The collection of data was performed in two stages. First was by observing the soil moisture at different conditions and secondly was by observing the relationship of soil moisture to plant growth. Figure 4 represents a beaker which contained Holland soil to observe the soil moisture. It is a type of loam soil made with a balance of the three main types of soil particularly sand, silt and clay soil which is perfect texture for plant growth.

![Figure 4. 200 g of Holland soil.](image)

2.2.1. Soil moisture experiment
This experiment has been run in lab is to analyze effect volume of water to the soil moisture. Five bottles placed inside greenhouse with 200 g of Holland soil each were poured by different volume of water. Soil moisture was monitored time by time and serial monitor displayed the result. Besides that, temperature and humidity were also recorded. Table 1 represents the bottles with specified volume of water poured into it.

| Bottle No. | Water Volume (ml) |
|------------|-------------------|
| 1          | 100               |
| 2          | 200               |
| 3          | 300               |
| 4          | 400               |
| 5          | 500               |

2.2.2. Relationship of soil moisture to plant growth
This experiment analyzed the relationship between rates of soil moisture to the plant growth. The soil moisture of the plant maintained at 30% for the first week. Second week, soil moisture increased to 60% and the final week, the soil moisture increased to 90%.

3. Result and Discussion

3.1. Indoor greenhouse monitoring system
Figure 5 shows the prototype of indoor greenhouse monitoring system equipped with sensors. The frames of greenhouse were made of Polyvinyl chloride (PVC) pipes. PVC pipes was chosen because of PVC’s good mechanical strength and toughness are key technical advantages for its use in building and construction of greenhouse [15]. PVC pipes can be cut, shaped, welded and joined easily in a variety of styles. Its light weight reduces manual handling difficulties. This indoor greenhouse was design with ½ meter high, ½ meter width and ½ length. Transparent plastics were used to cover up the greenhouse to prevent insect pest. The soil hygrometer and DHT11 temperature and humidity sensors act as input to detect change of environment parameter inside this indoor greenhouse.
3.2. Soil moisture experimentation

Figure 6 represents the experimentation of five bottles which contained 200 g of Holland soil with different volume of water poured. The results are presented in Tables 2-6.

Table 2. Initial reading before adding the water to the soil.

| Bottle | Input | Output |
|--------|-------|--------|
|        | Water (ml) | Soil Moisture (%) | Temperature (°C) | Humidity (%) | Waste water (ml) |
| 1      | 100     | 51      | 24            | 88           | 0               |
| 2      | 200     | 49      | 24            | 88           | 0               |
| 3      | 300     | 50      | 24            | 88           | 0               |
| 4      | 400     | 50      | 24            | 88           | 0               |
| 5      | 500     | 52      | 24            | 88           | 0               |

Table 3. Initial reading after adding water to the soil.

| Bottle | Input | Output |
|--------|-------|--------|
|        | Water (ml) | Soil Moisture (%) | Temperature (°C) | Humidity (%) | Waste water (ml) |
| 1      | 100     | 81      | 24            | 89           | 0               |
| 2      | 200     | 100     | 24            | 87           | 10              |
| 3      | 300     | 100     | 25            | 85           | 50              |
| 4      | 400     | 100     | 25            | 88           | 100             |
| 5      | 500     | 100     | 24            | 88           | 180             |
Table 4. Reading after day one.

| Bottle | Input | Output |
|--------|-------|--------|
|        | Water (ml) | Soil Moisture (%) | Temperature (°C) | Humidity (%) | Waste water (ml) |
| 1      | 100    | 79      | 26    | 88    | 0      |
| 2      | 200    | 95      | 23    | 89    | 30     |
| 3      | 300    | 97      | 23    | 90    | 90     |
| 4      | 400    | 100     | 23    | 90    | 150    |
| 5      | 500    | 100     | 23    | 90    | 230    |

Tables 2 and 3 show the changes of soil moisture before and after adding the water according to the specified volumes. Only bottle 1 does not reach 100% of soil moisture due to the limitation of water poured. This means that watering the plant already absorbed enough water. Waste water in Table 3 was recorded immediately after adding the water. Bottles 3, 4 and 5 have the most waste of water with more than 50 ml. Bottle 2 shows the best result with low in waste water but still maintained soil moisture of 100%. After day one of experiment, soil moisture in bottles 1, 2 and 3 started to decrease but not for bottles 4 and 5.

Table 5. Reading after day three.

| Bottle | Input | Output |
|--------|-------|--------|
|        | Water (ml) | Soil Moisture (%) | Temperature (°C) | Humidity (%) | Waste water (ml) |
| 1      | 100    | 73      | 27    | 88    | 0      |
| 2      | 200    | 85      | 26    | 89    | 30     |
| 3      | 300    | 88      | 27    | 89    | 120    |
| 4      | 400    | 90      | 27    | 88    | 150    |
| 5      | 500    | 95      | 27    | 88    | 230    |

Table 6. Reading after one week.

| Bottle | Input | Output |
|--------|-------|--------|
|        | Water (ml) | Soil Moisture (%) | Temperature (°C) | Humidity (%) | Waste Water (ml) |
| 1      | 100    | 58      | 25    | 89    | 0      |
| 2      | 200    | 72      | 25    | 89    | 30     |
| 3      | 300    | 78      | 25    | 89    | 120    |
| 4      | 400    | 83      | 25    | 92    | 150    |
| 5      | 500    | 88      | 25    | 90    | 230    |

Table 5-6 represents the results for each bottle soil moisture reduced gradually after one week. Besides that, temperature and humidity also recorded. The lowest temperature was recorded is 23°C and maximum reading is 27°C. The average of humidity is 88%. There is no extreme climate change happened. So, it’s suitable for a plant to growth.

3.3. **Relationship of soil moisture to plant growth**

Table 7 represents data collection during the second experiment. The data analyzed relationship between rates of soil moisture to the stems diameter. Four stems from plant type Basil were used to measured diameter. Photosynthesis is the process by which plants prepared their own food using carbon dioxide and water in the present of sunlight. In this process, functions of stem are to conduct water and mineral to leaves and to transport these products from the leaves to other parts of the plant including the roots. The stem conducts water and nutrient minerals from their site of absorption in the roots to the leaves. The higher soil moisture which means soil contains more water than bigger stem diameters [16-17]. Figure 7 represents the chart of four stems growth for three weeks. It can be observed that the rate of soil moisture effected the stems diameter.
Table 7. Data collection during Second experiment.

| Week | Average Soil Moisture (%) | Stem 1 | Stem 2 | Stem 3 | Stem 4 |
|------|---------------------------|--------|--------|--------|--------|
| 1    | 30                        | 0.8    | 0.9    | 0.7    | 1      |
| 2    | 60                        | 1.1    | 1      | 0.9    | 1.2    |
| 3    | 90                        | 1.6    | 1.4    | 1.3    | 1.5    |

Figure 7. Stems diameter vs rate of soil moisture.

4. Conclusion
The prototype of indoor greenhouse monitoring system equipped with soil hygrometer and DHT11 temperature and humidity sensor were successful develop. From both experiment that have been run, result shows the effect volume of water to soil moisture and relationship between rates of soil moisture to the plant growth. In this study, soil moisture plays important role to growth plant. If too much watering plant, its effects on soil moisture. Thus, it’s contributing to waste water. Besides that, there is no critical changed in temperature and humidity was recorded. For the recommendation in next project, this indoor greenhouse monitoring system should have control element to overcome the limitation. For example, temperature can be control by using fan.

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