# PRELIMINARY DEVELOPMENT OF AN AEROPONIC SYSTEM FOR TEMPERATE CROP CULTIVATION IN THE LOWLAND TROPICS

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**ABSTRACT**

*Innovative approaches in agriculture are deemed crucial in addressing the challenges posed by climate change on global food security. Hence the pressing need of growing crops in an environment outside their favourable conditions. This study explores the potential of cultivating temperate crops in lowland tropics using aeroponic system by designing, assembling and assessing a prototype aeroponic system. Much like the hydroponic system, aeroponic is a method of growing plants without the existence of media in an enclosed chamber. The exposed roots are supplied with the essential nutrient through regularly misting under a controlled environment. This research aimed to identify the essential design parameters and determine their optimal configurations in ensuring the efficiency and effectiveness of the aeroponic system. Optimum conditions for the grow chamber of the suspended roots are set to be within the temperature range of 10°C to 28°C, with relative humidity to be maintained at 99%. In order to achieved that, chiller's temperature is set at 5°C, 10°C, 15°C and 20°C. Additionally, the misting system is operated with varying intervals and frequencies, specifically at 5-minute off, 7-minute off, and 10-minute off, with a 30-second misting cycle. The collected data include the temperature and relative humidity readings for both the environment and the chamber itself. The initial data for comparing the temperature and relative humidity between the environment and the root growth chamber have been collected. The target temperature range can be achieved with a chiller temperature setting of 20°C and duration and interval of misting of 30 second-on and 10 minute-off.*

Keywords: aeroponic; lowland; tropics; food security; climate change; controlled environment

## INTRODUCTION

Climate change has been a prominent subject of discussion at numerous significant events over the recent years. The impacts of it can be seen affecting across industries, changing the landscape of agriculture too. Predicted temperature rise and declining water availability may contribute to the reduction of agricultural productivity (United States Environmental Protection Agency 2017). Coupled with the mishandling of soil that causes soil-degradation over the misuse and overuse of soil, the land has become less fertile and no longer suitable for agricultural activities. Thus, subsequently resulting in shortage of food supplies, compromising the food security to the people worldwide. Therefore, it is essential to find ways to mitigate these impacts to the already vulnerable agriculture industry. Progressive farmers and researchers alike are discovering new, climate-resilient alternatives to produce food (Union of Concerned Scientists USA 2019). Hence the implementation of aeroponics systems.

Aeroponics is a soil-less farming technique without the presence of soil within substrate culture or water culture. Utilizing this technique under a controlled environment offers a potential cultivation of crops regardless of their ideal planting conditions. With minimal use of input (nutrient water), no presence of soil, as well as the possibility of multiple plant harvesting with maximum output making this system a promising innovative agriculture solution, especially to countries that struggle with both climate change effects and limited agriculture (Lakhiar et al. 2018).

In this study, an aeroponics system to cultivate temperate crops in lowland tropics is being developed at a research plot with latitude N 2°59’ 51.4392”, longitude E 101° 41’ 26.2284” and 37.8 m above sea level (Diyana 2009), under a controlled environment that mimics typical cultivation nature of temperate crops. The required temperature, relative humidity and interval and frequency of misting were being investigated. The objective of this study is to determine vital design parameters and establish their optimal settings.

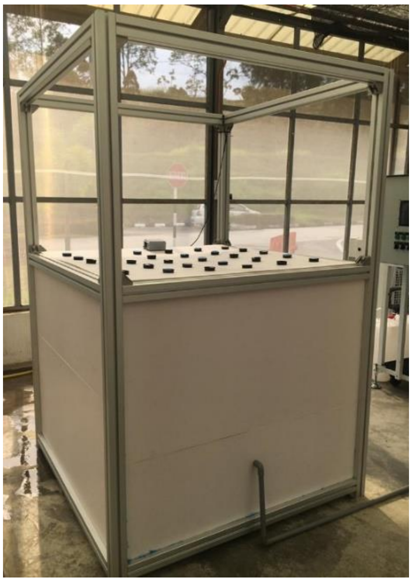
**MATERIALS AND METHODS**

The aeroponics system is made up of three main component which are planting system, chilled irrigation system and data monitoring system.

**Aeroponic planting system**

The planting structure for the aeroponic system has a total built up of 2.4 meters. Divided into two sections, the upper part is the plant canopy area while the lower part is the root growth chamber (Figure 1). The root growth chamber measuring 1.2 m x 1.2 m x 1.2 m was designed with the operator's body size in mind to facilitate with the handling, transplanting, care and harvesting of plants as well as the process of data collection and maintenance. The material for the main frame is made of T-slot aluminium. These slots aid the installation process of the frame structure and the maintenance process. The size of the canopy and root growth chamber area are adjustable based on the types of plant and system requirements.

Figure 1. Planting structure of aeroponic system



The plant canopy area at the upper part of the planting structure houses the space for plant leaves to grow. Five horticulture light emitting diodes (LED) were installed in between the rows of plants at a height of 70 cm from the cover of the root growth chamber with a distance of 20 cm between each LED lights.

The root growth chamber is covered with panels made of expanded polystyrene (EPS). 30 plant holes were punched through the cover panel of the root growth chamber. The diameter of the plant hole is 45 mm with a distance of 20 cm centre-to-centre. Due to the absence of root zone media for plants, baskets or support collars are needed to hold the plants and keep the plant in a hanging state. The interior floor is finished with a reservoir made of acrylic panels. An overflow of 2-cm height is installed at the bottom of the reservoir.

**Chilled irrigation system**

The irrigation system consists of a water tank of 60 gallons, three fertilizer and acid tanks, each with a capacity of 30 litre, complete with adjustable fertilizer dosing pumps with a flow rate of up to 1.8 litre/hour, a 1 hp water pump, a submersible water pump, an inline pipe mixer, timers and six rows of spraying nozzles (Figure 2).

Figure 2. Mobile chilled irrigation system

Figure 3. Spraying nozzles

36 units of spraying nozzles are installed in the position between the rows of plant holes with a height distance from the base of the plant roots to the spraying equipment of 30 cm (Figure 3). The water spraying radius is up to 30 cm. This system is also equipped with an industrial water-cooling machine which is used to continuously supply cold water to the aeroponic system. The lowest temperature setting for this water cooler is 5°C and the highest temperature setting is 30°C. All components of this irrigation system (except for the water tank and the industrial water cooler) are placed on a platform that allows it to be mobile. The operation of the irrigation system could be run manually or automatically by changing the mode knobs on the control panel (Figure 4). This irrigation system is a closed loop system; excess nutrient solution sprayed that is not absorbed by the plant roots will fall back into the reservoir to be reused for subsequent spraying cycles.

Figure 4. Control panel

**Data monitoring system**

The optimal conditions for the growth of a healthy root system are where the temperature and relative humidity in the chamber to be in the range of 15 - 25°C and 95 - 99 % (Lakhiar et al. 2018; Otazú 2014). Several sensor units are installed on different parts of this aeroponic cultivation system to measure the following parameters: temperature and relative humidity of the environment, readings of electrical conductivity (EC) and potential of hydrogen (pH) of the irrigation system as well as temperature and relative humidity in the root growth chamber (Figure 5). The data taken by the sensors are stored in a local computer system on the control and monitoring panel and displayed on a dashboard (Figure 6).

Figure 5. Sensors: temperature and relative humidity sensors for environment and root growth chamber

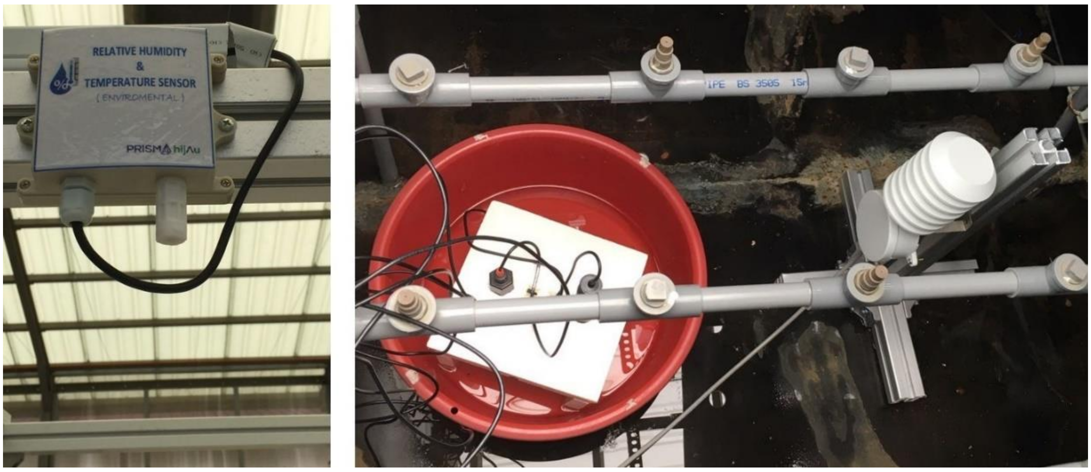
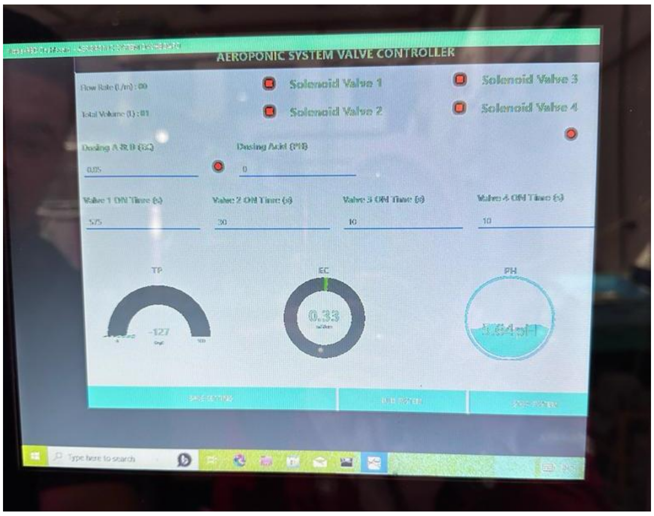



Figure 6. Dashboard for control and monitoring irrigation system




### Data collection

Nutrients are mixed with water in a water reservoir which then chilled to achieve root growth chamber's temperature in the range of 15°C to 28°C. The irrigation system will be supplying the chilled nutrient water at a pressure of 2 to 4 bars to the chamber through a distribution system of pipes and spraying nozzles. The readings of temperature and relative humidity inside the root growth chamber were observed and recorded.

## RESULTS AND DISCUSSION

Two studies were conducted to obtain the parameters required to achieve optimal root growth conditions. The first study involved the influence of irrigation temperature on root growth chamber parameters. The temperature of the water cooler was set at 5°C, 10°C, 15°C and 20°C. The second study explored the influence of spraying duration and interval on root growth chamber parameters. Intervals for subsequent spraying were set to be every 5 minutes, 7 minutes and 10 minutes while the spraying duration was done for 30 seconds for all interval setting. The spraying duration is the time water is sprayed to the plant's roots while the spraying interval is the time between one spray and the next.

### Influence of irrigation temperature on root growth chamber parameters

Table 1 shows the root growth chamber parameters subjected to different water chiller temperature setting. The water chiller setting at a temperature of 5°C resulted in a temperature of the root growth chamber in the range of 19.5 – 21.0°C while a setting at a temperature of 20°C gave a temperature range of 23.1 – 26.2°C. The relative humidity of the root growth chamber was consistent at 99.9% for all water chiller temperature setting.

Table 1. Root growth chamber parameters subjected to different water chiller temperature setting

| Water Chiller Temperature Setting | $T_{Chamber}$ | $RH_{Chamber}$ |
|---|---|---|
| 5°C | 19.5 – 21.0°C | 99.9% |
| 10°C | 17.8 – 20.8°C | 99.9% |
| 15°C | 19.9 – 21.5°C | 99.9% |
| 20°C | 23.1 – 26.2°C | 99.9% |

* Abbreviation of variables were $T_{Chamber}$: root growth chamber temperature, $RH_{Chamber}$: root growth chamber relative humidity.

Therefore, the water-cooling machine does not need to be set at the lowest temperature (5°C) to obtain the optimal range of temperature and relative humidity for the root growth chamber. However, environment temperature and relative humidity notably affect the efficiency of chilled irrigation system in obtaining the optimal temperature and relative humidity of the root growth chamber.

**Influence of spraying duration and interval on root growth chamber parameters**

Table 2 shows the root growth chamber parameters subjected to different spraying duration and interval. The interval of spraying water every 5 minutes for 30 seconds produced a temperature ranging 23 - 26°C for the root growth chamber while a 10 minute-interval resulted a temperature range of 25 - 28°C. The relative humidity of the root growth chamber was consistent at 99.9% for all conditions.

Table 2. Root growth chamber parameters subjected to different spraying interval and frequency

| Spraying Interval and Frequency | $T_{Chamber}$ | $RH_{Chamber}$ |
|---|---|---|
| 30-sec on and 5-min off | 23 – 26°C | 99.9% |
| 30-sec-on and 7-min off | 24 – 27°C | 99.9% |
| 30-sec on and 10-min off | 25 – 28°C | 99.9% |

Therefore, the frequency of spraying can be reduced to obtain the optimum range of temperature and relative humidity of the root growth chamber. This contributes to conservation of water and power consumption.

## CONCLUSION

The environmental conditions and the timing and frequency of spraying play crucial roles in shaping the root growth environment to attain the desired temperature and relative humidity. By configuring the water-cooling machine to maintain a temperature of 20°C and spraying for 30 seconds at intervals of 10 minutes, this aeroponic system can effectively reach the optimal parameter range for the root growth chamber: a temperature ranging from 10 to 28°C and a relative humidity of 99%.

The application of a water-cooling machine to decrease temperatures within the root growth chamber offers the potential to grow cold-climate plants in tropical lowlands using an aeroponic system.

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