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Smart Monitoring of Nutrient Content, pH Condition and Temperature in Vegetable Leaf Grown through Deep Flow Technique

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Abstract

This research aims to develop a hydroponic farming system by utilizing the Internet of Things (IoT) as a medium for monitoring the quality of plant nutrition, pH Condition, and Temperature. The research method used quantitative analysis of plant nutrient content measurements for 26 days with two treatments, namely indoor and outdoor. We used several vegetable leaves (i.e. Bok Choy, Water Spinach, and Lettuce) as these plants are easy to grow, have a low risk of withering, and have a relatively short planting time until harvest (26 days). The findings presented that by implementing IoT in agriculture, the nutritional content of plants can be measured accurately, from pH, plant nutrients (ppm), to temperature. With the monitoring system, we can detect whether the nutrient content is deficient or excessive. The system can also maintain optimum conditions in nutrient content quality, pH condition, and temperature. In conclusion, this research can be used as a reference for developing an optimal hydroponic monitoring system.

Keywords: *Hydroponic, Internet of Things, Smart monitoring, Vegetables Leaf.*

1. Introduction

Hydroponic is a method of growing plants that do not require soil. The use of the hydroponic method depends on the nutrient content of the plants given to the water. The benefits of a hydroponic system include more efficient land use and fertilizers as well as water. In addition, it includes higher yields, higher quantity and quality of production, cleaner, more efficient use of, and easier pest and disease control [1]. To get optimal growth, it is necessary to carry out regular checks to maintain nutrient content, pH, and water level [2]. However, hydroponic methods can be inefficient when farmers do not monitor intensively. Although hydroponic is an alternative technique to be applied in the limited land for farming, the treatment's complexity is the reason this method has not been broadly applied in agriculture [3].

The internet of things (IoT) is a networked system of mechanical and digital machines, interconnected computing devices, objects, animals, or people with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction [4]. This makes IoT been widely used [5]. IoT is currently being widely adopted because of the nature of hydroponic, which requires nutritional stability for plants [6-9]. The implementation of IoT in hydroponic farming systems will ensure that plants receive the nutrients they require to thrive optimally. Pitakphong [10] conducted a study using the Artificial Neural Network (ANN) to predict hydroponic growth potential. The ANN was created based on the data obtained from pH, water level, temperature, and light intensity. In another study, IoT in the pond can provide comfort and speed of growth for fish [11]. In addition to automating hydroponics with IoT technology, intelligent algorithms are required to provide follow-up on the input obtained. The role of machine technology is significant on IoT in automating plant growth [5, 12].

Several studies on smart monitoring hydroponics have been carried out. Patil et al. conducted research on a hydroponic monitoring system using IoT technology. They created a system that assists people in growing plants or crops by reducing the amount of water and nutrients used. They used the IoT to collect data every five minutes [13]. Shetty et al. also researched smart farming with a hydroponic system. They are, however, focused on developing a Fully Automatic Hydroponics system. In hydroponic techniques, the system aids monitoring and controlling temperature, humidity, and pH [14]. A study also focused on hydroponic monitoring and controlling the plant condition using IoT. Specifically, the system is designed by a specialized wireless sensor network that monitors the critical parameters for hydroponic [15]. Supriyanto and Fathurrahmani also conducted research on hydroponic plants. On the other hand, this research focused on developing a monitoring and controlling system for hydroponic plants. They also developed a smart greenhouse prototype to monitor hydroponics plant conditions such as water temperature, pH, nutrient condition, and water level [16]. Meanwhile, Loresco et al. conducted a study on lettuce plant segmentation in a smart farm hydroponics setup. To improve lettuce plant segmentation, they used a simple linear iterative clustering concept [17]. Furthermore, this study focused on monitoring nutrient content, pH condition, and temperature in the vegetable leaf using the deep flow technique in various hydroponic environments. For 26 days, the vegetable leaf growth was monitored, and the nutrient content, pH condition, and temperature were checked regularly.

The goal of this study is to create a hydroponic farming system that used IoT to monitor and control the quality of plant nutrition, pH condition, and temperature. The research method utilized a descriptive qualitative analysis to examine studies that have been studied for 30 days and had two treatments, namely indoor and outdoor. The nutritional content of plants can be used properly due to the use of IoT in agriculture, beginning with the pH content, plants (ppm), and temperature.

2. Literature Review

2.1. Urea - CO(NH2)2

Urea has the chemical formula of CO(NH2)2. Urea, as a fertilizer, is a high source of nitrogen. High nitrogen content is able to accelerate the growth of plants. This finding was proven by Liang which stated that the nitrogen content in urea facilitates the photosynthesis process, making the plant produces more chlorophyll than usual [18]. In addition, Nitrogen has a high contribution in agriculture [9]. Urea cycle occurs in plants to release Urea in the body through the reaction of ammonia, thereby reducing toxic substances in the body. The continuity process of the urea cycle is shown in Figure 1.

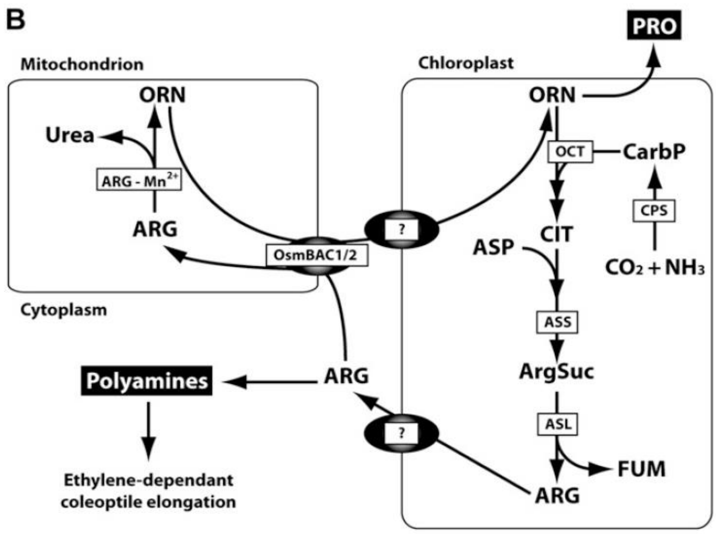

Figure 1. Urea Cycle in Plants [19].

Additionally, biochar-based urea fertilizer also helps support plant growth and reduces nitrogen leaching [20]. Biochar is a porous material that is rich in carbon and has many functional groups that have the potential to increase nutrient and water retention, soil fertility, as well as supports plant growth and agricultural yields [21]. However, the application of biochar in large quantities (more than 10 t ha-1) is less practical agronomic or economic value due to the absence of adequate Natrium, Phosphor, and Kalium [22].

2.2. NPK (Natrium, Phosphate, Kalium)

NPK fertilizer are generally used to balance macro and micro nutrients in the soil. It is due to the nature of NPK contains the most of the nutrients needed by plants, namely Sodium, Phosphor, and Kalium (Potassium). The N value in NPK stands for nitrogen, while the P and K values are represented by their oxide forms, namely P_2O_5 and K_2O (see Figure 2). The advantage of NPK is

that it can make the roots stronger and longer so that it is easy to absorb nutrients in the soil. In addition, NPK can also prevent plants from stunting, help improve seed quality, stimulates plant division, accelerate fruit ripening, strengthens plant stems, and enlarges cell tissue [23].

Nitrogen fertilizers include nitrogen compounds such as ammonium, nitrate, and urea. Nitrogen can be absorbed by plants as ammonium (NH4+) or nitrate (NO3) (Fig. 3). When charged particles are taken up by plant roots, the plant normally releases particles with the same charge in order to maintain a balanced pH. Under optimum crop production circumstances, nitrate is the primary type of nitrogen that plants absorb. Under aerobic circumstances, ammonium-based nitrogen fertilizers are transformed to nitrate bacteria, which emit hydrogen ions (H+). This H+ combines with hydroxide ions (OH), which are produced by plants during nitrate absorption. Overall, the impact on soil pH is near to neutral. Plants that take up nitrogen directly in the form of nitrate are referred to as nitrate nitrogen-based fertilizers. Nitrogen from urea is promptly degraded to ammonia.

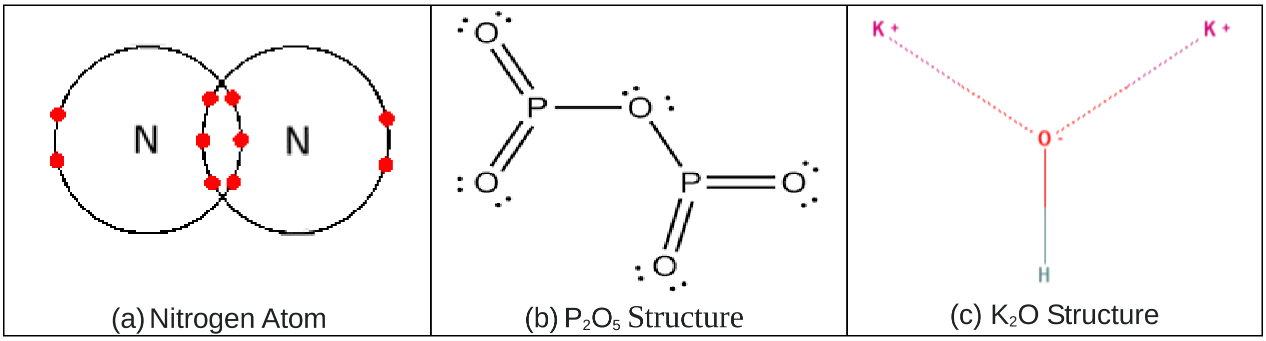

Figure 2. Chemical structure of NPK content.

As a result, it resembles ammonia-based nitrogen fertilizers. Overall, plants emit H+ ions, which lower pH in the rhizosphere when ammonium ions are taken up. When nitrate ions are taken up and increase the pH of the soil, an OH is released. Ammonium-based nitrogen fertilizers, on the other hand, are used in excess to replenish leached nitrates. As a result, the pH of the soil gradually drops over time. This can happen as a result of H+ buildup during the nitrification process [24].

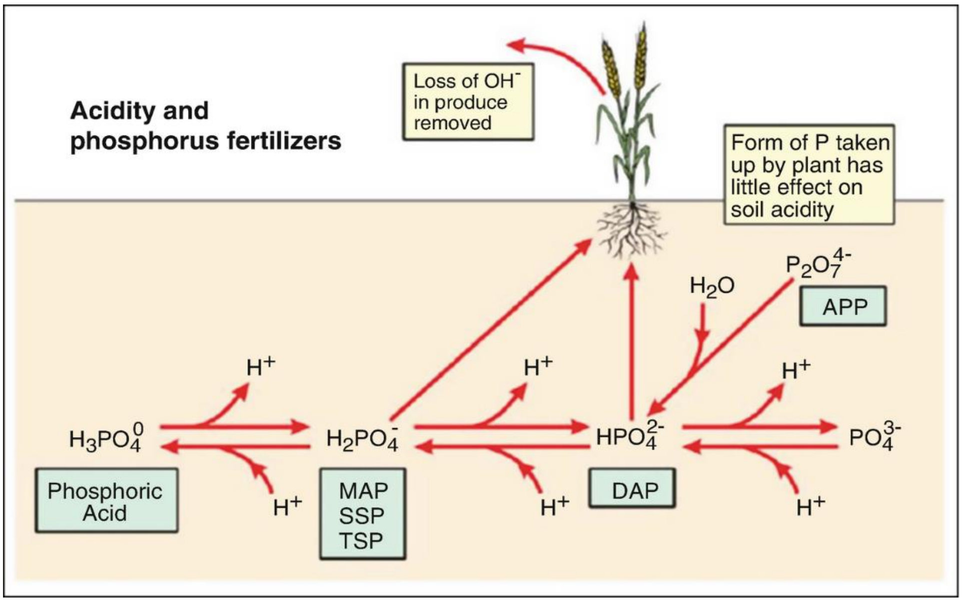

Figure 3. Phosphor reaction in plants. This figure was adopted from reference [25].

3. Method

The quantitative analysis of plant nutrient content measurements was used as the research method. The experiment lasted 26 days and included two different treatments, namely indoor and outdoor. We used several vegetable leaves (i.e. Bok Choy, Water Spinach, and Lettuce) as these plants are easy to grow, have a low risk of withering, and have a relatively short planting time until harvest (26 days).

The following is a flowchart of the monitoring system experiment that was carried out (see Figure 4). The first stage of the study involved providing plant nutrition by mixing and dissolving NPK and urea fertilizers in water. The solute fertilizer contained Nitrogen (16.6%), Phosphorus (16.6%), and Potassium (16.6%), as well as urea (50%). The fertilizer composition was gradually poured per 10 mL into the 26.5 L of hydroponic growing media. The IoT sensor sent the nutrient content of the plant to the web. The system maintained the content threshold of between 1200 and 1400 ppm.

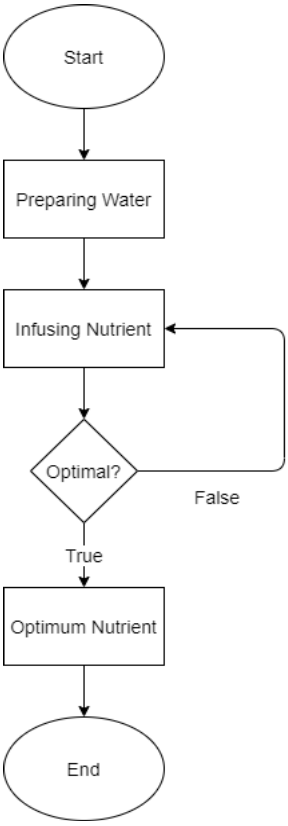

Figure 4. Different phosphate particles size samples.

Figure 4 depicts the initial experimental nutrition flow in hydroponic plants. If the content value displayed on the system is deemed deficient, then additions must be made to keep it according to the nutrient threshold levels required for plant growth. Nutrient values are monitored using IoT, paired with pH, temperature, and plant nutrient content sensors. An IoT architecture based on hydroponic growing media is shown in Figure 5. Figure 5 explains the architectural system consisting of four primary modules, namely Raspberry Pi, pH sensor (that measures the acid/alkaline levels of water), Total Dissolved Solid (TDS) sensor (that measures the concentration of water nutrients), and temperature sensor. All sensors were linked to relays and pumps. We also utilized the PHP language and HTML 5 on the web to present the data while creating the program

to control every input from the sensor and output. All sensors are arranged in a hydroponic smart system configuration. All data collected by the sensor will be forwarded to the Raspberry Pi. The Raspberry Pi then delivers the data from the sensor every minute. The data storage from Raspberry Pi is transmitted to Server using a Router. After that, the Raspberry Pi will send the sensor's value in JSON form to the Server through SQL to be stored in the database. Then, the database will transmit the data using SQL language to be accepted by PHP to be presented on the web, which farmers and citizens can access. The input data sent from the Raspberry Pi to the database will be filtered by a system built with the PHP programming language. The system will notify the web client if the input is less than or greater than the minimum or maximum limit. The notification contains information that the plant nutrition is not in accordance with the conditions for plant growth, and that special treatment is required to restore the plant's stability.

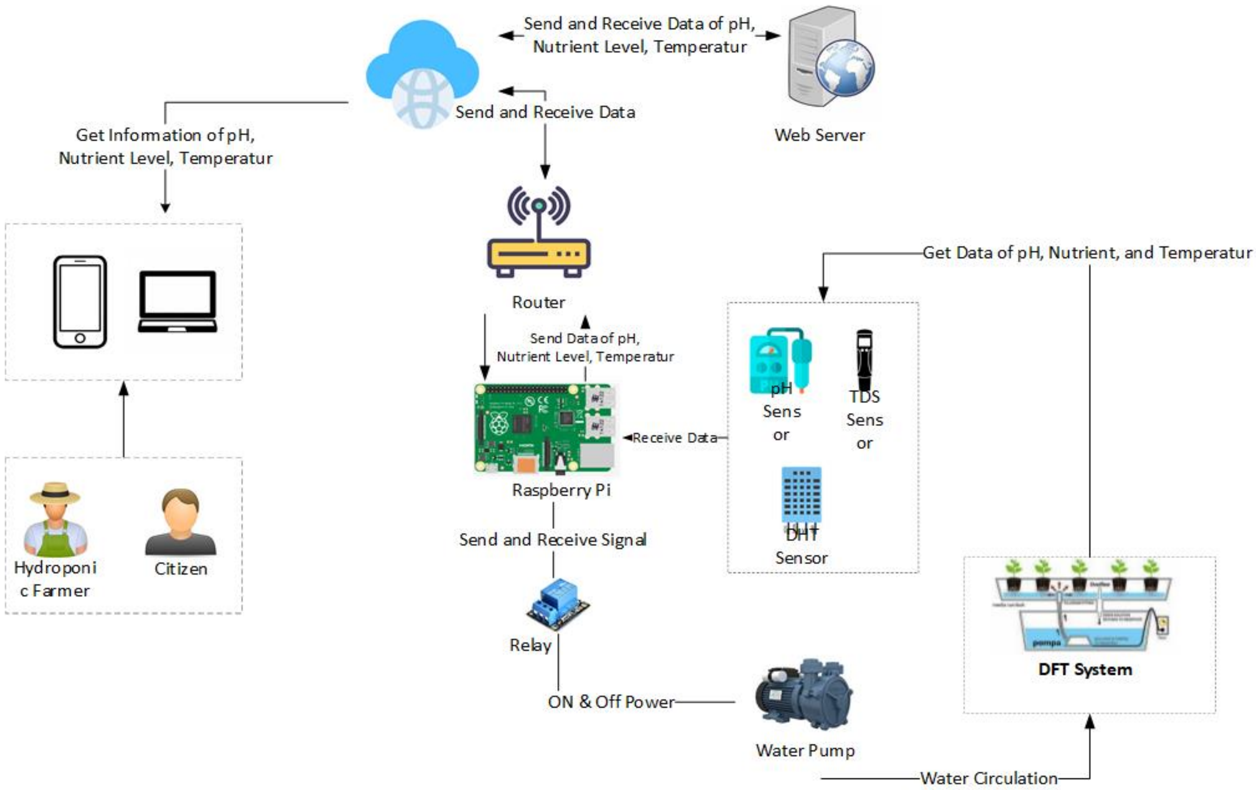

Figure 5. General IoT Architecture.

4. Results and Discussion

This research was conducted for 40 days. From the first day until the 14th days were the seeding process. From the 14th day to the 40th of the planting process. During the planting period, the average nutrient content value was obtained daily to keep it within the optimal nutrition scale, namely on a scale of 560-1400 ppm [26]. Table 1 shows the results of measuring the nutrient value of vegetable plants with indoor and outdoor treatments. In the indoor treatment, the first five days of plant nutrient content tended to be stable even though the nutrient value was low at the beginning of the measurement. However, it can be increased back to stable on the next day according to the plant's nutrient needs. The nutrient content then decreased from the sixth to the tenth day. Therefore, numerous attempts were made to increase the nutrient content to return to stability.

Table 1. Periodic Value of Vegetable Leaf Nutrient Content, pH, and temperature

Day after plant	Indoor			Outdoor		
	pH	**Nutrient Concentration (ppm)**	**Temperature**	**pH**	**Nutrient Concentration (ppm)**	**Temperature**
Day-1	6.71	678	28.20	6.82	646	28.00
Day-2	6.07	1310	29.30	6.79	656	25.80
Day-3	6.50	1260	26.90	6.65	696	27.40
Day-4	6.60	1210	28.70	7.75	740	29.90
Day-5	6.47	1310	27.00	7.17	746	26.10
Day-6	6.33	1290	29.80	7.22	946	28.20
Day-7	6.60	710	26.80	7.4	946	24.80
Day-8	6.60	710	26.80	6.91	1046	28.10
Day-9	6.86	671	27.70	6.82	1046	28.10
Day-10	6.86	671	27.70	7.01	1142	28.10
Day-11	7.70	703	28.50	7.22	1160	28.60
Day-12	7.70	703	28.50	6.82	1206	29.30
Day-13	7.40	234	28.20	6.79	1251	28.10
Day-14	7.80	1400	29.30	6.65	1284	28.60
Day-15	6.50	1410	26.90	7.75	1300	27.70
Day-16	6.79	1390	28.70	7.17	1650	25.30
Day-17	6.79	1390	26.70	7.22	1640	29.30
Day-18	6.82	1332	30.40	7.40	1440	26.40
Day-19	7.75	1300	27.70	7.74	1470	26.50
Day-20	7.70	1260	31.00	7.38	1500	25.30
Day-21	7.88	1360	28.90	7.25	1440	28.40
Day-22	7.30	1570	26.90	5.65	1440	26.50
Day-23	7.16	1640	27.10	7.25	1440	28.40
Day-24	7.11	1700	25.40	7.22	1300	24.80
Day-25	6.80	1400	28.90	6.82	1284	28.10
Day-26	6.43	1600	25.90	6.82	1640	28.10

As a result, the nutrient content returns to normal on the tenth day, and the plant's nutrient needs can be fulfilled. Meanwhile, the plant nutrients tend to be low in nutrient content in the outdoor treatment in the first ten days. However, the increase occurred on the eighth day and continued until it stabilized at levels >1000 ppm. In addition to the nutrient content of plants that ensures good growth, the degree of acidity (pH) was also measured periodically to ensure that the pH content of the water remains within the minimum and maximum limits. To maintain the degree of acidity in the water, the pH level of good water for vegetable plants varies from 6.5 to 9. Table 1 shows the pH value of water with indoor and outdoor hydroponic plants. In the indoor treatment, the value of the pH content fluctuated but was well maintained and within normal limits. The lowest and highest indoor pH values were recorded at 6.07 and 7.88, respectively.

It is the same as the outdoor treatment plants, which remained within the normal range with the lowest and highest pH values of 5.65 and 7.75, respectively. Although the lowest pH value was below the threshold, overall, the pH value remained stable and normal in the 26 days from planting to harvest.

The last parameter to be measured is the water temperature content. Water temperature is a benchmark for measuring the level of good water quality. A good water temperature in Indonesia ranges from 20 – 32°C [27-29]. Table 3 displays the value of measuring water temperature in Indoor and Outdoor. Thus, both temperatures are in accordance with the levels needed by plants to grow. In the indoor treatment, the lowest temperature was at 25.4°C, and the highest was at 31°C. Meanwhile, in the outdoor treatment, the lowest value was at 24.8°C, and the highest was at 29.9°C. The three measured parameters present a good value for leaf plant growth until they can be harvested with optimal results. The data for the measurement values of the three parameters are presented in graphical form to see fluctuations in their content values in Figures 6 - 8.

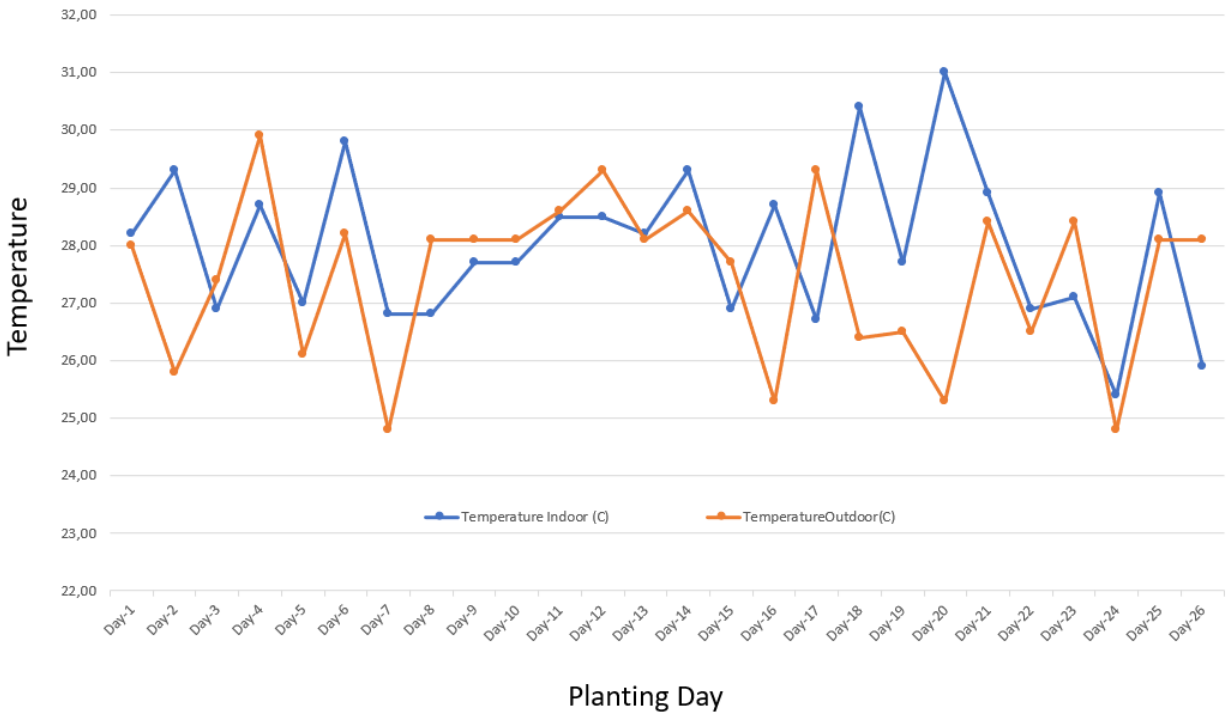

Figure 6. Temperature Monitoring Condition.

We planted bok choy, water spinach, and lettuce with two different treatments, indoor and outdoor, for 26 days. We planted about 40 Bok choy plants for each treatment. The number of bok choy plants that grew in the indoor treatment, on the other hand, was 38, while the number of plants that grew in the outdoor treatment was 32. It means that the success rates for bok choy planting were 95 and 80%, respectively. Water spinach was also planted for 26 days. In both treatments, we grow 20 water spinach plants.

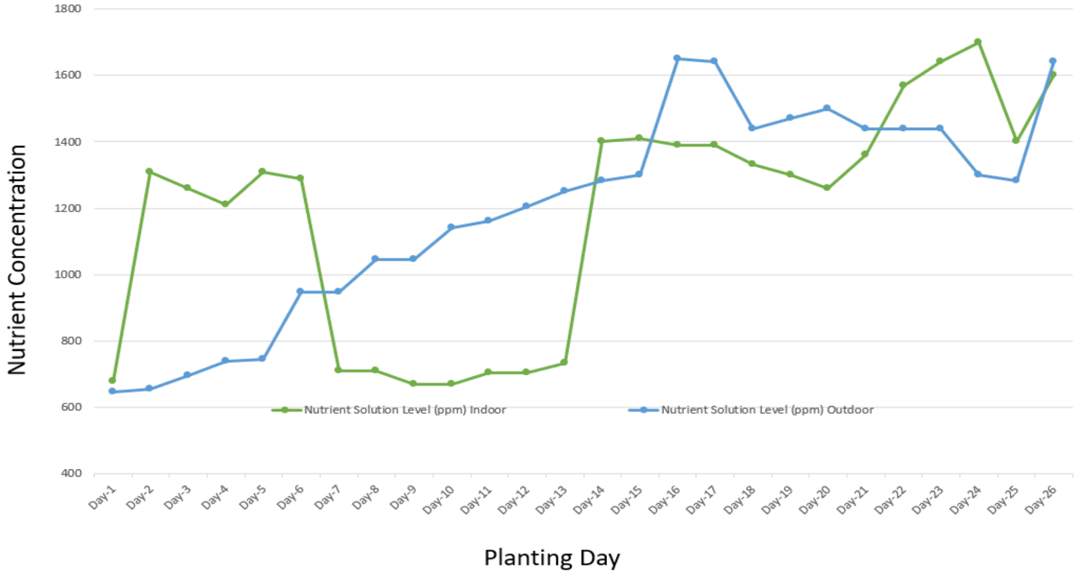

Figure 7. Nutrient Concentration Condition.

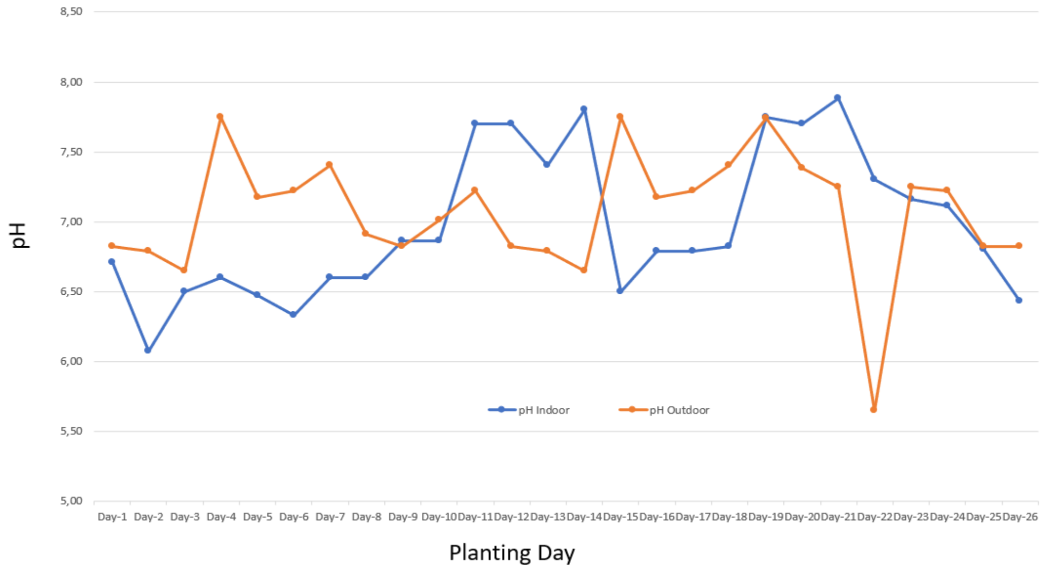

Figure 8. pH condition.

In both the indoor and outdoor treatments, 20 water spinach plants were grown. It means that the water spinach planting success rate is 100% [30]. We grew lettuce for about 20 in indoor and outdoor treatment. However, the number of lettuces that grew in the indoor treatment is 18, while the number of lettuces that grew in the outdoor treatment is 15, resulting in a percentage of planting success rate of 90 and 75%, respectively (See Table 2).

Table 2. Percentage of Vegetable Leaf Productivity output.

Plant	Planted Amount (Indoor)	Planted Amount (Outdoor)	Grow Amount (Indoor)	Grow Amount (Outdoor)	Percentage (Indoor)	Percentage (Outdoor)
Bok Choy	40	40	38	32	95%	80%
Water spinach	20	20	20	20	100%	100%
Lettuce	20	20	18	15	90%	75%

Figures 9 - 13 show vegetable leaf conditions in the treatment indoor and outdoor. Figures 9 and 10 present the growth of water spinach. Furthermore, Figure 11 shows bok choy growth conditions in the outdoor treatment, whereas Figures 12 and 13 display the growth of lettuce both in indoor and outdoor treatment. The application of this farming method is prospective for being applied for various plants, making it applicable for planting some herbs and medicine [31, 32]. This study also good for being applied in education that can create more development in science [33-38].

Fig. 9. Water spinach in indoor treatment.

Fig. 10. Water spinach growth condition in indoor treatment

Fig. 11. Bok choy growth in outdoor treatment.

Fig.12. Lettuce growth condition in indoor treatment.

Figure 13. Growth of lettuce in outdoor condition.

Conclusion

The study of particles sedimentation velocity of different particles size with and without flocculant shows that the flocculant has an important effect on particles less than a specific size of 125µm. Beyond this specific size the flocculant has no considerable effect on thickening. The particles larger than 125µm can decant by a simple free sedimentation without needing the flocculant. To achieve that, a hydrocyclone was dimensioned and modeled in order to eliminate this granulometric ranges which will undergo free sedimentation. This new developed hybrid technology (Thickener coupled Hydrocyclone) allows to target only fine particles overflow of the hydro-cyclone that require the addition of flocculant. In this study, the new developed process can reduce the consumption of flocculant by 50%.

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