Intelligent Monitoring and Controlling System for Hydroponics Precision Agriculture

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***Abstract*—Hydroponics agriculture comes up as a solution to limited agricultural land that can lead to a decline in agricultural production capacity. In Hydroponics agriculture, there is a challenge of precision agriculture, especially for some sensitive plants, e.g., bok choy and lettuce. These kinds of plants need a precise amount of nutrient and water every time to grow ideally. Internet-of-Things (IoT) is a technology that enables regular monitoring of every aspect of human life. It can be a solution to monitor the water and nutrition needs of the plants periodically. In this paper, we propose a monitoring and controlling system for hydroponics precision agriculture based on the IoT concept and Fuzzy logic. IoT is utilized to enable regular monitoring of plants nutrition and water needs, while fuzzy logic is used to control the supply of nutrition and water to the plants. The experiment result shows that the proposed system can produce better growth for lettuce and bok choy plants in terms of the size of leaves.**

***Keywords*— IoT, fuzzy logic, hydroponics, hydroculture**

I. INTRODUCTION

Agriculture is the most critical sector in Indonesia. With the population increasing every year, the availability of food is a necessity that must always be achieved by the agricultural industry. However, with the increasing development in Indonesia, a lot of agricultural lands is converted to non-agricultural uses such as the construction of housing complexes, industrial estates, trade zones and public facilities which will undoubtedly have a negative economic, social and environmental impact. This reduction in agricultural land will certainly also cause a decline in agricultural production capacity, thus making the government have to import agricultural products to meet domestic food needs.

Agricultural technology is proliferating in urban areas now. One solution that can be done by the community is to develop an agricultural system that can be done with limited land availability or commonly called urban farming or urban agriculture. Urban farming or urban agriculture is one of the practical solutions to overcome the reduction of agricultural land. Urban agriculture uses land that is not used in urban areas, such as roofs, balconies, patios, even on walls of buildings. One of the agricultural techniques used in urban farming is hydroponics [1].

Agricultural methods using hydroponics are one of the possible alternatives to be able to do agriculture even without extensive agricultural land [2]. Hydroponics comes from Greece, hydro means water, and ponous means work[3], [4]. Hydroponics is a method of planting plants without using soil media, but using a medium of water mixed with a mineral nutrient solution[5]. The advantage of hydroponic farming methods is that it does not require soil media with vast land for agriculture, but agriculture can be done in a narrow area with water media. Each hydroponic plant is also treated without using pesticides, so it is safer to consume[6].

Hydroponic farming methods need special treatment in controlling water temperature, water level, and acidity (pH) of nutrient solutions. To be able to produce plants that are good until the harvest period, they must carry out these treatments with regular checks every day[7]. Examinations carried out include checking the water content in the installation, the nutrients, the size of the PH, the temperature and humidity of the air, which must be under the dose. If the quantity of one of the elements is excess or lacking, it can result in the inhibition of plant growth. The maintenance that must be done routinely every day causes agriculture with hydroponic methods to be inefficient because it requires a considerable effort and requires high costs for maintenance.[8]. This, of course, automatically impacts the selling price of hydroponic plants that are expensive. Therefore, although the method of hydroponics is the solution to the current problem of limited land, the complexity of treatment is an obstacle in its implementation.

Based on the problems above, the researcher tried to overcome this by combining hydroponic farming methods, the IoT technology, and fuzzy logic to make a smart controlling that can automatically control plants nutrition and water needs. By utilizing internet of thing (IOT) technology, each sensor device can communicate or send data to a cloud server to be processed and monitored in real time [9]. Each sensor is connected to Arduino to control plant needs automatically using fuzzy logic. For example, electrical conductivity sensors (EC) will detect if the nutrient levels in the installation are reduced so that the control system will automatically add nutrients to the plant. The results of processing data from the cloud server will be beneficial information for farmers as an evaluation material to continue to improve their agriculture.

II. RELATED WORK

Paper [5] discuss the use of IoT using an Arduino microcontroller to control and analyze data from all connected devices and sensors. The IoT device used here is useful for monitoring humidity, the temperature of nutrient solution, air temperature, PH, and EC using an android application. In its application, the data from the sensor will be combined into one string then converted to JSON. The microcontroller will send the string to the server through MQTT Broker, namely a connectivity protocol for IoT. The evaluation is done only ensures that the system can function in automatic or manual mode, and verification that control via the mobile application is functioning correctly. The result of this journal is to imple-

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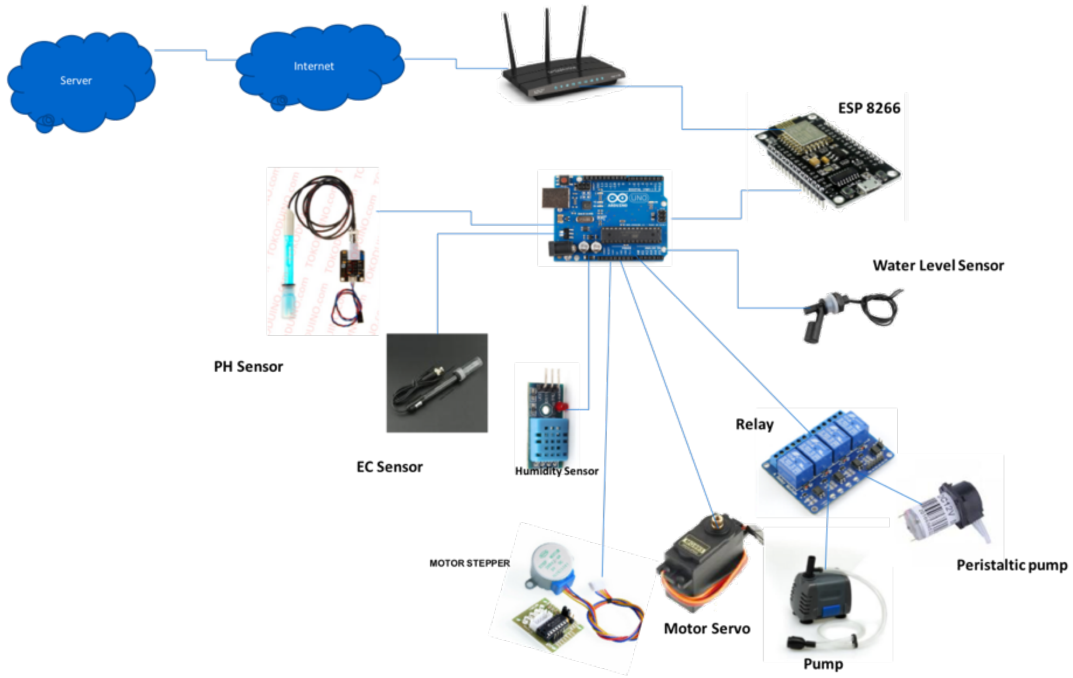


Fig. 1 System General Architecture

ment an Internet of Things for Smart Hydroponic Farming Ecosystem (HFE) that can help new farmers or people who want to have hydroponic farming but do not have time to manage and grow crops. In this study, the system can function appropriately in automatic or manual mode.

According to [3] The significant decline in agricultural land and the rapid development of hydroponic system technologies such as Nutrient Film Technique (NFT), has brought significant challenges to farmers. The hydroponic system is designed in the form of hydroponic farming management that can monitor water temperature, water level, a higher density of nutrient solution and acidity (pH) from nutrient solution using related sensors and connected to the microcontroller via the website. This system allows users to remotely control and monitor the plants. This research also utilizes solar panels that are converted into electricity as the primary source of energy to power all devices. Various sensors are installed to detect any changes in the physical or chemical environment. Each of these devices is connected to the network and can be accessed via the web using a browser. Changes in values that occur in the environment will be read by the sensor and will help the farmers to improve the effectiveness and efficiency of monitoring and controlling NFT Hydroponic Agriculture. The results of this study are the creation of a system that can help farmers or owners of hydroponic farming systems to maintain or create hydroponic farming systems by using hardware modules that are easily found in the market with the affordable prices.

Paper [10] also proposes the use of sensors as a Wireless Sensor Network System by sending data to the cloud and controlling values such as temperature, light, etc. Sensor technology is intended for specific mobile control devices. Application control uses the Blynk application where the application can control existing devices through the API provided by Blynk's control. The hardware used is NodeMCU used to implement monitoring modules. DHT11 sensor is a relatively inexpensive sensor to measure temperature and humidity, Soil Moisture Sensor (KG003) to measure soil moisture, Relay Board (5V) to switch AC / DC is used to trigger the AC motor (220V) to operate the valve, Ultrasonic Sensor Module (HC-SR04) includes ultrasonic transmitters, receivers, and circuits.

III. Proposed System Design

The system is designed to be able to monitor the nutrient and water needs of the plants. In general, we propose a system design based on the IoT concept and fuzzy logic to support the monitoring and controlling process, respectively. In this section, we discuss the design architecture, fuzzy logic design, and flowchart of the system

A. Design Architecture

As shown by Fig.1. The architecture of the system consists five major modules, i.e., ESP8266 microcontroller module, PH sensor module, EC sensor module, water level sensor that is connected to relay and pumps, and humidity sensor module design that is connected to a servo to open or close the paranet curtain. In designing the application to be able to control each input from the sensor and output to be carried out, the author also uses the C language which is compiled using esp-open-SDK toolchain via the Arduino IDE to write programs on the Arduino Uno microcontroller. Each input from the sensor will be read by Arduino Uno and then by using fuzzy logic to decide what to do. The microcontroller will read each value that will be sent by the sensor to be then analyzed, and a decision will be made. The microcontroller will connect to the server via an existing internet connection to store measurement data. There is four sensors used in this research, i.e., PH sensor, EC sensor, the water level sensor, and the humidity sensor [11].

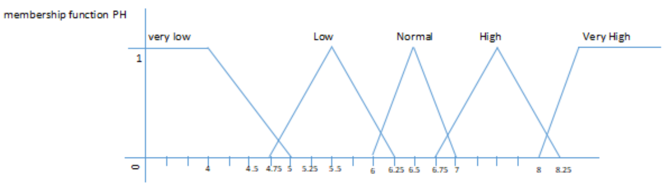


Fig. 2 The membership function of PH level

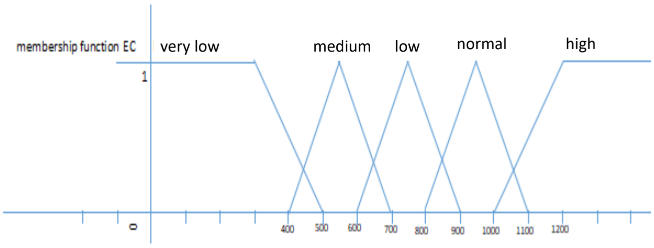


Fig. 3 The membership function of the EC level

B. Fuzzy Logic Design

Fuzzy Logic control in this system consists of four inputs from the sensor, namely the PH value, EC, water level, and air temperature that will be identified to the fuzzy set. fuzzy-logic membership functions are designed to produce fast reaction time for the control[4], the result of fuzzification will determine whether it enters the specified value for each sensor (PH, EC, Water Level, and temperature). The working principle here, the input value of the sensor will be compared with the range that has been determined, then the value will be processed by fuzzy logic control. The output parameters that will be carried out consist of the duration of time (long, medium, fast) to open the tap valve on the PH tube, nutrition, water and to order the servo to open or close the paranet curtain. This old, medium, the fast output value will be converted in seconds. For example, the PH readings on the fuzzification process plant are input from the PH sensor and the input from the water level in the installation which is then made into a fuzzy set into a fuzzy membership function. Fig. 2 shows the membership function of PH parameter level. The PH value is categorized as follow: very low (0-5), low (4.75-6.25), normal (6-7), high (6.75-8.25), very high (8-10). Fig. 3 shows the membership function of EC parameter level. The EC parameter is categorized as follow: very low (0-500), medium (400-700), low (600-900), normal (800-1100), high (1000-1200). The membership function category is decided based on the normal range of PH and EC for lettuce and bok choy plants[12].

For PH settings automatically in the form of a defined rule that will be controlled by fuzzy logic control. In this case, the set rules are to turn on the PH Up pump and PH Down pump according to the conditions of the PH value and water level. As shown by table 1, the following are the examples of rules that will be applied from a knowledge base:

- If (PH very low and V Waterless) Then Valve PH Up on the duration is moderate. Here if the PH condition is inferior and the water conditions are lacking, then the PH Up Faucet will be turned on in a medium duration.
- If (PH very low and V Water Many) Then Valve PH Up On Long duration. Here if the PH is very lacking and the water conditions are many, then the PH up tap will be turned on for a long time.
- If (PH high and V Waterless) Then Valve PH Down On fast duration. Here if the PH is high and the water conditions are lacking, then the tap will be turned on in a fast duration.

TABLE 1 KNOWLEDGE BASE OF PH SENSOR

PH / Water Level	Pump PH Up On		OFF	Pump PH down On	
	PH Very Low	PH Low	Normal	PH High	PH Very High
Low	medium	fast	stop	fast	medium
Normal	medium	medium	stop	medium	medium
High	long	medium	stop	medium	long

TABLE 2 KNOWLEDGEBASE OF EC SENSOR

EC / Water Level	Very Low	Medium	Low	Normal	High
Low	medium	fast	fast	stop	stop
Normal	long	Medium	fast	stop	stop
High	long	Medium	medium	stop	stop

TABLE 3 OUTPUT OF FUZZY PARAMETER

Output Parameter	**Duration**
Fast	0-3 second
Medium	3-5 second
Long	5-8 second

As shown by table 2, the following are the examples of rules that will be applied from a knowledge base:

- If the EC conditions are lacking and there are many water conditions, the TDS pump will be turned on for a long duration
- If the EC condition is not much and the water condition is lacking, the TDS pump will be turned on in a fast duration.
- If the EC conditions are lacking and the water condition is lacking, the TDS pump will be turned on in a fast duration

In this study, fuzzy logic was designed using Mamdani rules with the Center of Area (COA) method. Whereas, affirmation (defuzzification) for the universe is done by using eq. (1)

$$Z = \frac{\sum Z_j \mu(Z_j)}{\sum \mu(Z_j)} \tag{1}$$

Table 3 shows the output value of the above parameter is the duration of time to open the tap in the duration grouping.

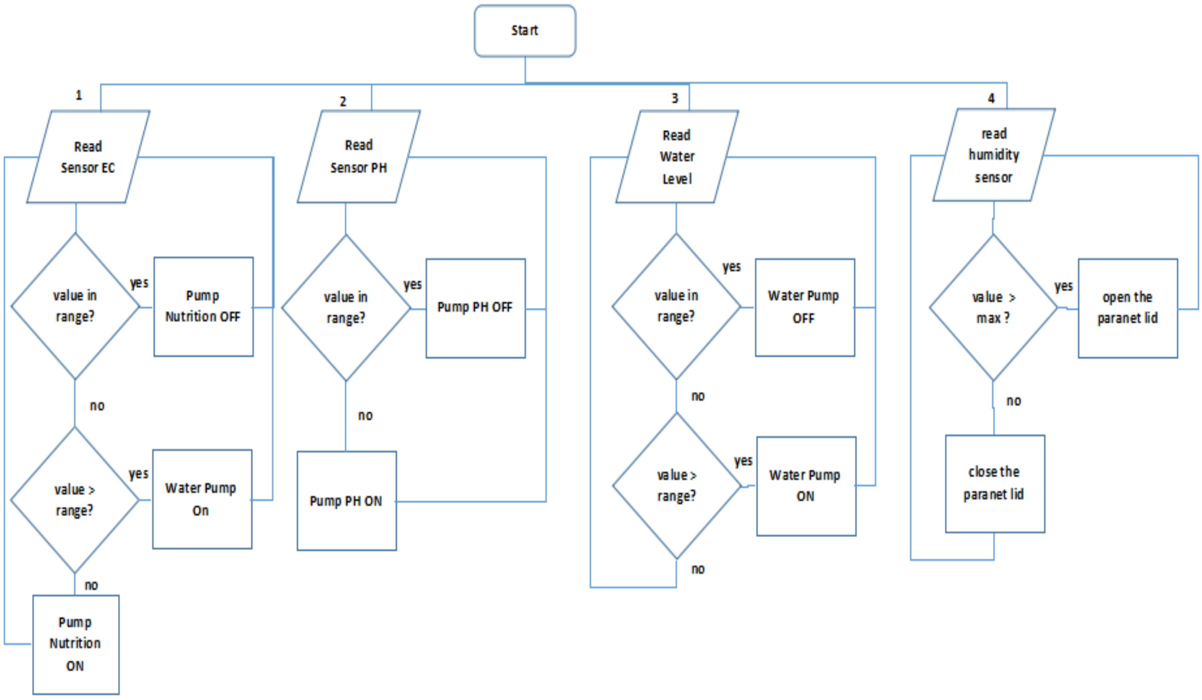


Fig. 4 Flowchart of the System

C. System flowchart

The system is working as defined by Fig. 4.. Following are the detail explanation of the flowchart :

1. The sensor reads the EC value. If the value in the range specified, then the valve position would be turned off. However, if the EC value outside the range, it will be checked whether it exceeds the specified range or not. If it exceeds the specified range, the system will turn on the pump to pump water from the water source to neutralize nutrients so as not to exceed the range. If the EC value is less than the specified range, the system will open the tap valve to drain nutrients at a specific time until the EC value returns in the specified range.
2. The sensor reads the PH value. If the PH value is outside the specified range, then the system will turn on the valve faucet to drain the liquid PH acid / PH base in order to return the PH value into the range. If the PH value is in range, then the system will close the tap valve.
3. The sensor reads the water level. If the water level outside the specified range, the system will open the tap valve to drain water from the water source into the installation tank. If the water level is within the specified range, the valve will be closed.
4. The sensor reads the air temperature value. If the air temperature exceeds the maximal temperature, then the system will instruct the servo to open the paranet curtain to protect the plant from sunlight. If the air temperature is below the specified limit, the system will order the servo to close the paranet curtain.

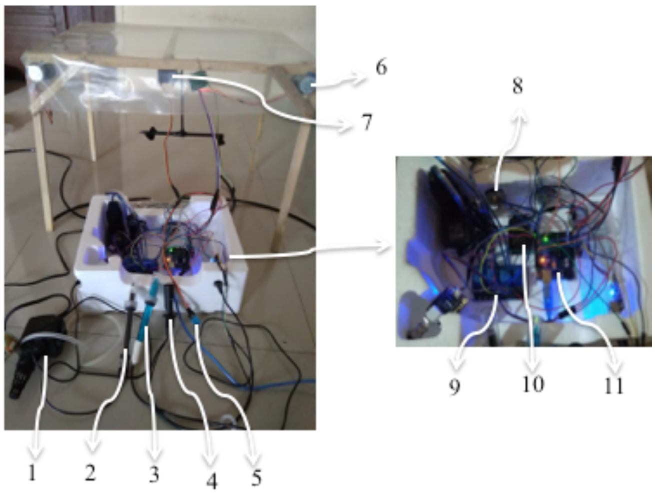


Fig. 5 System Implementation

IV. Results And Discussion

In this section, we discuss system implementation and evaluation. The evaluation includes the fuzzy logic evaluation and the evaluation of plants growth.

A. System Implementation

The system implementation of intelligent monitoring and controlling system is shown by Fig. 5 The tools arranged in a cork container to make it easier to move and secure from splashing water when it rains. The design consists of several parts; there are:

1. PH sensor that used to measure the PH value of the installation if it is in the normal range
2. EC sensor that is a sensor used to measure the nutritional value of the installation every 3 (three) hours, if the EC

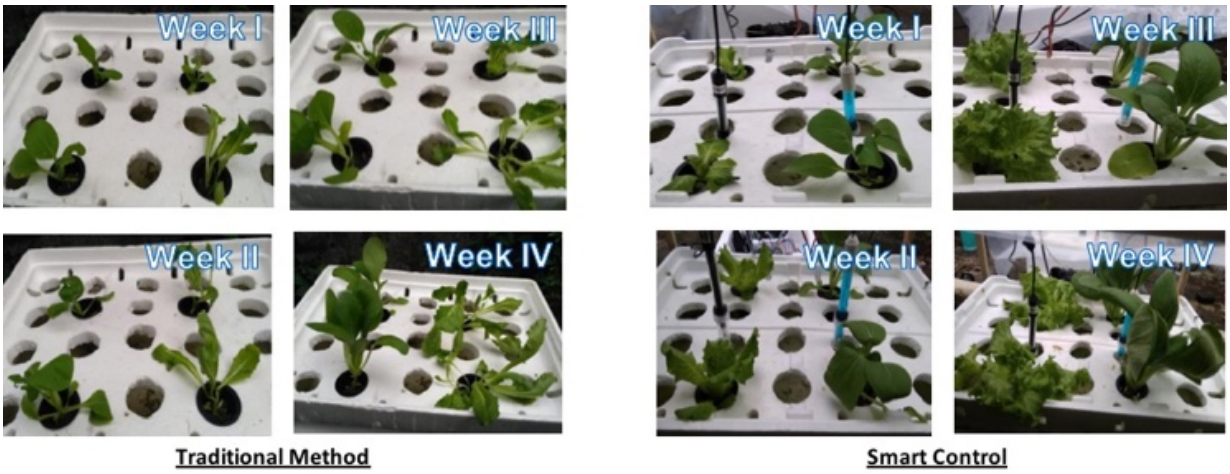


Fig. 6 Plant Growth Comparison of Traditional Method and Smart Control

condition is below the normal range value (800-1000), the system will instruct the relay to turn on the pump according to the duration of fuzzy logic.

3. Water level sensor that is designed like a water float will automatically check every 1 hour and will turn on the pump when the water conditions in the installation are reduced.
4. Humidity sensor to measure air temperature in the system installation every 1 hour.
5. Stepper motor to open and close the paranet curtain.
6. Because the PH sensor and EC sensor are sensors for lab needs that cannot stand if soaked for a long time, so researcher used an MG995 servo motor to be used as a robot arm to dip the PH sensor and EC sensor into the installation water when going to take measurements of PH and EC.
7. The peristaltic pump used to enter liquid nutrients and PH fluids into plant installations. The duration of the pump is to pump liquid nutrients and liquid PH into the installation depending on the results of the fuzzy logic output given until the PH value and EC value return to normal conditions.
8. Relay function is as a switch to turn the pumps and peristaltic pumps.
9. ESP 8266 functions as wifi for Arduino to send measurement data to each sensor and actions taken to the web server. The esp8266 module can communicate to the web server as long as it is connected to an internet modem.
10. Arduino Uno functions as a microcontroller that regulates the work of the smart control system.

B. *Evaluation of Plants Growth*

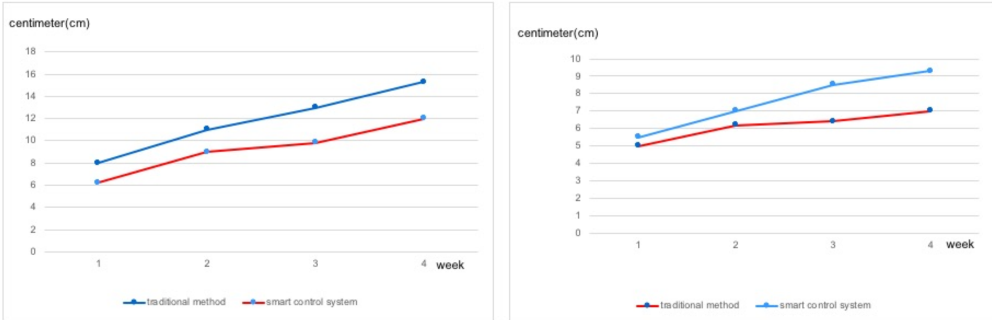
After a series of tests carried out both on the sensor and the smart controlling system as a whole part according to the desired scenario, the researcher begins to conduct experiments on applying this smart controlling system to plants directly. In this experiment, the researcher compared two installations, the first installation was a hydroponic planting, which was controlled manually every 3 (three) days, and the second is installation controlled using a proposed system. The plants planted in these two installations are lettuce and bok choy.

Then to evaluate the system performance, the researcher measured leaf length and width on both installations every three days. To facilitate measurement, the researcher only measured the oldest length and width of leaves of each installation pot. The results of plant measurements on the two plant installations shown on the graphic to make it easier to see the comparison of the increase in plant growth in each installation.

Fig. 6 is a comparison of traditional methods with a smart controlling system can be read from the results of the graphs and images. The results of research using smart controlling systems show growth in lettuce plants better. The results can be seen from the growth of leaf length and width (see Fig. 7 and Fig. 8). This result is different from the results of using the traditional method, the lettuce plant growth leaves are longer, but the leaves are not wide, so these results indicate the growth of lettuce plants is not too good. In bok choy plants, the results of smart controlling systems show better width and length of leaves and plant height. In traditional methods, bok choy plants grow more slowly.

For planting using the traditional method is done every three days to check the value of the nutritional content and pH of the plant installation. If the measurement results are not within the specified range, they will be added manually until the nutritional value and pH of the plant are within the specified range. The results of manually measuring the nutritional and pH content of plants are certainly not too efficient because they have to check every three days continuously and sometimes forget it. Then this method manually also does not guarantee the condition of the value of nutrients and pH in the installation is in the desired range because in a short time many factors can change the value suddenly like the weather factor. As for the smart controlling system, the system will automatically measure the value of the nutrient content and pH according to the time specified then the system will adjust the value of the nutrient content and pH to always be within the desired range.

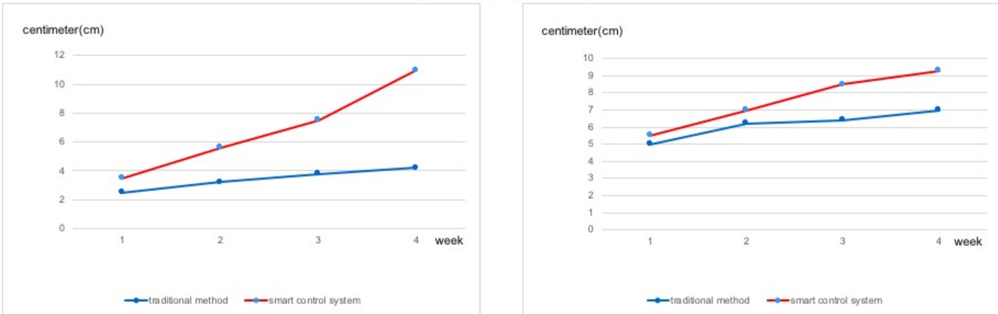
Leafs Length Comparison



Lettuce plants **Bok Choy plants**

Fig. 7 Leafs Length Comparison

Leafs Width Comparison



Lettuce Plants **Bok Choy Plants**

Fig. 8 Leafs Width Comparison

V. CONCLUSION

In this paper, we have proposed a smart monitoring and controlling system for hydroponics plants using IoT technology and Fuzzy logic. The IoT technology is used to monitor the water and nutrition needs of the plants, while the fuzzy logic is designed to control the supply of water and nutrition precisely. The experiment results with lettuce and bok choy plant shows that the hydroponics that was planted with proposed method grows better than the one planted with traditional manual method. It is validated through the visual look of the plants and measured leaf length and width for 4 weeks.

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REFERENCES

[1] D. Yolanda, H. Hindersah, F. Hadiatna, and M. A. Triawan, "Implementation of Real-Time Fuzzy logic control for NFT-based hydroponic system on Internet of Things environment," in *2016 6th International Conference on System Engineering and Technology (ICSET)*, 2016, pp. 153–159.

[2] N. N. Cometti, D. M. Bremenkamp, K. Galon, L. R. Hell, and M. F. Zanotelli, "Cooling and concentration of nutrient solution in hydroponic lettuce crop," *Hortic. Bras.*, vol. 31, no. 2, pp. 287–292, Jun. 2013.

[3] P. N. Crisnapati, I. N. K. Wardana, I. K. A. A. Aryanto, and A. Hermawan, "Hommons: Hydroponic management and monitoring system for an IOT based NFT farm using web technology," *2017 5th Int. Conf. Cyber IT Serv. Manag. CITSM 2017*, 2017.

[4] . M. D. S., "A Review on Plant without Soil-Hi A review on plant without soil-hydroponics," *Int. J. Res. Eng. Technol.*, vol. 02, no. 03, pp. 299–304, 2015.

[5] S. Ruengittinun, S. Phongsamsuan, and P. Sureeratanakorn, "Applied internet of thing for smart hydroponic farming ecosystem (HFE)," *Ubi-Media 2017 - Proc. 10th Int. Conf. Ubi-Media Comput. Work. with 4th Int. Work. Adv. E-Learning 1st Int. Work. Multimed. IoT Networks, Syst. Appl.*, 2017.

[6] P. K. Wahome, T. O. Oseni, M. T. Masarirambi, and V. D. Shongwe, "Effects of different hydroponics systems and growing media on the vegetative growth, yield and cut flower quality of gypsophila (Gypsophila paniculata L.)," *World J. Agric. Sci.*, vol. 7, no. 6, pp. 692–698, 2011.

[7] S. Charumathi, R. M. Kaviya, R. Manisha, and P. Dhivya, "Optimization and Control of Hydroponics Agriculture using IOT," *Asian J. Appl. Sci. Technol.*, vol. 1, no. 2, pp. 96–98, 2017.

[8] R. Lochan Mishra, P. Jain, and M. E. Student, "Design and Implementation of Automatic Hydroponics System using ARM Processor," *Int. J. Adv. Res. Electr. Electron. Instrum. Eng. (An ISO*, vol. 3297, 2007.

[9] M. U. Farooq, M. Waseem, S. Mazhar, A. Khairi, and T. Kamal, "A Review on Internet of Things (IoT)."

[10] J. Pitakphongmetha, N. Boonnam, S. Wongkoon, T. Horanont, D. Somkiadcharoen, and J. Prapakornpilai, "Internet of things for planting in smart farm hydroponics style," *20th Int. Comput. Sci. Eng. Conf. Smart Ubiquitous Comput. Knowledge, ICSEC 2016*, no. December, 2017.

[11] M. Manju, V. Karthik, S. Hariharan, and B. Sreekar, "Real-time monitoring of the environmental parameters of an aquaponic system based on Internet of Things," in *2017 Third International Conference on Science Technology Engineering & Management (ICONSTEM)*, 2017, pp. 943–948.

[12] D. S. Domingues, H. W. Takahashi, C. A. P. Camara, and S. L. Nixdorf, "Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production," *Comput. Electron. Agric.*, vol. 84, pp. 53–61, 2012.