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Portable automatic nutrient mixing based on microcontroller for hydroponic vegetable cultivation

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Abstract. The growth of the hydroponic vegetable cultivation industry has become the main focus in meeting increasing food needs. However, proper and consistent nutritional management is necessary to achieve optimal results in hydroponic cultivation. This research describes the design of a microcontroller-based portable automatic nutrient mixing system designed to simplify and increase the efficiency of hydroponic vegetable cultivation. This system uses a microcontroller as the system's brain to regulate nutrient concentrations automatically. The nutrients needed for hydroponic plants, such as liquid fertilizer, humic acid, and macro-micro nutrients, can be measured and mixed according to predetermined parameters. The success of this system is supported by the EC (Conductive Capability) sensors integrated into the system. The advantage of this nutrient mixing system is its portability, which allows users to organize hydroponic vegetable cultivation in various locations without significant limitations. The system can also be monitored and controlled remotely via a mobile app or computer, allowing users to control their plants' nutrition even when they are away. Experimental results show that this system can produce a consistent nutrient mixture that meets the needs of hydroponic plants. Thus, this microcontroller-based portable automatic nutrient mixing system can effectively support the sustainable and efficient growth of the hydroponic vegetable cultivation industry.

1. Introduction

Indonesia, as one of the largest agricultural countries in the world, has enormous agricultural potential. The agricultural sector significantly contributes to the country's economy and provides livelihoods for a large part of the population. However, various challenges occur, both in the form of climate fluctuations, reduced agricultural land, decreased soil quality, and the need to increase productivity and efficiency in agriculture. BBC analysis found that maximum temperatures rose by 0.5°C over the past few decades compared to the long-term average from 1980 to 2009[1]. The area of Indonesian rice fields in 2013 was 8,128,499 hectares; in 2015, it was 8,087,393 hectares and will continue to decrease yearly [2]. On people's plantation lands, management methods that result in conventional soil damage occur more quickly [3]. In Indonesia, smallholder plantation land reaches 64.8% of the total national plantation area, 26.5 million ha [4]. Soil damage on large private and state plantations is more controlled than on community plantations because there is easier access to labor supplies, nutrient inputs and capital sources [5].

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Technological developments in the agricultural sector have now grown rapidly from year to year. Hydroponics is a method of planting that uses air as a nutrient medium, which plants will directly absorb to support plant growth [6]. The hydroponic planting method was developed in Indonesia in 1980. In recent years, interest in hydroponics in Indonesia has increased, with many farmers and entrepreneurs adopting this method to increase productivity and efficiency in the agricultural sector. Smart Farming is an Internet of Things (IoT) application for growing crops that can save labor and resources [7]. Smart farming can help farmers make wise decisions based on data obtained through sensors and data management software. This data can be used to monitor and predict plant conditions, optimize resources, and improve overall production performance. By applying Smart Farming technology to hydroponic planting methods, such as the Internet of Things (IoT), big data processing, predictive analysis, and artificial intelligence (AI), productivity, efficiency and sustainability in agricultural production will be increased.

The advantages of the hydroponic system include more efficient land use, plants are produced without using soil, there is no risk of continuous planting throughout the year, the quantity and quality of production are higher and cleaner, the use of fertilizer and air is more efficient, the planting period is shorter, and Pest and disease control is easier. However, despite the many advantages, there are several disadvantages of the hydroponic system, including requiring a large amount of capital and requiring extra attention because farmers have to control nutrition and air pH levels continuously or periodically from time to time. Skills are needed to implement the hydroponic system, from the seeding process, sowing, and applying fertilizer according to what has been determined to care according to the plant characteristics.

Along with technological developments, there is a need to develop tools that use Smart Farming. Automatic Nutrition Mixing technology innovation can be an effort to overcome the shortcomings of the hydroponic system. Automatic Nutrient Mixing makes it possible to increase production effectiveness and efficiency by collaborating between the Internet of Things (IoT), Big Data Processing (Big Data) and predictive analysis technologies. It will produce a tool with a sophisticated automation system that can design the right and accurate nutrient mixture according to the needs of plants in a hydroponic system so that plants planted in a hydroponic system will grow well and have the potential to produce abundant harvests. Apart from that, this tool can also increase efficiency in using resources such as air and fertilizer in a more measured manner and avoiding waste and damage to environmental quality due to excessive fertilizer use. The addition of IoT (Internet of Things) in real-time aims to monitor the level of air in the box and availability of fertilizer, calculate the flow of fertilizer used and check ppm levels in the air, which are detected by sensors as process status on the Automatic Nutrition Mixing tool. It is hoped that this research can be a solution to overcome the shortcomings of the hydroponic system and increase productivity and efficiency in farming while supporting the development of technology in the agricultural sector.

2. Related Work

As an agricultural country, Indonesia is a upper-middle country with a population of around 278,696,200 people, and the availability of existing food needs must follow this number. However, the lack of food is currently due to the decreasing agricultural land in both rural and urban areas. In rural areas, the concentration of land ownership in the hands of the elite is one of the factors that make it difficult for agriculture to develop. Meanwhile, high and accelerated development in urban areas has resulted in large-scale land conversion [8]. The threat of a food crisis demands increased agricultural production, which cannot be met if we survive only with conventional agriculture. The involvement of advanced technology is very necessary to overcome these big challenges. One concept of using advanced agriculture technology is smart farming or Smart Farming 4.0.

Smart farming is a technology and innovation-based agricultural management by utilizing agricultural machines and equipment (agricultural tools and devices) and digital technology in the agricultural sector to increase productivity, added value, competitiveness and profits sustainably [9].

This agricultural system is an evolution of precision agriculture, which aims to increase the quality and quantity of agricultural products and optimize the use of labor [10]. Smart farming uses data collected through sensor systems, drones and remote sensing, a precision agricultural innovation to improve the accuracy of farming business management [11].

Hydroponics is an agricultural activity carried out using water as a medium to replace soil. So, the hydroponic farming system can utilize narrow land. Hydroponic cultivation is a method without using soil media but using water/nutrient mineral solutions plants need [12].

Some of the advantages of hydroponic cultivation:
1. Vegetables are grown without direct contact with the soil, so the results are cleaner and healthier
2. Pests and diseases rarely attack vegetables, and the nutrients disbursed are the nutrients needed by the plants
3. Does not require a large area of land
4. Has a high selling value.
5. Vegetable harvests can be used immediately fresh.

Based on the advantages of hydroponics, people can increase their income by utilizing their home gardens. Apart from that, the commodities produced have high economic value and meet health standards. The Internet of Things, often called IoT, is an idea where all things in the world can communicate as part of a unified system that uses the Internet network as a link [13]. IoT works by utilizing a programming argument. Each argument command will result in an interaction between machine and machine that is connected automatically without human intervention and is not limited by distance. The internet becomes a link for interaction between the two machines, while the human's job is to control and supervise the tool's work directly[14].

3. System Design

3.1 Hardware Design

Automatic Nutrition Mixing (AN-Mix) consists of three main components: control system components and tool framework, which are integrated with the IoT system. AB mix uses a frame made of hollow iron with dimensions of 125 cm x 25 cm x 100 cm. In the AB mix, there are two reservoirs for Nutrition A and Nutrition B, with a capacity of 3 liters each. In each reservoir, there is a 12v submersible pump, which is used to stir the nutrients so that the nutrients can be mixed perfectly. In nutrient reservoirs A and B, there is a 12v pump that supplies nutrient storage to the mixing tank. This tool has several sensors, such as a flow sensor, to regulate the nutrient flow entered into the mixing tank. Furthermore, a TDS meter sensor is used to measure the density of water in the nutrient mixture and a water level sensor to keep the water and nutrient levels above normal limits so that sufficient water and nutrients enter the plants. The control system uses the Arduino Mega2560 built-in ESP8266 microcontroller, which will be integrated using IoT in the mobile application.

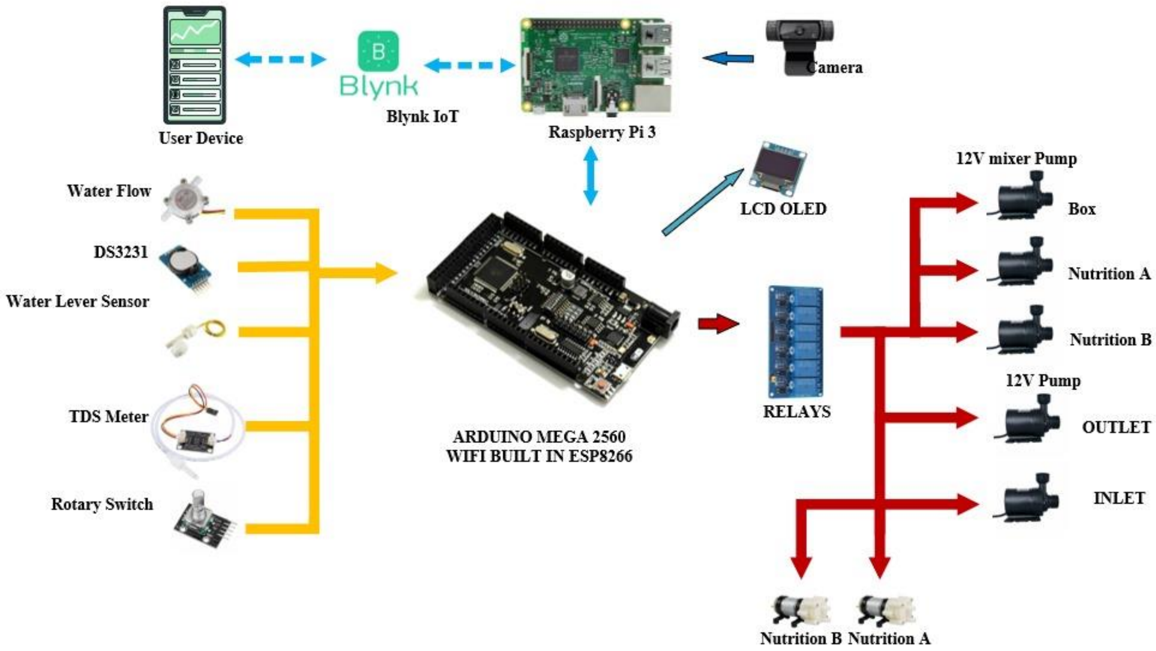

Figure 1. Block Diagram System

3.2 Software Design

There are three kinds of programming for the monitoring system: Python programming for raspberries, Arduino IDE programming, and Android programming for mobile-device-based programming. First, the Raspberry Pi will check the internet connection by pinging Google. If an internet connection is detected, raspberry will access the NTP server time data (GMT+7). Environmental condition data such as light intensity, temperature, air humidity, soil moisture, and image data will be sent to the database every 1 minute. In addition, the Raspberry Pi device will read planting data every 06.00 and 15.00 from the database. If there is a difference between the data and the previous data, raspberry will send the planting data to the ATMega2560 microcontroller. ATMega2560 will save the data to EEPROM. Figure 3 is a flowchart of Raspberry Pi programming. The device is also reset every midnight to avoid errors caused by full memory. Figure 2 is a user-friendly GUI display displaying sensor and cropping data on the panel.

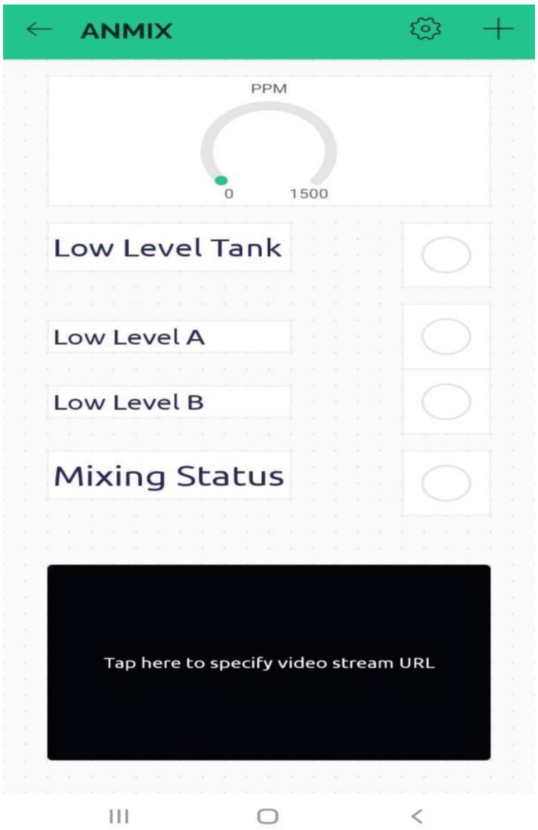

Figure 2. Application Display

The working principle of Automatic Nutrition Mixing is as a control system in NFT hydroponic planting, where the raw water entering the Automatic Nutrition Mixing holding box will automatically mix nutrients A and B until it reaches a predetermined water density. The density of the water is read using a TDS meter sensor connected to a microcontroller so that the density data is read. When the water density is below the target, Automatic Nutrition Mixing will automatically first stir the nutrient A and B reservoirs using a 12v aquarium pump, which will then be put into the storage box alternately. The nutrients are pumped using a 12 v pump where the incoming nutrient flow rate will be read by a flow sensor, which is then processed by a microcontroller to enter nutrients at a predetermined dose. Then, the stirrer pump in the storage box will turn on to mix the nutrients and water, which will then Check the density of the water again using a TDS meter. Then, if it is still insufficient, the microcontroller will process the water density data and order another nutrient-filling pump to the box to pump nutrients until the water density is met. If this is fulfilled, the 12 v aquarium pump will turn on to distribute water to the NFT hydroponics. The tool workflow is depicted in Figure 3.

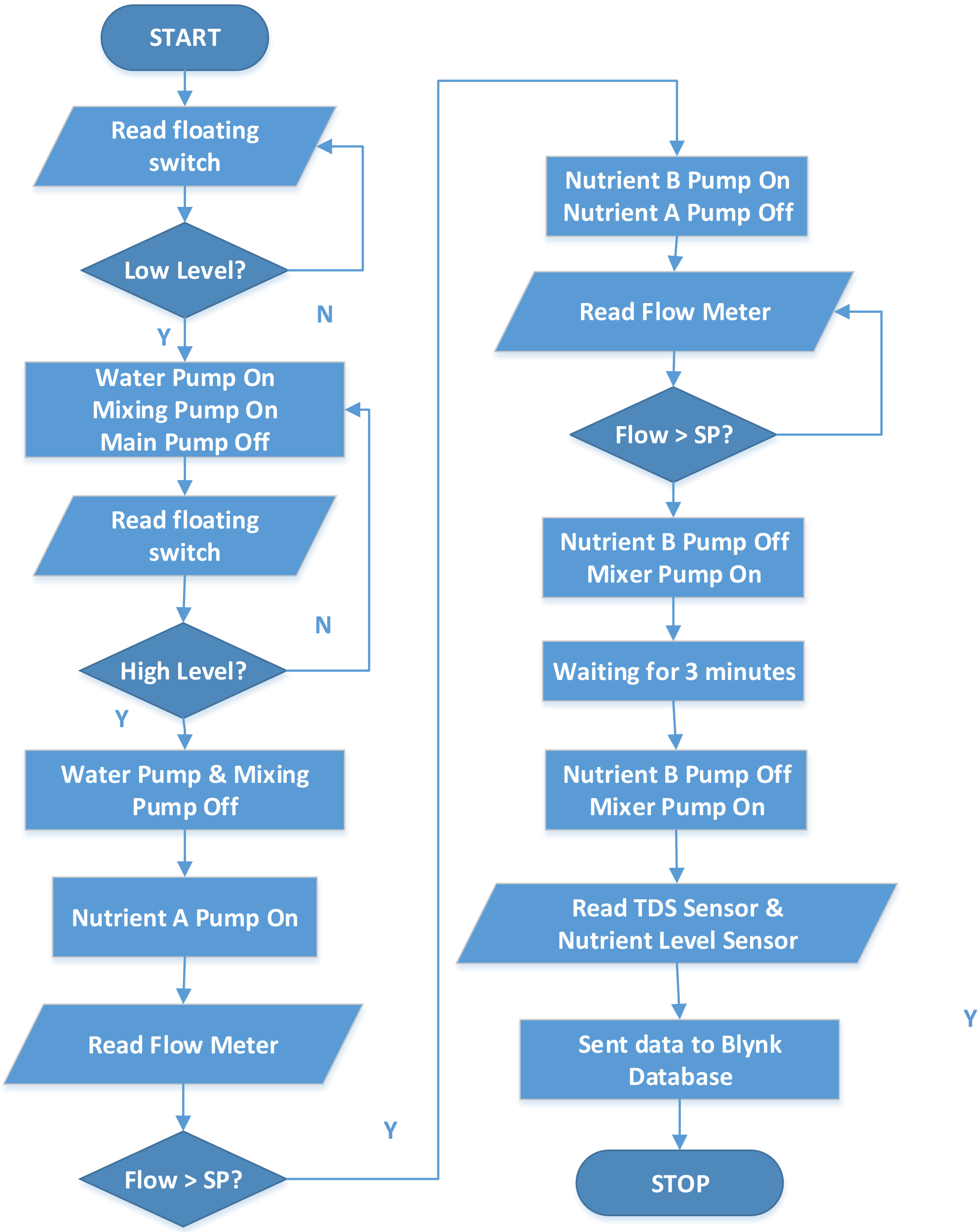

Figure 3. Flowchart system

4. Result and Discussion

4.1. AN Mix Realization

The entire device is shown in Figure 4. All devices are placed on a panel made of ABS. The panel has a 5volt 10A Switching adapter as a power supply for the Raspberry Pi and ATMega2560 microcontroller. The panel is equipped with a fan to maintain air circulation inside the panel to prevent errors due to overheating.

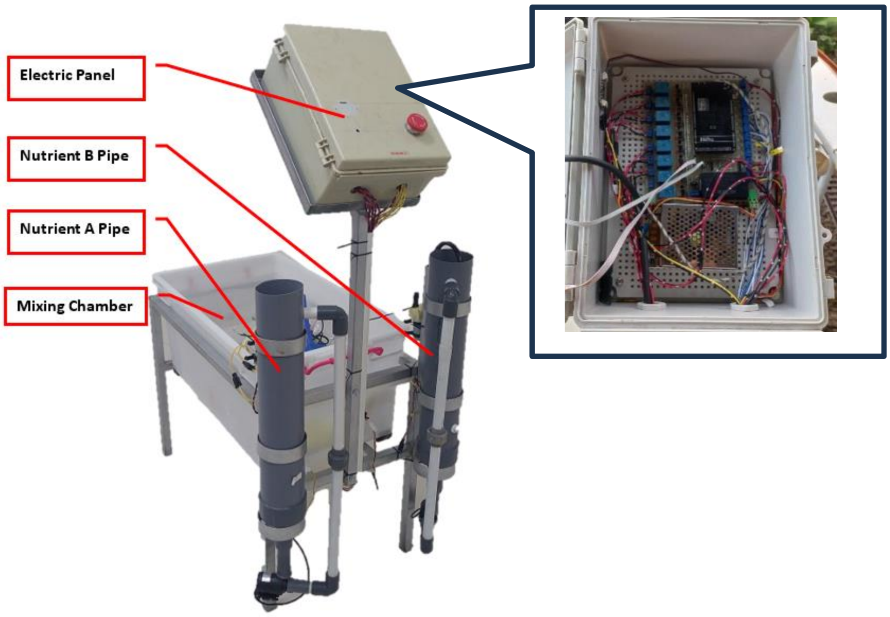

Figure 4. AN-Mix device

4.2. Testing result
Based on the Water Flow Sensor YF-S401 datasheet, 1 liter of water requires 5880 pulses with a duty ratio of 50%. So, 1 mL of water takes 5.88 ~ 6 pulses. Interrupt pins are used for flow sensor pulse counting. The concentration is a mixture of 500 grams of nutrients dissolved in 1 liter of water. Based on this data, with a mixing chamber capacity of 60 liters, the following formula is used to produce a certain PPM value:

$$Pulse_{Flow} = (SetPoint\_PPM / 1000ppm * 5mL/L) * 60L * 6pulse/mL \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Table 1 On-line Data Connection Test

No	Parameter	Controller	Blynk
1	Low Level Sensor Nutrient A	On	On
2	Low Level Sensor Nutrient A	Off	Off
3	Low Level Sensor Nutrient B	On	On
4	Low Level Sensor Nutrient B	Off	Off
5	Low Level Sensor Mixing Chamber	On	On
6	Low Level Sensor Mixing Chamber	Off	Off
7	TDS Sensor	835	835

Video streaming from the Raspberry Pi to the Blynk app requires several configuration and integration steps. The first is Raspi's access to the Pi camera. Next is the server configuration for streaming. To be accessed online, the Zerotier facility is used. ZeroTier is a peer-to-peer (P2P) virtual private network that makes it possible to create virtual private networks. Figure 5 measures the PPM value in the mixing tank from the AN Mix processing results. It can be seen that the PWM set point on the tool is 853, and the nutrient solution produced is 858 PPM. It can be seen that the results of mixing nutrients based on the expert system embedded in the controller provide results that are almost similar to the manual mixing process. Figure 6 is a photo of the online monitoring application. The condition of the level switches in nutrient reservoirs A and B, mixing tanks, PPM values and plant images can be accessed via the application.

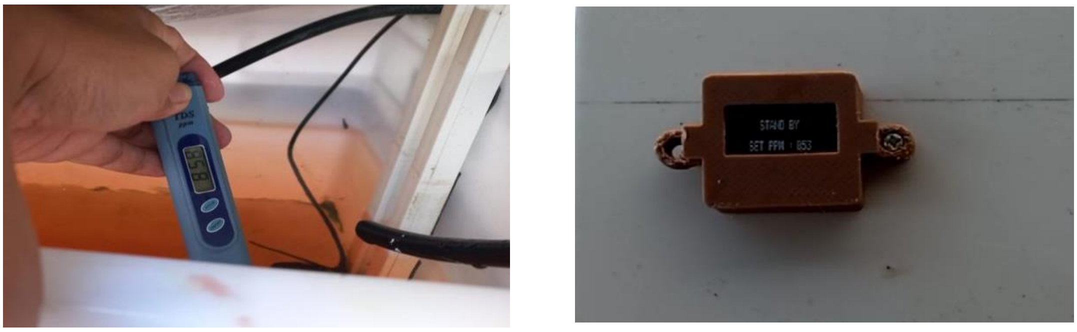

Figure 5. AN-Mix nutrient mixing result

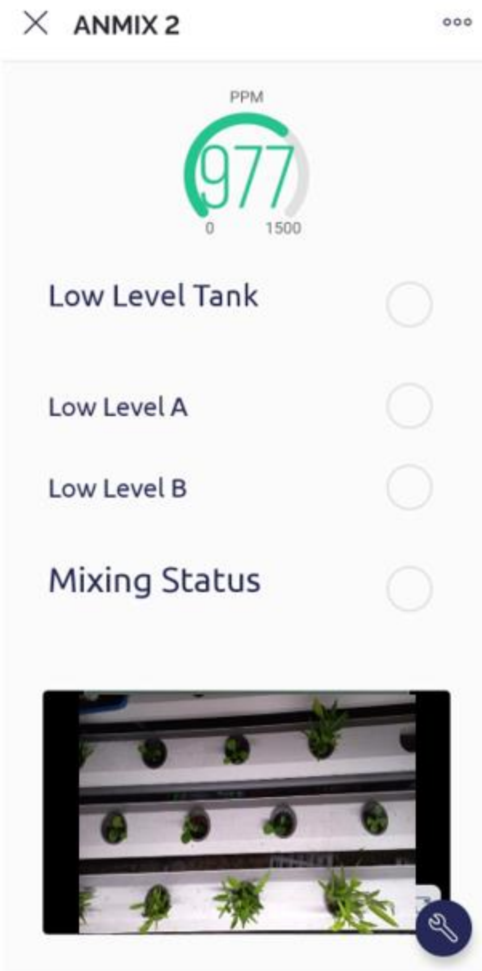

Figure 6. Application result

Figure 7 shows the results of cultivating hydroponic vegetable plants using AN Mix equipment. With automatic equipment, the nutrient mixture can be provided with the same consistency every time. It ensures that the plants get the right intake according to their needs. Additionally, mixing nutrients no longer needs to be done manually, saving time and effort. Manually, there may be an opportunity to make errors in dosage or proportions. Automated tools reduce the risk of such errors. Plant growth can be optimized with the right and consistent nutrient dosage, resulting in better crop yields. It can also avoid wasting nutrients.

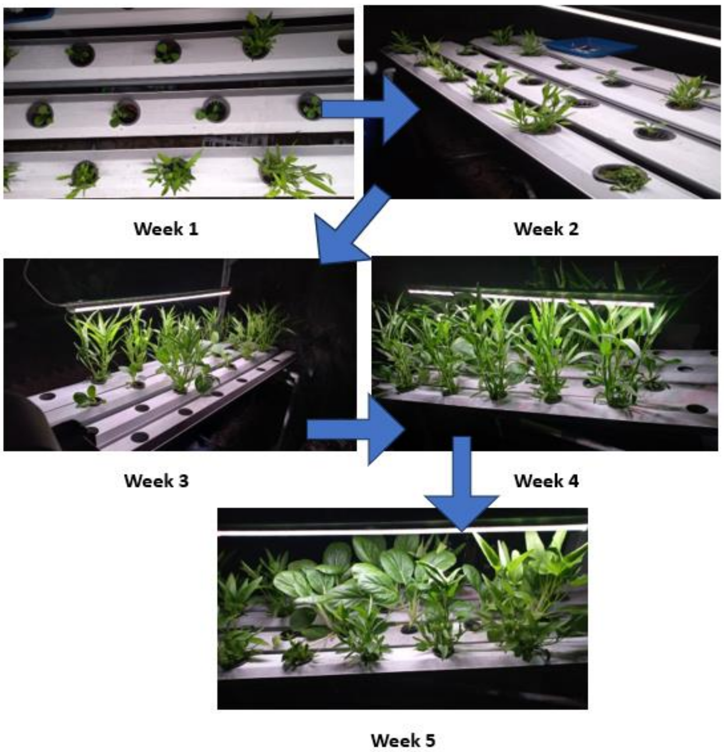

Figure 7. Planting Data

5. Conclusion

Based on the research results, implementing an automatic nutrient mixing tool developed using a microcontroller and Internet of Things (IoT) technology with the Blynk platform has shown significant effectiveness in the hydroponic cultivation of vegetable plants. The following are the conclusion points from the research: a. Effectiveness of Nutrient Mixing: The developed tool can mix nutrients with high consistency and accuracy, ensuring that plants receive optimal nutritional intake for their growth. b. Ease of Monitoring: Thanks to integration with the Blynk platform, farmers can monitor the condition and status of equipment online and in real-time via smartphone, enabling quick intervention in case of problems or irregularities. c. Optimizing Plant Growth: From the results of planting experiments, it was proven that the vegetables produced grew well, indicating that the dose and quality of nutrients provided by the tool supported optimal plant growth.d. Operational Efficiency: Automated tools reduce the need for manual intervention in the nutrient mixing process, resulting in efficiency in cultivation operations. e. Flexibility and Adaptability: With IoT capabilities, these tools offer flexibility in setup and adaptation to specific plant needs or environmental conditions. f. Error Reduction: Automation and real-time monitoring reduce errors when manually mixing nutrients. Innovation and Technological Integration: Implementing microcontrollers and IoT technology in hydroponic vegetable cultivation shows relevant innovation in encouraging modern and sustainable agricultural practices. Thus, this microcontroller and IoT-based automatic nutrient mixing tool offers an innovative solution that improves the quality and efficiency of hydroponic vegetable cultivation and provides convenience and better control for farmers through the Blynk platform.

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