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Smart Hydroponic Farming using the NFT Method

John Frederick D. Roy
San Carlos College
Naguilayan, San Carlos City,
Pangasinan, Philippines

Sammy Butch V. Eleria
San Carlos College
Longos, San Carlos City,
Pangasinan, Philippines

Rosenda D. De Guzman
San Carlos College
Bituag, Urbiztondo
Pangasinan, Philippines

Carriza B. Salomon
San Carlos College
Camambugan Urbiztondo,
Pangasinan, Philippines

Jenniea A. Olalia
San Carlos College
Magtaking, San Carlos City,
Pangasinan, Philippines

ABSTRACT
For every nation, farmers play the most essential role and that is to feed the population. To fulfill this role, farmers should produce good crops to help us sustain our basic needs. Seeing things from a wider perspective, producing good crops had become very difficult for every farmer because of the effects of climate change. Unpredictable weather and more severe events such as floods and droughts are some of the effects of climate change which greatly affects the productivity of crops by allowing the prosperity of weeds, pests, and fungi. The problem of growing crops had become a serious and critical matter which had resulted in low crop yield production, food shortage, and economic losses.

Smart Hydroponic Farming using the NFT Method helps the farmer to stay connected to their farm anytime and anywhere. Various sensors and modules were used to monitor, control and collect farm conditions. The settings can be configured and viewed using the mobile application anytime and anywhere via the internet. This system is automated to maintain the water nutrient of the crop and would result in an increase in crop production. The farm owner can monitor water nutrients, acidity in the plant condition, humidity, temperature, and water level and also can control the hydroponic farm.

Keywords
Hydroponic farming, nutrient film technique, internet-of things, urban farming.

1. INTRODUCTION
For every nation, farmers played the most essential role and that is to feed the population. To fulfill this role, farmers should produce good crops to help us sustain our basic needs. Seeing things from a wider perspective, producing good crops had become very difficult for every farmer because of the effects of climate change. Unpredictable weather and more severe events such as floods and droughts are some of the effects of climate change which greatly affects the productivity of crops by allowing the prosperity of weeds, pests, and fungi. The problem of growing crops had become a serious and critical matter which had resulted in low crop yield production, food shortage, and economic losses. These problems led the different researchers to conduct further studies that had to pave the way to introduce several alternative solutions. One of these solutions is hydroponic farming.

Hydroponic farming was simply the production of crops without soil. It is also an alternative solution to the problems faced by farmers due to the effects of climate change which the low soil quality and low water supply. [1] Like other alternative solutions, hydroponic farming was not exempted from such failures.

The majority of hydroponic crops failed due to the absence of nutritional components in their production method, which requires proper nutrient solution preparation and management as well as hydroponic chemical content [2]. Nutrition solutions played an essential role in hydroponic farming. There were various processes for hydroponic farming, but the nutrition solution was the most sensitive. Research studies have proved that to ensure high crop yield, optimum quality of nutrition solution was important. The nature of nutrition solutions varies randomly throughout the growth cycles of crops [1].

Hydroponic farming can be done in several methods. Among these methods were the Kratky method, Deep Water Culture, and Nutrient Film Technique (NFT) method. In propagating plants in hydroponic using the Nutrient Film Technique (NFT) method, manual monitoring of water nutrients was one of the reasons behind the problem faced by farmers. Based on research, the abnormal nutrient solution, EC (Electrical Conductivity), and pH can be detrimental to plant growth. If the nutrient solution and pH are too high, the plants may wilt, and their leaves turn yellow. Increasing the pH level also increased alkalinity and calcium, causing a "nutrient lockout" in the crops. The crops do not absorb enough nutrients to stay healthy. While high EC (Electrical Conductivity) caused water stress in crops and also causes water loss which returns the more concentrated nutrient solution around the roots. A lower EC means a lower salt concentration. [3]

To address the problems encountered in hydroponic farming using the NFT method, a study was conducted to turn its manual monitoring into an automated system. The purpose of the Automated System for Farming with Hydroponic Style was to atomize crop monitoring during the growth process using a network of sensors and actuators. The features of this project are to produce higher quality crops and monitor and control the physical events in the fields, such as water level, pH, electrical conductivity, water temperature, and relative humidity. The system gathered all the data and puts it in a MySQL database. Farmers were able to access sensor data for real-time measurements. [1]

Considering the automation done in this method of hydroponic farming, the proponents decided to adopt the existing features and added some features like solenoid valves that helped the nutrient film technique (NFT) method be flexible. A water flow sensor helped to monitor the amount of liquid flowing through the nutrient container. The proponents proposed a project entitled Smart Hydroponic Farming using the NFT Method, which helped the farmer to stay connected to their farm anytime and anywhere. Various sensors and modules were used to monitor, control and collect farm conditions. The farm condition was configured and viewed using the mobile application anytime and anywhere via the internet. This system is automated to maintain the water nutrient of the crop and increase crop production. The farm owner monitored water nutrients, the acidity of the plant, humidity, temperature, and water level and also controlled the hydroponic farm.

The proponents were motivated to innovate the existing solutions in the farming industry to help farmers yield more crops or increase crop production. This project also helped other farmers where locations were having difficulties in farming. Hydroponic smart farming helped farmers in a form that they do not even need to operate or monitor the conditions of the plants manually. This project also helped the farmers reduce the hassle and problems they face in past situations. This study served as a reference for future researchers to innovate and make the farming industry smarter.

2. RELATED LITERATURE

Food, water, and land were one of the most essential resources to mankind, and these three resources were dependent on each other. Without quality land and a good amount of water, one cannot produce a healthy batch of crops. Climate change has an impact on crop quantity and quality, which might have a major effect on a country's economy in the coming years. Many countries suffered from economic crises due to a lack of food production. A solution was needed to preserve the water resources and maximize the profit per square feet of land, which helped produce higher quality and quantity yield, and directly or indirectly, profits the farmer or economy of the country or region. One of the ways integrated to address the lack of food is hydroponic farming. Hydroponic was a type of agricultural technique that grows most terrestrial plants without the use of soil, using water, and nutrients. [4]

Hydroponic farming was one way to grow crops but has different factors to consider including abnormal nutrient solutions, temperature, and humidity. Hydroponic farming faces a great challenge which even fails due to poor management of these factors. The majority of hydroponic crops fail due to nutrient solutions such as pH and Electrical Conductivity (EC), temperature, and humidity.[5]

The nutrient solution was considered to be one of the most important determining factors of quality crop yield. A nutrient solution for the hydroponic system was an aqueous solution containing mainly inorganic ions from soluble salts of essential elements for higher plants [6]. The nutrient solutions were inorganic or organic. Plants in hydroponic need continuous care from the farmer for healthy crops. The nutrient solution needs to be supplied properly at regular intervals without any time delay. In case of nutrients were insufficient, roots submerged in water solvent were got rotten [7].

An essential element has a clear physiological role, and its absence prevents the complete plant life cycle. Among the minerals, nitrogen (N), phosphorus (P), and potassium (K) were the most decisive elements in plants [8]. Nitrogen was largely responsible for the growth of leaves on the plant. Phosphorus was largely for root growth and glower fruit development while potassium helps root growth and also strengthens the plant.[9]

The pH level of the nutrient solution was very important. The rise and fall of the pH can leave an impact on the crops. Algae and bacteria were the main types of organic matter that affect pH levels. If pH levels rise in the morning and drop later in the day, algae may be the culprit. As algae consume acidic carbon dioxide during the day, pH levels rise and then fall by evening. On the other hand, bacteria from root disease can cause a dramatic drop in pH levels. As diseased roots decompose, bacteria released acids into the hydroponic solution. Several factors can cause pH levels to change in hydroponic systems. When the amount of the nutrient solution drops below one gallon, the solution becomes more concentrated as plants absorb the nutrients. This results in widely fluctuating pH levels. It was therefore important to monitor nutrient solution levels, keep the reservoir full, and regularly test the pH in the reservoir [9]. The control of pH was extremely important, not only in hydroponic but also in the soil. Crops lose the capability to absorb different nutrients when the pH differs. Different crops have a particular pH that is optimal for them, generally, most crops prefer a slightly acid-growing environment. Changing the pH level too quickly was not a good idea as this stressed the crop out too much [10]. The recommended pH for hydroponic culture is between 5.5 to 5.8 [11].

Inadequate management of nutrient solution such as the use of a too-high or a too-low concentration of the nutrient solution, or an imbalanced ion composition could inhibit plant growth due to either toxicity or nutrient-induced deficiency. The optimal EC was crop-specific and depends on environmental conditions. In general, higher EC hinders nutrient uptake by increasing the osmotic pressure of the nutrient solution, wastes nutrients, and increases the discharge of nutrients into the environment, resulting in environmental pollution. Lower EC may severely affect plant health and yield [12]. The ideal EC was specific for each crop and dependent on environmental conditions. However, the EC values for hydroponic systems range from 1.5 to 2.5 ds/ m [11]. The proponents used pH and EC sensors to determine the pH and EC of the nutrient container. When the sensors detect a decrease or increase in the content of the nutrient container, the peristaltic pump worked to provide the needed plant nutrients such as; nutrient solution, pH down, and pH up to maintain the ideal pH and EC of the crops.

Another factor that contributes to the failure of hydroponic farming was the temperature and humidity. Temperature-controlled growth of plants directly affects photosynthesis, respiration, mineral nutrition, dehydration, and relative humidity directly affects the dehydration plant. When humidity was high, the crop becomes less dehydrated and also causes certain diseases. As a result, the supply of nutrients from the roots to the leaves were fall and the temperature was rise. In addition, high humidity also causes certain diseases so a good level of humidity averages out at 80.54% [13]. A favorable temperature is just as important for plants in artificial culture as for those in soil.

Lastly, lighting as a contributing factor to the failure of hydroponic greatly affects the growth and development of plants because the light was an important factor in building food or photosynthesis of plants with chlorophyll. Lighting as a factor may include wavelength, light intensity, and duration of light on the crop that affect the growth of plants grown with the hydraulic system. Exposure of hydroponic crops to high-intensity light may cause the temperature to rise accordingly [13].

Shown in Figure 1 upon building and creating this project, the project used an open-source electronic platform, and all sensors and modules connected to it. The proponents used the open-source electronic platform as the microcontroller and act as the brain of the system. All data gathered by the sensor were sent to the microcontroller and processed based on the algorithm embedded in it. A necessary electronic module was triggered based on predefined conditions.

3. PRESENTATION OF ANALYSIS OF DATA

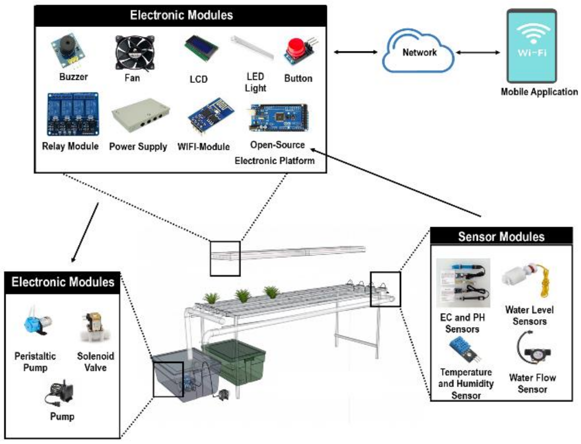

Figure 1. Operational Framework for the Proposed Project

The water level sensor helped determined the water level on the nutrient container. If it is detected below the minimum water level in the nutrient container, the water pump automatically flashed out the excess nutrient solution, and the water pump located inside the water reservoir pumped water to the nutrient container. Manual refilling of the water reservoir was done to replenish the water source.

Temperature and humidity sensors were used to determine the temperature and humidity of the crop environment. The ideal temperature range for hydroponic for most crops was between 72 to 82 °F. Most plants are very comfortable up to 82 °F but were sensitive to higher temperatures [14]. When the temperature and humidity in hydroponic reach the highest point a fan was turned on which helps cool the environment. If a low temperature was detected the LED lights were turned on to help maintain the required temperature of plants.

For pH and EC sensors, the proponents used a pH sensor to measure the acidity of the water while the EC sensor monitors the number of nutrients, salts, or impurities in the water. The pH and EC sensors assist in monitoring the proper amount of nutrients required by the plant. The ideal EC range for hydroponic for most crops was between 1.5 to 2.5, while the pH was between 5.5 to 6.5 higher EC was prevent nutrient absorption due to osmotic pressure, and lower levels severely affect the plant. Increasing the pH level also increases alkalinity and calcium, causing a "nutrient lockout". An imbalance has occurred, and the plant showed some deficiency or toxicity symptoms. When the sensors detected a decrease or increase in the content of the nutrient container, the peristaltic pump worked to provide the needed plant nutrients such as; nutrient solution, pH down, and pH up to maintain the ideal pH and EC of the crops. A water flow sensor helped to monitor the amount of liquid flowing through the nutrient container.

Solenoid valves helped the hydroponic system be more flexible and smarter. The solenoid valves prevent the water from flowing when a power outage occurs.

The buzzer was alarmed if the sensor modules are not working. Through the LCD monitor, the user can change and easily configure the system for different crop types depending on predefined conditions based on the algorithm embedded even without the internet.

The mobile application served as a tool for monitoring and configuration if the internet is available. The mobile application and LCD screen allowed the user to monitor the status of the hydroponic setup. Additionally, it allowed configuring the settings of the system including threshold values of temperature and humidity, pH level, and others.

During this project, proponents analyzed the project's functional and non-functional requirements based on the information gathered during the requirements gathering phase in order to know whether it was feasible or not. Based on the information gathered during the previous phase, the functional requirements were defined during the project's requirement gathering phase and can help identify the missing requirements. It allows the proponents to determine the system's intended service and behavior, and non-functional requirements are a specification that described the project's characteristics to make it work more efficiently and effectively. It should manage the crop environment based on the configured threshold.

Functional and Non-Functional Requirements.

- It should automatically circulate the needed nutrient solution of the crops.
- It should automatically respond based on the detected needs of the crops.
- It can monitor the current level and threshold of factors needed in hydroponic such as temperature, humidity, EC, pH, and water level.
- It should automatically transform into a deep-water culture method when a power outage occurs.
- It can notify the farmer whenever a sensor module was not working properly.
- It can monitor and configure the threshold for the type of each crop requirement.
- The system must be able to manage the farm quickly.
- The system must be available anytime and anywhere through the mobile application.
- The system must be reliable in terms of monitoring.
- The system must be a friendly-user.

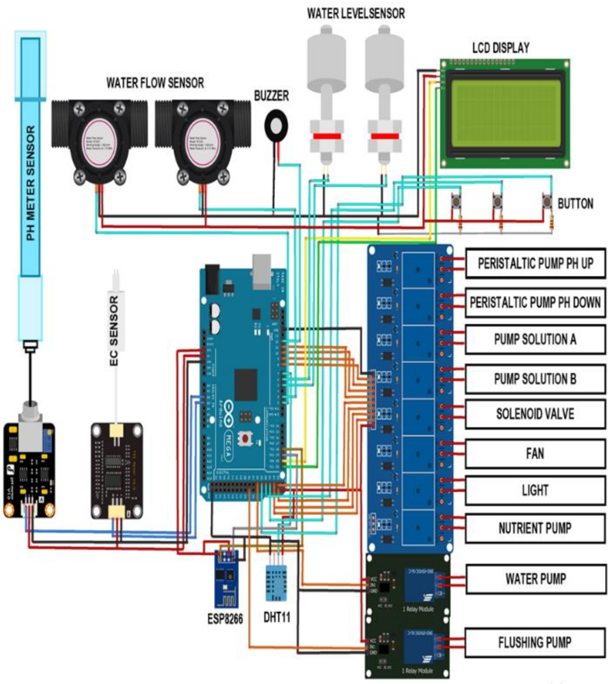

Figure 2. Schematic Diagram of Smart Hydroponic Farming using the NFT Method

Shown in Figure 2 is a diagram of the microcontroller and module's interconnectivity. This Schematic Diagram contains wiring and sensors that are connected via the open-source electronic platform (Arduino Mega) as the microcontroller which acts as the brain of the system. The modules and sensors utilized in this project are the float switch, water flow sensor, TDS sensor, pH sensor, temperature and humidity sensor.

Smart hydroponic farming has a sensor that measures water's acidity and alkalinity. The normal range of pH is 5.5 – 6.5 for all crops. If the pH sensor detects below 5.5, a designated peristaltic pump (PH UP) automatically turns on but when it detects 6.5 and above, a designated peristaltic pump (PH DOWN) automatically turns on. The EC sensor determines the electrical conductivity of a solution. It detects impurities in the water. The ideal EC range for hydroponic for most of the crops is between 1.5 to 2.5. The water flow sensor detects the volume of supplied nutrient solutions A at B. The water level sensor helps monitor the water level in the nutrient container. If it detects below minimum water level in the nutrient container, the water pump automatically flashed out the excess nutrient solution and the water pump located inside the water reservoir pumped water to the nutrient container. On the other hand, the Temperature and Humidity sensor detects the environment of the hydroponic. The ideal temperature range for hydroponic for most crops is between 15 to 32 °C. When the temperature and humidity in hydroponic reached the highest threshold, a fan automatically turns on which helps cool the environment, otherwise, if it's low temperature, the LED light turns on to help maintain the required temperature of plants. Moreover, the buzzer alarms if the sensor modules are not working. The ESP8266 receives the sensor data from Arduino Mega and is sent to Firebase. Finally, the LCD and button work together to monitor and configure the threshold if the phone and internet connection is not available or accessible.

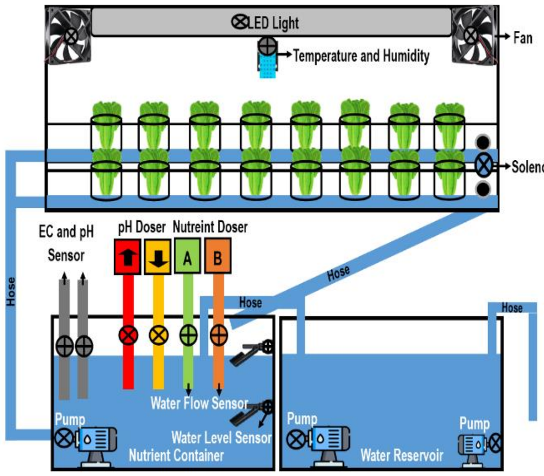

Figure 3. Actual Design of Prototype

Shown in Figure 3 The proponents created a sketch for Smart Hydroponic Farming to visualize the final look of the prototype (Figure 3). All modules and sensors were placed in the designated area. The Arduino Mega sends data received from EC, pH, water level, temperature, and humidity sensors to the ESP8266. The ESP8266 sends the data received from the Arduino Mega to Firebase. The mobile application gets the data from the Firebase database to allow monitoring and configuration of the threshold using the mobile application. The DHT11 or the temperature and humidity sensor is located at the top of the crops to detect the hotness or coldness in the hydroponic farm together with a fan and LED light to normalize the temperature and humidity of the hydroponic farm. The water level sensor is located inside the nutrient container to monitor the water level. If the water level sensor detects the appropriate level of water, the pump inside the nutrient container automatically turns on to the growing tube. If it detects below minimum water level in the nutrient container, the water pump automatically flashed out the excess nutrient solution and the water pump located inside the water reservoir automatically turned on to transfer the water to the nutrient container. The pH and EC were located in the nutrient container to monitor the nutrient levels of the water. The pH doser, nutrient doser, and water flow sensor were located above the nutrient container. The pH doser worked through the peristaltic pump if the pH sensor detects the acidity or alkalinity of the water. The water flow sensor detected the amount of nutrients doser. If a power outage occurred, the solenoid valve below in the growing tube transformed the NFT method into Deep Water Culture.

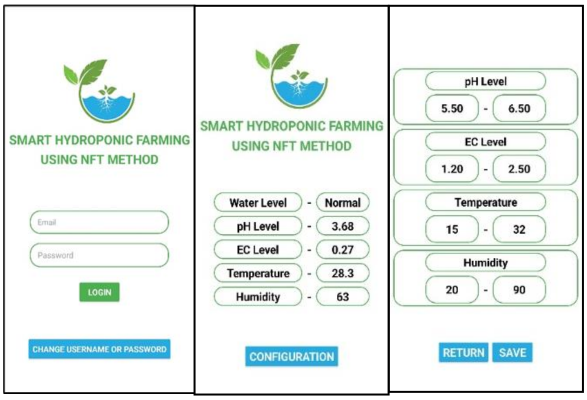

Figure 4. Mobile Application

Shown in Figure 4 The proponents create the Login screen or the main display of the mobile application where the user signed up to access the hydroponic system. If the user forgot the password, they used the "Change username or password" button. After the user logged in, the main screen of the mobile application contains real-time monitoring of water level, pH level, EC level, temperature level, humidity level, and a button for configuration. After pressing the configuration button, the configuration screen of the mobile application popped up. It contains textboxes for a low and high threshold for water level, pH level, EC level, temperature level, and humidity level. In this screen, the user pressed each button could configure the requirement for the pH level, EC level, temperature level, and humidity level. The configuration screen has two buttons: one is the “return” button, which can be clicked if the owner wanted to return his previous screen, and the other is the “save” button, was clicked if the owner wanted to save the set that the crop requires. Each threshold level has range-setting limit that if it exceeds, it not saved.

The Arduino IDE was used as the programming tool to programmed and uploaded the code to the microcontroller so that the modules function properly throughout the hardware portion of the project's construction. Arduino programming was supported by a large number of libraries. During the coding phase, proponents used the Arduino IDE programming tool to create and debug the software that was uploaded to the Arduino Mega board.

The proponents chose Kodular to create the actual mobile application since it is user-friendly and used a simple tool for generating user interfaces. This mobile application was used to configure the threshold for the type of each crop requirement.

The proponent used Firebase the online database software to store the project’s data. The mobile application sent and received from the data from Firebase. Both mobile application and the ESP8266 sent and received data from the Firebase.

The proponents performed a test run of the entire system. It is critical to test the operation before implementing the project to know what needs to be fixed in order for the system to run smoothly. After ensuring the reliability of the prototype, the proponents informed the owners that actual testing be done on their farm. The stakeholders tested the prototype to see if there were any additional requirements for the project or feedback that may help improve the prototype.

Figure 6. The actual model of Smart Hydroponic Farming

Shown in Figure 6 shows the actual model of the Smart Hydroponic in which the modules and sensors were installed in the proper places. The proponents presented the project to the hydroponic owner to see if it was valuable and feasible. The project was carefully defined and discussed to the stakeholders. After testing the system, the client also evaluated the system to determine the prototype's effectiveness and efficiency.

After numerous testing, the proponents have fixed the different errors and integrated the different comments and suggestions of the respondents. The proponents went to Malasiqui, Pangasinan, to present to the respondents the hydroponic prototype and explain and discuss all the features of the prototype and how it works. In this phase, the proponents had already finished the project and is ready for implementation.

Figure 7. Demonstration of the prototype to the farm owner

Shown in Figure 7 The proponents presented the project to Mrs. Marisa L. Rangel, the farm owner of Tadena Hydroponic Greenhouse at Malasiqui, Pangasinan. The proponents presented the features and how the project works such as; automatic dispensing of the nutrient and pH solution; easy monitoring of water level, pH level, EC level, temperature, and humidity level of the farm using the LCD screen; and mobile application to easily manage the farm by configuring the threshold requirements of the crops (Figure 7 and 8).

After presented, the proponents explained the different questions found in the evaluation form and asked the stakeholders to evaluate the effectiveness and efficiency of the system through the evaluation form made by the proponents This evaluation tool served as the basis to determine the project's effectiveness and efficiency.

4. RESULT AND CONCLUSION

Nutrient solution is one of the most vital factors in growing hydroponic crops. Inadequate and too much nutrient solution may result to less crop production. With Smart Hydroponic Farming Using NFT Method, the proponents concluded that the nutrient solution was maintained appropriately through the water flow sensor which can detect the appropriate amount of nutrient solution needed by the crops.

The Smart Hydroponic Farming Using NFT Method has a subsequent feature in the mobile application which allows configuration. Upon further testing, the proponents concluded that using the mobile application, the different threshold values can be easily configured based on the owner’s preferences considering the general requirement of growing crops.

Table 1. Survey Result for Hydroponic Owner and Employees

Farm Owner	100%
Employees	100%
Total	**100%**

Smart Hydroponic Farming Using NFT Method project helped the farm owner and employees monitor their different crops on the farm to prevent dying crops, primarily during the dry season or summer. The proponents concluded that the project was effective and efficient for hydroponic farms for it had received a high percentage of effectivity and efficiency (100%) from the survey answered by farm owner and employees of Tadena Hydroponic Greenhouse in Brgy. Osmeña Street, Malasiqui, Pangasinan. (Table 1)

5. RECOMMENDATION

The project still faced some drawbacks which allow room for improvements for other researchers. The proponents recommend further study on the actual measurement of the nutrients left in the nutrient container so that the right amount of nutrient solutions can be added to the nutrient container and can prevent flushing off the excess nutrient solution. In addition, the proponents also recommend supplementary studies in determining other criteria that can contribute to an increase in crop production. Lastly, the proponents recommend including plant disease detection and prevention that may affect the crops.

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