

Monitoring the Condition of Hydroponic Growing Media Based on Internet of Things

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ABSTRACT

Manual hydroponic techniques still make it difficult for farmers to control nutrients accurately, so new innovations are needed to make it easier for farmers to farm with hydroponic methods. This study aims to develop hydroponic farming using internet of things technology. This study was conducted using an experimental method. With this method, researchers took some data such as volume, temperature nutrients and water pH and then compared them with actual values. The author also took some component stress measurement data and then compared it with the component datasheet to determine the condition and suitability of the component. The research object used is celery plants. The test results prove that the development of monitoring and control technology for hydroponic planting media has been successfully carried out. Testing proves that the system can automatically control nutrients and pH and monitor the condition of the planting media at the same time. When nutrients are added, the pH of the water decreases because the graph of increasing nutrients is inversely proportional to the decrease in water pH. When the pH of the water decreases, the motor automatically turns on to increase the pH to the ideal value. Thus, farmers can more easily control the nutrients in the planting media.

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1. INTRODUCTION

Indonesia is known as an agricultural country because the majority of its population works in the agricultural sector. This is supported by Indonesia's fertile soil and rich natural resources. In general, [1] recorded that Indonesia's total agricultural production from various commodities reached 53,625,539.51 tons in 2023. Therefore, the agricultural sector contributed up to 13.28% to national GDP. This proves that the agricultural sector plays a significant role in boosting the national economy, and therefore, it must be improved. To increase agricultural yields, the agricultural sector must be further expanded, from rural to urban areas [2]-[3]. In urban areas, the main problem is the limited land available for growing crops. Therefore, hydroponic techniques are used to address this issue [4]-[5]. Hydroponics is a method in the agricultural industry that can cultivate plants without the need for land, but instead uses water and nutrient solutions as a growing medium [6]-[7]. This hydroponic cultivation has many advantages, including more practical maintenance and more controlled pest problems, not depending on natural conditions, and can be carried out on limited land [8]-[9].

In hydroponic methods, although maintenance tends to be more practical, farmers require good skills in controlling plant nutrition [10]-[11]. To control these nutrients, accurate data on environmental conditions such as oxygen levels, pH, air temperature, and nutrients in the growing medium are required [12]-[13]. This data is essential for farmers to monitor water nutrients and to calculate nutrient deficiencies. However, most farmers currently still monitor hydroponic water conditions conventionally, making it

difficult to obtain accurate parameter data. Furthermore, manual methods tend to be impractical because they are not real-time. Therefore, a technological solution is needed that can assist farmers in monitoring hydroponic water conditions practically, in real time, and accurately.

Several researchers have previously developed a technology for hydroponic monitoring. This is the Microcontroller-Based NFT Hydroponic Monitoring System using an LCD as a monitor [14]. This research successfully obtained environmental parameter data. However, farmers must continue to check the growing medium because the monitor is attached to the growing medium. A Hydroponic Monitoring System using IoT was created where parameter data is displayed on a website [15]. The IoT concept refers to the use of connected intelligent devices and systems to utilize data collected by sensors and actuators embedded in machines and other physical objects [16]-[17]. With IoT applications, users can monitor and control remotely in real time. This research also successfully obtained accurate environmental parameter data that can be accessed remotely. However, the website designed is only compatible with laptops/PCs, while farmers may not necessarily have laptops/PCs to access it.

Based on the above issues, the aim of this research is to develop a monitoring and control tool for hydroponic growing media using the Internet of Things. The benefits of this research include facilitating hydroponic farmers' control and monitoring of growing media nutrients, thereby improving plant growth..

2. METHOD

The design process begins with the creation of a block diagram. A block diagram is a basic description of the system to be designed in the form of a diagram connected by lines as indicators between blocks [18]-[19]. Each part of the system block in the block diagram has its own function. The I/O block diagram on the device can be seen in Figure 1.

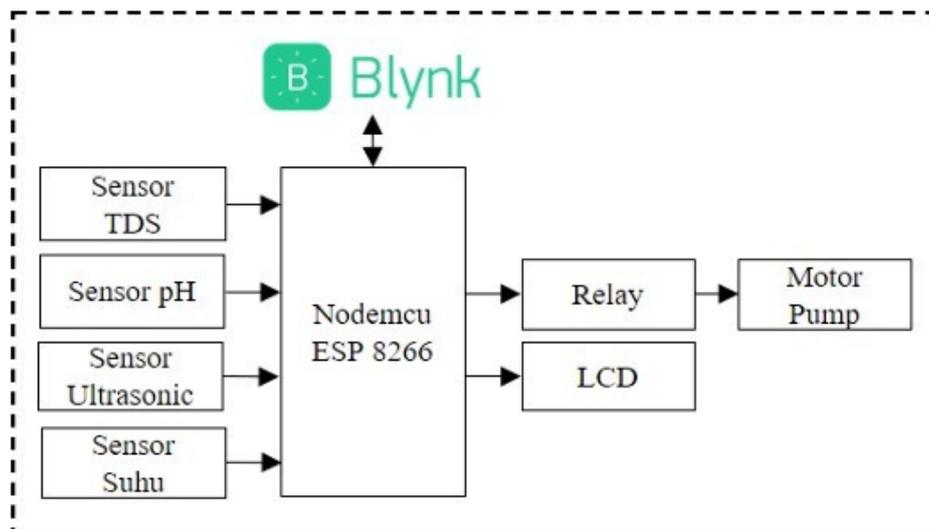


Figure 1. Diagram block of IO system

Based on Figure 1, the function of each block diagram can be explained as follows. The pH sensor measures the pH of the water. The DS18B20 temperature sensor measures the ambient temperature or the temperature within the water. The ultrasonic sensor detects the water level. The pH sensor is used to determine the pH level in the water. The Nodemcu ESP8266 microcontroller sends sensor values to a smartphone application. Blynk is used as a smartphone application that monitors the sensors using a WiFi network. The relay acts as a driver to control the pump motor's on-off control. The LCD is used for direct monitoring of the device. This device monitors water conditions in hydroponic systems. It has four input sensors: an ultrasonic sensor, a TDS sensor, a pH sensor, and a temperature sensor. The TDS, pH, and temperature sensors detect nutrient levels, pH, and temperature in the water. Data from these three sensors is sent to the ESP8266 and then to Blynk via the internet. The ultrasonic sensor is used to detect the water level in the water container. The water level data is then sent via the ESP8266 to the Blynk application via the internet. When the water level has decreased, the user can turn on the pump using the button on the Blynk. The mechanical design includes the design of the tool's frame. This design is created in 3D using SolidWorks. A 3D design drawing of the tool to be built can be seen in the Figure 2.

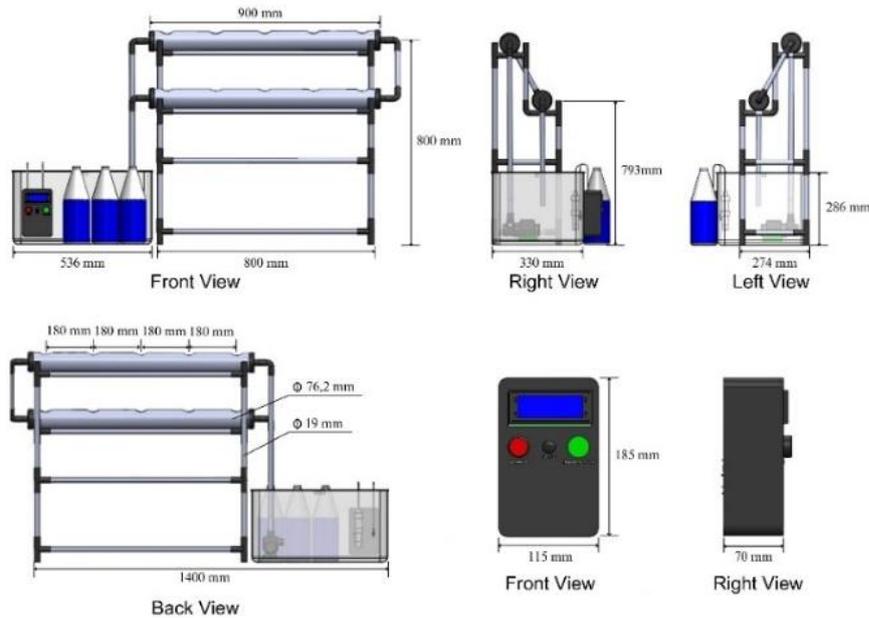


Figure 2. Mechanical design of Proposed system

Based on Figure 2, the tool is made of PVC pipe with a length of 800 mm and a width of 330 mm with a total of 22 component items. The schematic circuit of the tool circuit is shown in Figure 3. The software design in this study involves creating a display for an Android-based application using Blynk. The display of the application can be seen in Figure 3.

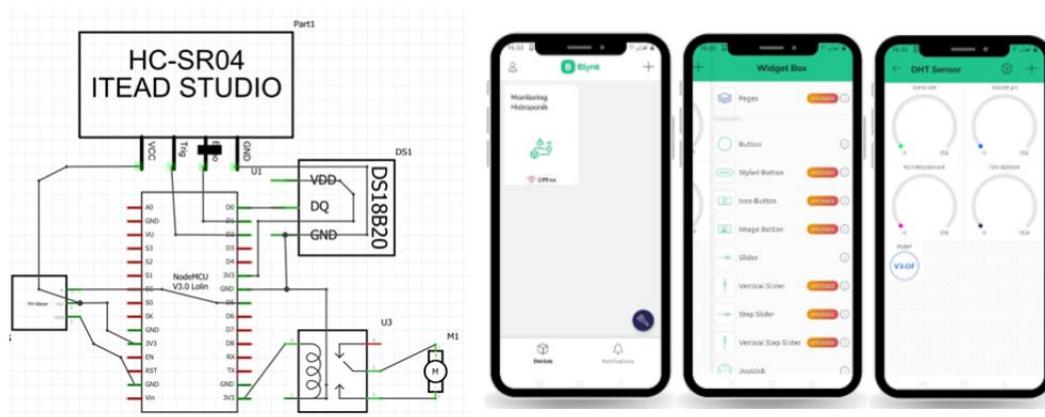


Figure 3. Electronic circuit and IoT interface design of Proposed system

Based on Figure 3, the Blynk application will be used to display data on water conditions and dissolved nutrients in hydroponic water. Figure 3(a) shows the initial display of the Blynk menu after the user creates a new project. In this final project, the project created is named Hydroponics. After the new project is created, the display will be as in Figure 3(a) where the status is still offline because it is not connected to the device. In this final project the device used is ESP8266. Figure 3(b) is the edit display in the Blynk application where the user is free to design the application display as attractive as possible, according to taste and according to the user's needs. In designing this final project, the researcher is still using the free version of Blynk so the features provided are still limited. However, the free version of Blynk is able to meet the monitoring needs in this study such as creating data displays and buttons. Figure 3(c) is the final display after the user designs the application display for hydroponic monitoring. The designed display displays four pieces of monitored data: water temperature, pH, water level or volume, and water nutrients in ppm. As can be seen, this monitoring display doesn't yet contain any data because it hasn't been connected to the device or sensors. Once connected to the device, users can view the data sent from each sensor through the designed application interface.

3. RESULTS AND DISCUSSION

This section tests the developed system. Testing was conducted on both hardware and software to compare the developed system with the planned design. Furthermore, this chapter also discusses and analyzes the test results by comparing them with existing theory and relevant research conducted by previous researchers.

To meet the nutritional needs of celery plants using hydroponic techniques, nutrients must be added to the containers until they reach the ideal range. The addition of nutrient concentrates A and B was done automatically using a 5V motor pump in the A container and a 5V motor pump in the B container. The results of the nutrient addition test are shown in Table 1.

Table 1. TDS Sensor Measurement Results with the Addition of AB Nutrients

Time (seconds)	Condition of Pump Motors A & B	AB Mix (ml)	pH	Nutrition (PPM) Sensor	Nutrisi (PPM) instrumentation	Error TDS (%)
1	On	20	6.8	105	107	0.02%
2	On	40	6.5	491	498	0.01%
3	On	60	6.1	601	610	0.01%
4	On	80	5.9	790	795	0.01%
5	On	100	5.6	813	821	0.01%
6	On	120	5.3	1050	1100	0.05%
7	On	140	5.1	1200	1210	0.01%
8	On	160	4.8	1390	1400	0.01%
9	On	180	4.3	1450	1460	0.01%
10	Off	200	4.1	1605	1620	0.01%

Based on Table 1, the pump motor continues to automatically replenish nutrients using the nutrient data read from the TDS sensor. The ideal nutrient level for celery plants using the hydroponic method is 1400-1600 PPM [20]-[22]. When the ideal nutrient level of 1600 PPM is reached, the 5V pump motor automatically turns off. If the nutrient level falls below 1400 PPM, the pump motor will restart to replenish nutrients. The system takes approximately 10 seconds to replenish nutrients to the ideal nutrient level. Table 1 also shows that the nutrient reading error on the TDS sensor when nutrients are added is greater, at 0.05%. This figure is greater than the error value for sensor readings without nutrients, which is 0.03%. When the nutrient level reaches the ideal value, a decrease in the water pH is observed. Before the nutrient level is added, the average pH is 7.04. However, when 200 mL of AB Mix nutrient is added, the water pH gradually decreases over 10 seconds until it reaches 4.1. This means the water solution is in an acidic state because the lower the pH value, the more acidic the solution will be. The relationship between nutrient content and water pH over a 10-second interval is shown in the graph in Figure 4.

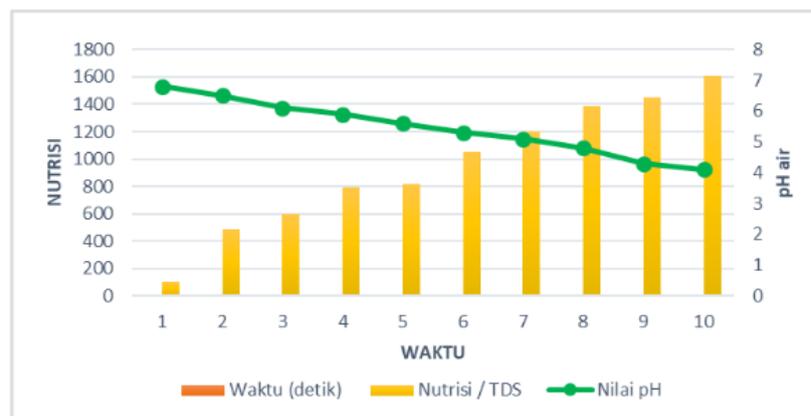


Figure 4. Graph of increase in nutrients against pH Value

Based on the graph in Figure 4, it can be seen that the increase in water nutrient value is inversely proportional to the pH value. The higher the nutrient value, the lower the pH value. This is consistent with the theory put forward by [23]-[24] that the higher the nutrient concentration in a solution, the lower the pH value due to the chemical composition of the nutrient solution. Furthermore, to meet the pH requirements of celery plants using hydroponic techniques, the pH was automatically increased using a 5V motor pump in the pH solution container. The results of the pH increase test are shown in Table 2.

Table 2. Adding Water pH Using Basa pH Solution

Time (seconds)	Motor Pump	Base pH (mL)	pH Sensor	pH Meter	Error (%)
1	On	20	4.1	5	0.18%
2	On	40	4.3	5.2	0.17%
3	On	60	4.8	5.4	0.11%
4	On	80	5.2	5.6	0.07%
5	On	100	5.7	5.8	0.02%
6	On	120	5.9	6	0.02%
7	On	140	6.1	6.2	0.02%
8	On	160	6.2	6.4	0.03%
9	On	180	6.4	6.7	0.04%
10	Off	200	6.7	7	0.04%
Standard Deviation			0,9	0,65	

Based on Table 2, the pump motor continues to automatically replenish the pH. The ideal pH for celery grown hydroponically is 6 to 6.5 [25]-[26]. When it reaches the ideal maximum pH of 6.5, the 5V pump motor automatically turns off. If the pH drops below 6, the pump motor will restart to replenish the pH solution. The system takes approximately 10 seconds to replenish the pH to the ideal pH value. Table 8 also shows that the pH sensor's reading error when adding a basic pH solution is greater, at 0.18%. This figure is higher than the sensor's reading error of 0.04% without using the pH solution. A comparison graph of pH values can be seen in Figure 5.

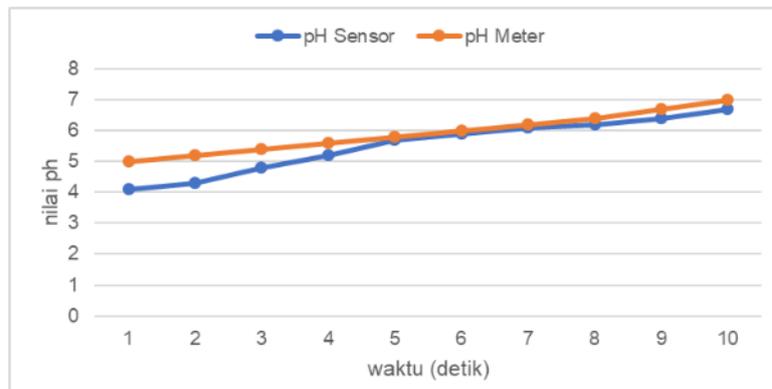


Figure 5. Comparison of pH Values

Based on Figure 5, it can be seen that the graph of the increase in pH values read by the pH meter is more stable compared to the increase in pH values read by the pH sensor. This can be seen from the standard deviation value of the pH meter which is smaller than the standard deviation value of the pH sensor, namely 0.65 on the pH meter graph and 0.9 on the pH sensor graph.



Figure 6. Blynk and datalogger application display

The application was created using the available open source application, Blynk. The UI display of the application and its components, as well as the data logger stored in the database, can be seen in Figure 6.

4. CONCLUSION

Based on the test results, the development of hydroponic growing media monitoring and control technology has been successful. Tests have proven that the system can automatically control nutrients and pH while simultaneously monitoring the condition of the growing media. When nutrients are added, the water pH decreases because the graph of increasing nutrients is inversely proportional to the decrease in water pH. When the water pH decreases, the motor automatically turns on to raise the pH to the ideal value. This allows farmers to more easily control the nutrients in the growing media.

REFERENCES

- [1] B. Siregar, S. Efendi, H. Pranoto, R. Ginting, U. Andayani and F. Fahmi, "Remote monitoring system for hydroponic planting media," *2017 International Conference on ICT For Smart Society (ICISS)*, Tangerang, Indonesia, 2017, pp. 1-6, doi: 10.1109/ICTSS.2017.8288884.
- [2] D. Yumeina, "Dynamic Optimization Of Water Temperature For Maximizing Leaf Water Content Of Tomatoes In Hydroponics Using An Intelligent Control Technique. *International Journal Of Computer Engineering And Applications* ", Volume X, Issue Iii, March 16, ISSN 2321-3469. Matsuyama : Ehime University, 790-8566, Japan, 2016.
- [3] H.S Utama, "Perancangan Dan Implementasi Sistem Otomatisasi Pemeliharaan Tanaman Hidroponik ". *Jurnal. Teknik Elektro, Fakultas Teknik Universitas Tarumanagara*, 2006.
- [4] E. V. Novaldo, T. Dewi and Rusdianasari, "Solar Energy as an Alternative Energy Source in Hydroponic Agriculture: A Pilot Study," *2022 International Conference on Electrical and Information Technology (IEIT)*, Malang, Indonesia, 2022, pp. 202-205, doi: 10.1109/IEIT56384.2022.9967806.
- [5] M. F. Hilmi Ameran, R. Abdullah, N. Ismail, R. Shafie, S. Omar and S. A. Che Kar, "Design and Implementation of an IoT Integrated Dual Sensors for Hydroponic Cultivation Root Growth Monitoring System," *2024 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS)*, Shah Alam, Malaysia, 2024, pp. 262-266, doi: 10.1109/I2CACIS61270.2024.10649842.
- [6] A. M. Thalwate, U. G. K. L. P. S. Ranasinghe, M. F. A. Sakee, M. M. Ikram, H. Mahaadikara, and S. Wellalage, "Fully Automatic Hydroponic Cultivation Growth System," in *ICAC 2021 - 3rd International Conference on Advancements in Computing, Proceedings, Institute of Electrical and Electronics Engineers Inc.*, 2021, pp. 205-209. doi: 10.1109/ICAC54203.2021.9671167.
- [7] A. M. Zaid et al., "IoT-based Smart Hydroponic System Using Nutrient Film Technique (NFT) for Lettuce Plant," in *GCCE 2023 - 2023 IEEE 12th Global Conference on Consumer Electronics*, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 976-980. doi: 10.1109/GCCE59613.2023.10315640.
- [8] A. J. Turner, C. I. Arzola, and G. H. Nunez, "High pH stress affects root morphology and nutritional status of hydroponically grown rhododendron (*Rhododendron* spp.)," *Plants*, vol. 9, no. 8, pp. 1-12, Aug. 2020, doi: 10.3390/plants9081019.
- [9] I. A. Prince, M. A. Adnan, R. I. Rifat, M. S. Mostafiz and S. M. I. Rahman, "IoT Based Monitoring Framework For a Novel Hydroponic Farm," *2022 IEEE Region 10 Symposium (TENSYP)*, Mumbai, India, 2022, pp. 1-4, doi: 10.1109/TENSYP54529.2022.9864365.
- [10] F. K. Aditama and R. Mukhaiyar, "Control of Smart Aquarium Using Smartphone," *Journal of Industrial Automation and Electrical Engineering (JIAEE)*, vol. 01, no. 01, pp. 21-26, 2024..
- [11] M. Yuhendri, A. Aswardi, and A. Ahyanuardi, "Implementasi Pompa Air Tenaga Surya Menggunakan Inverter Boost Satu Fasa," *INVOTEK J. Inov. Vokasional dan Teknol.*, vol. 20, no. 3, pp. 1-10, 2020, doi: 10.24036/invotek.v20i3.813.
- [12] B. J. Jangan and N. K. Madzhi, "IoT based Monitoring and Investigation of the Effect of Water Level, Temperature and humidity to the Hydroponic based plant," *2024 IEEE 7th International Conference on Electrical, Electronics and System Engineering (ICEESE)*, Kanazawa, Japan, 2024, pp. 1-6, doi: 10.1109/ICEESE62315.2024.10828563.
- [13] A. Hernández-Benitez, J. Vázquez-Castillo, J. J. Estrada-López, G. Becerra-Nunez, N. Cólín-García and A. Castillo-Atoche, "Self-Tuning Model for Energy-Context Optimization in Perpetual Sensor Nodes Within IoT-Integrated Hydroponic Systems," in *IEEE Embedded Systems Letters*, vol. 16, no. 3, pp. 267-270, Sept. 2024, doi: 10.1109/LES.2024.3387310.
- [14] Q. T. Minh, V. N. T. Gia, S. N. Tan, P. N. Huu and T. Tsuchiya, "Fog Computing Enabled Hydroponic Farming Systems," in *Journal of Mobile Multimedia*, vol. 18, no. 4, pp. 981-1008, July 2022, doi: 10.13052/jmm1550-4646.1842.
- [15] M. D. Sadare and S. Admane, "A review on plant without soil hydroponics," *IJRET: International Journal of Research in Engineering and Technology*, vol. 2, no. 3, pp. 299-304, 2013.
- [16] T.-H. Wu, C.-H. Chang, Y.-W. Lin, L.-D. Van, and Y.-B. Lin, "Intelligent plant care hydroponic box using iotalk." *IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, 2016.
- [17] R. Rajkumar and R. Dharmaraj, "A novel approach for smart hydroponic farming using iot," *International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)*, vol. 5, no. 5, 2018.
- [18] M. Yuhendri, E. Mirshad, and A. R. Sidiqi, "Real-time Control of Separately Excited DC Motor Based on Fuzzy PI System Using Arduino," *Przegląd Elektrotechniczny*, vol. 2024, no. 10, pp. 123-127, 2024, doi: 10.15199/48.2024.10.22.
- [19] U. Syarah and M. Yuhendri, "Constant Torque Control of Induction Motor Using Variable Frequency Drive Based on Internet of Things," *Journal of Industrial Automation and Electrical Engineering (JIAEE)*, vol. 1, no. 1, pp. 7-12, 2024.
- [20] M. I. Alipio, A. E. M.D. Cruz, J. D. A. Doria, and R. M. S. Fruto, "A smart hydroponics farming system using exact inference in bayesian network." *IEEE 6th Global Conference on Consumer Electronics (GCCE)*, Nagoya, 2017, pp. 1-5..
- [21] G. L. Priya, C. Baskar, S. S. Deshmane, C. Adithya and S. Das, "Revolutionizing Holy-Basil Cultivation With AI-Enabled Hydroponics System," in *IEEE Access*, vol. 11, pp. 82624-82639, 2023, doi: 10.1109/ACCESS.2023.3300912.
- [22] Y. V. Bhargava, P. K. Chittoor, C. Bharatiraja, R. Verma, and K. Sathiyasekar, "Sensor fusion based intelligent hydroponic farming and nursing system," *IEEE Sensors J.*, vol. 22, no. 14, pp. 14584-14591, Jul. 2022, doi: 10.1109/JSEN.2022.3177777.
- [23] H. S. Grewal, B. Maheshwari, and S. E. Parks, "Water and nutrient use efficiency of a low-cost hydroponic greenhouse for a

- cucumber crop: An Australian case study,” *Agricult. Water Manage.*, vol. 98, no. 5, pp. 841–846, Mar. 2011, doi: 10.1016/j.agwat.2010.12.010.
- [24] S. V. S. R. Raju, B. Dappuri, P. R. K. Varma, M. Yachamaneni, D. M. G. Verghese, and M. K. Mishra, “Design and implementation of smart hydroponics farming using IoT-based AI controller with mobile application system,” *J. Nanomater.*, vol. 2022, pp. 1–12, Jul. 2022, doi: 10.1155/2022/4435591.
- [25] W. Claussen, “Growth, water use efficiency, and proline content of hydroponically grown tomato plants as affected by nitrogen source and nutrient concentration,” *Plant Soil*, vol. 247, no. 2, pp. 199–209, 2002, doi: 10.1023/a:1021453432329.
- [26] A. Richa, M. Fizer, and S. Touil, “Advanced monitoring of hydroponic solutions using ion-selective electrodes and the Internet of Things: A review,” *Environ. Chem. Lett.*, vol. 19, no. 4, pp. 3445–3463, Apr. 2021, doi: 10.1007/s10311-021-01233-8.