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Implementation of an IoT-Based Drip Irrigation System for *Cucumis melo* Cultivation in Greenhouse Environments: Initial Evaluation

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Abstract: The cultivation area for melon (*Cucumis melo* L.) in Indonesia has been declining despite increasing consumption, necessitating innovative production techniques. This study evaluates the application of the Internet of Things (IoT) in greenhouse-based melon cultivation using an automated drip irrigation system. The system integrates solar-powered sensors and microcontrollers to monitor temperature, humidity, pH, and Total Dissolved Solids (TDS), with real-time feedback via the Blynk application. Melon plants were grown hydroponically (cocopeat: sawdust 1:1) in a 6×12 m greenhouse at P4S Bumiaji Sejahtera, Batu, East Java. Results showed that measured temperature (21.9–30.3 °C) and humidity (57–99.9%) were generally within optimal ranges for melon growth. The TDS of the nutrient solution (≈1860–1894 ppm) was near the recommended 1600–1800 ppm for hydroponic melon. The humidifier operated as intended (ON at 50–70% RH, OFF at 80–90%). Blynk connectivity allowed real-time data display only when the internet was available. Water discharge from the drippers varied widely (10–60 mL/min) across seven points, attributed to emitter placement and backflow. Camera feeds from the greenhouse were viewable in the Blynk app when online, but not when offline. The IoT drip-irrigation system functioned and provided remote monitoring, but sensor issues and uneven flow limited optimal automation. Future work should improve sensor calibration, flow uniformity, and integrate fertigation.

Keywords: crop monitoring, drip irrigation, greenhouse, hydroponics, internet of things

1. INTRODUCTION

The *Internet of Things* (IoT) refers to a network of physical objects embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices via the internet (Patel et al., 2023; Sandi & Fatma, 2023). Originally developed for industrial and business automation, IoT has found widespread applications in modern agriculture. IoT facilitates precision farming, reducing manual labor and improving efficiency through automation and monitoring (Kim et al., 2020; Shahab et al., 2024). It has revolutionized farming practices by enabling real-time monitoring, automated irrigation, precision fertilization, and improved resource use efficiency (V. Sharma et al., 2022; Wang et al., 2021).

In the context of horticulture, IoT technologies allow for environmental and crop condition monitoring via interconnected sensors and actuators, improving productivity and sustainability (Farooq et al., 2022; Kumar et al., 2022). This is particularly relevant for high-value crops such as melon (*Cucumis melo* L.), which requires controlled conditions for optimal growth. Melons are highly valued for their sweet flavor, nutritional content, and high-water content, making them a staple in many tropical fruit markets. Melon (*Cucumis melo* L.) is a popular fruit crop known for its sweet, refreshing flavor and nutritional content (Amzeri et al., 2020, 2022). However, in Indonesia, melon production remains suboptimal, with annual consumption reaching 332 million tons, but production in 2019 only 122,105 tons (BPS, 2021). In East Java, the melon cultivation area declined from 3,781 ha in 2019 to 3,154 ha in 2020, prompting the need for more efficient cultivation techniques such as hydroponics in greenhouse environments (Nora et al., 2020). Melon cultivation in greenhouse make the plants easy control water and nutrition, also from pest and disease (Monica et al., 2022).

Hydroponic systems, which utilize inert media such as cocopeat or husk charcoal instead of soil, offer several advantages: reduced land use, cleaner operations, and more precise nutrient control (Shin et al., 2023; Utama et al., 2006). Combining hydroponics with drip irrigation ensures accurate water delivery to plant roots, minimizing waste through evaporation and runoff (Rostini & Junfithrana, 2020). Integrating IoT into this setup allows for real-time sensor data acquisition and automated actuator control based on environmental feedback (Kumar et al., 2022; Rostini & Junfithrana, 2020).

Several studies have validated the potential of IoT for greenhouse crop monitoring and control (Patel et al., 2023; Shahab et al., 2024; V. Sharma et al., 2022; Wang et al., 2021). However, practical evaluations under local conditions—particularly for specific crops like melon—remain limited. This study aims to assess the performance of an IoT-based drip irrigation system in a greenhouse environment for melon cultivation. Specifically, we evaluate system stability, sensor performance, automation efficiency, and suitability for small-scale tropical agriculture. The objectives were to assess the system's environmental sensing accuracy, automation functions, and effectiveness in maintaining suitable conditions for melon growth. The contribution is a preliminary assessment of system performance (environmental sensing, actuator control, connectivity, and water delivery) under real greenhouse conditions, providing insights for further optimization.

2. MATERIALS AND METHODS

Study site and conditions

The experiment was conducted in a 6 × 12 m greenhouse at the P4S Bumiaji Sejahtera, Batu, East Java. The greenhouse was equipped with a hydroponic trough containing yellow melon plants grown in a 1:1 mixture of cocopeat and rice-husk charcoal (Supriyanta et al., 2023). Nutrients and fertilizers (organic liquid fertilizer, ZA, NPK Mutiara, ZK) were applied to support plant growth.

System components

The drip irrigation system consisted of drip tubing, pipes, valves, a water reservoir with filter, and a DC water pump. The electronic control system was built around an ESP8266 microcontroller with a 2-channel relay module. Sensors included an infrared (IR) sensor, a pH meter, a TDS (total dissolved solids) meter, and a soil moisture sensor. Additional hardware comprised: Wi-Fi module, solar panel and solar cell for power, a circuit breaker (MCB), cabling, a humidifier, and a V380 Pro camera. The system was powered by solar panels, which supplied electricity to the pump and electronics. A smartphone app (Blynk) was used for IoT connectivity and user interface.

System design and operation

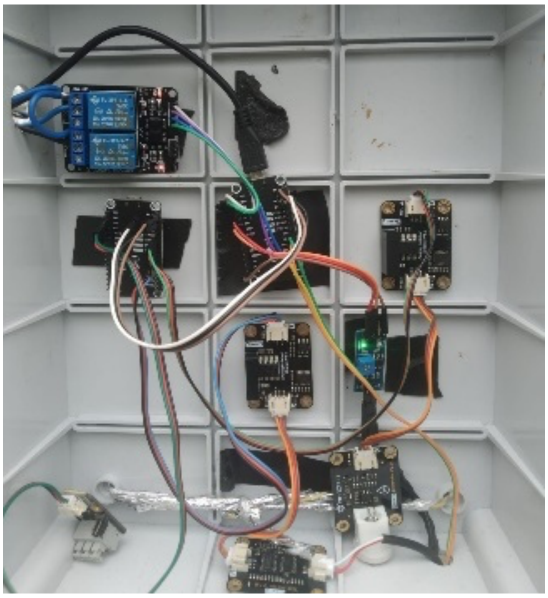

Figure 1. Design of the electronic component layout.

testing sensor-based systems, following procedures similar to Samsuri et al. (2024). The ESP8266 served as the central controller, interfacing with sensors and relay (Figure 1). The working schemes were solar panels provide power to the system and pump, sensors continuously measure environmental parameters, and data are sent to the Blynk cloud. The humidifier and pump are actuated based on sensor readings: in this design, if the air humidity falls below a set threshold (80% RH), the relay is activated to start the pump and irrigate plants (Figure 2).

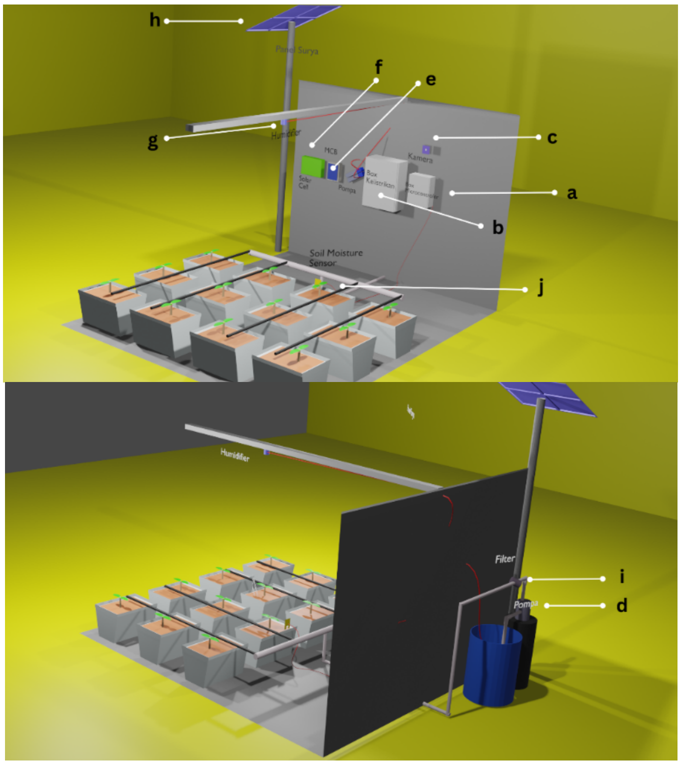

Figure 2. Illustration layout shows the arrangement of equipment within the greenhouse (a=microcontroller box, b=electricity box, c=camera, d=pump, e=MCB, f=solar cell, g=humidifier, h=solar panel, i=filter, j=soil moisture sensor).

Procedure

The system was installed and tested as follows: setup the hydroponic trough with melon seedlings and the drip lines connecting to the pump and water reservoir, Assemble the electronics: mount the ESP8266 with the relay board and connect sensors (IR, pH, TDS, soil moisture) and actuators (pump, humidifier, camera), configure Wi-Fi and Blynk: upload code to ESP8266 to read sensors, control relays, and transmit data to the Blynk app. Set humidity threshold at 80% for humidifier activation. Provide power via the solar panel to the pump and electronics. Ensure stable operation of the pump and camera. Turn on the system daily and allow continuous operation. Monitor for one month. Record data: at several times of day, log the greenhouse air temperature (°C) and humidity (%), nutrient solution pH and TDS (ppm), and Blynk connectivity status. Measure water discharge: with the pump on, collect drip water at seven emitter points for 1 minute each, and record the volume (mL). Test camera output: view real-time images from the greenhouse in the Blynk app under online vs. offline conditions. Throughout the experiment, smartphone and app access allowed real-time monitoring of all sensor readings, and controls for turning the pump/humidifier on or off remotely.

3. RESULT AND DISCUSSION

General measurements of the system parameters are summarized in **Table 1**. Ambient temperature ranged from about 21.9 to 30.3 °C, and relative humidity from 57.1% to 99.9%, depending on the time of day. These values are largely consistent with the recommended conditions for melon growth (25–30 °C and 70–80% RH). The nutrient solution pH stayed near neutral (7.2–8.0), which is within acceptable limits (optimal pH ~5.8–7.8 for melon). The TDS of the hydroponic solution remained around 1860–1894 ppm, close to the optimal range of 1600–1800 ppm for hydroponic melons. Overall, the sensors captured stable environmental data, indicating the system can maintain favourable growing conditions. The humidifier response is shown in **Table 2**. When the measured relative humidity fell below 80%, the humidifier was triggered ON, while it remained OFF at higher humidity levels. This behaviour matched the design threshold.

The results demonstrate that the IoT-based drip irrigation system largely functioned as intended, providing real-time monitoring and automated control. The recorded environmental conditions (Table 1) remained within suitable ranges for melon growth. The automated humidifier successfully maintained humidity above the threshold, turning on below 80% RH. These outcomes indicate that the core hardware (sensors, relays, pump, humidifier) and software logic (ESP8266 program) were correctly implemented.

Table 1. Environmental parameters recorded by the system at various times of day

Time (WIB)	Temperature (°C)	Humidity (%)	pH	TDS (ppm)
07:00	23.10	94.30	7.3	1869
09:00	30.30	57.10	8.0	1878
12:00	28.70	79.60	7.9	1862
13:00	28.20	74.50	7.8	1894
18:00	21.90	99.90	7.2	1889
22:00	25.10	85.70	7.5	1884

Table 2. Humidifier ON/OFF response to relative humidity

Humidity (%)	Humidifier State
50	ON
60	ON
70	ON
80	OFF
90	OFF

A

B

Figure 3. Illustrate the Blynk app interface when connected (A) and disconnected (B), respectively.

IoT connectivity tests with the Blynk app showed that sensor data were transmitted in real-time only when the device was online. When the Wi-Fi was connected, temperature, humidity, pH, and TDS values were displayed on the smartphone app instantaneously. Conversely, if the app was offline (no internet), the data did not update (the graphs showed "no data") (Figure 3-A and 3-B). The Blynk IoT platform enabled comprehensive data access and control from a distance, consistent with previous reports on smart home IoT systems. However, connectivity dependence was evident: data only updated when internet was available. In practice, this means growers can monitor parameters only with network access; offline operation yields no remote feedback.

Water discharge measurements at seven drip points are listed in **Table 3**. The flow rates varied widely from 10 to 60 mL/min. Four of the emitters delivered about 10–12 mL/min, two emitted 30 mL/min, and one delivered 60 mL/min (likely an outlier). The average of the four lower-rate points was ~10.5 mL/min. These results indicate non-uniform water distribution across the drippers, which is confirmed by the original analysis. The variability is attributed to different emitter positions and backflow effects within the pipe network. Non-uniform drip rates can lead to inconsistent irrigation among plants. This issue was noted in the field data, likely due to differences in emitter placement and fluid dynamics (backflow). To improve this, emitters should be calibrated or adjusted, and the pipe layout optimized to ensure even flow.

Table 3. Water discharge (mL/min) at each drip emitter (pump on for 1 minute).

Emitter Point	Discharge (mL/min)
1	30
2	60
3	10
4	10
5	10
6	30
7	12

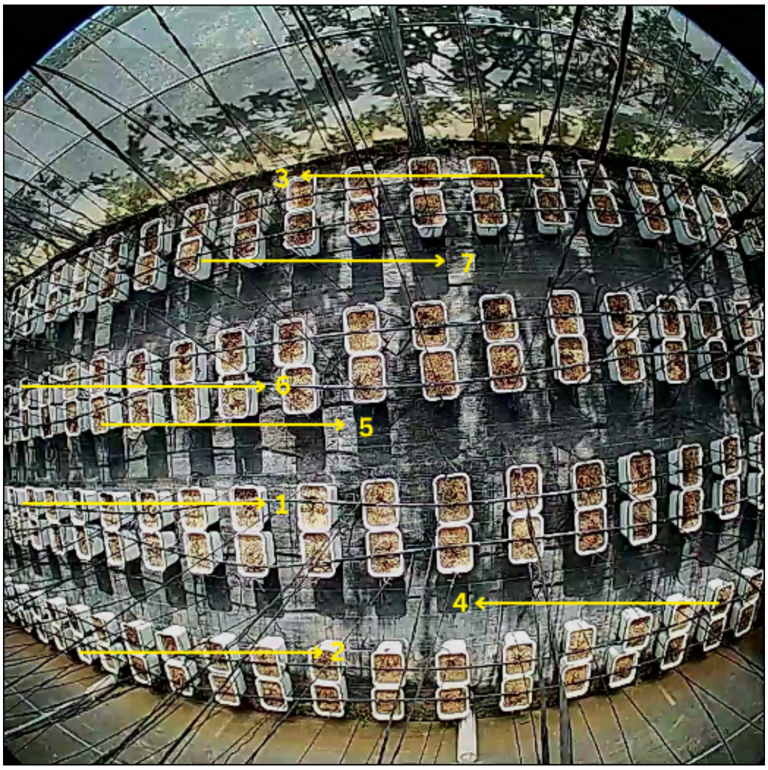

Figure 4. The locations of the sampled emitters in the greenhouse (as per the original schematic).

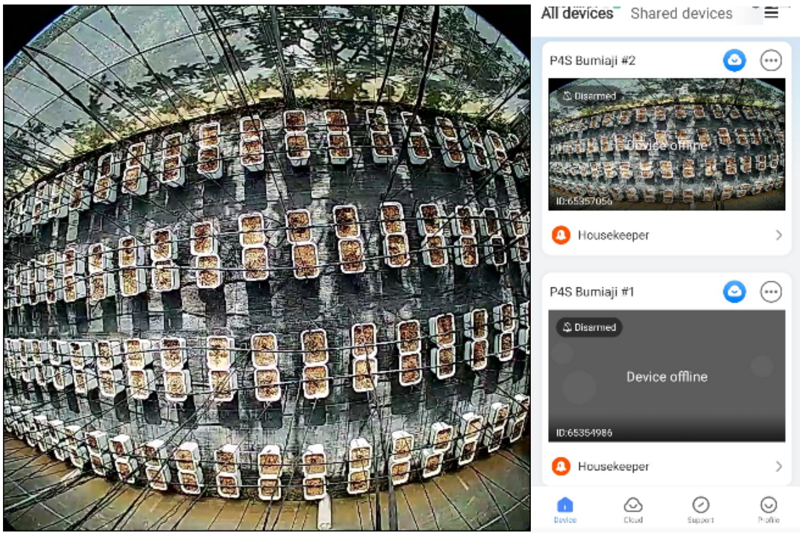

Figure 5. The Blynk app display when connect to internet (up) and disconnect (bottom)

Finally, the greenhouse camera output was verified. When the V380 Pro camera was functioning and the IoT device was online, real-time images of the plants could be viewed in the Blynk app. If the camera was offline or malfunctioning, no image was transmitted to the Blynk app (Figure 5).

Another practical consideration is fertigation: in this implementation, nutrient delivery was not integrated into the irrigation (no liquid fertilizer injection), as the pump was simply turned on manually when needed. Future designs should include automatic fertigation to synchronize nutrient supply with watering (Radočaj et al., 2022; Raza et al., 2023; S. Sharma, 2023). Sensor accuracy and reliability also limited full automation; for example, some sensors may have drifted or failed, requiring manual overrides. The original analysis similarly concluded that while the IoT scheme was sound, hardware issues prevented the system from operating at full potential.

Despite these limitations, the system achieved its main goals. It successfully automated irrigation based on humidity thresholds and provided users with real-time visibility into greenhouse conditions via a smartphone. This proof-of-concept aligns with other studies highlighting the benefits of IoT for agricultural monitoring (Nora et al., 2020; Sandi & Fatma, 2023). In terms of practical implications, such a system could help improve efficiency and responsiveness in melon cultivation, especially where labour for monitoring is scarce.

Future work should focus on enhancing system robustness: improving sensor calibration and durability, ensuring stable power supply, and achieving uniform water distribution. Integrating automated fertigation and perhaps soil moisture sensing for individual plants would make the system more comprehensive. Additional data collection over a full growing season would clarify the agronomic impact on plant health and yield.

4. CONCLUSION

An IoT-based automatic drip irrigation system was implemented for melon cultivation in a greenhouse, enabling solar-powered operation, environmental sensing, and remote monitoring. The system successfully recorded key parameters (temperature, humidity, pH, TDS) and operated a pump and humidifier according to the programmed logic. The Blynk app allowed real-time data viewing and control when online. However, some components did not perform optimally: sensor issues prevented full automation, and water flow was uneven across emitters. Overall, the IoT drip irrigation implementation functioned, but requires further refinement. These findings provide a basis for improving smart irrigation systems in greenhouse melon production.

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