

ABSTRAK

Peningkatan kebutuhan cabai di Indonesia tidak diimbangi oleh kestabilan produksi akibat ketidaksesuaian kondisi lingkungan seperti suhu dan kelembapan tanah, serta menyempitnya lahan pertanian akibat alih fungsi lahan. Budidaya cabai secara *indoor* menjadi solusi alternatif karena memungkinkan pengendalian lingkungan secara terkontrol. Namun, sistem ini membutuhkan mekanisme otomatis yang mampu menjaga kondisi lingkungan tanaman secara konsisten. Penelitian ini bertujuan merancang dan membangun sistem otomatis pada media simulasi pot cabai *indoor* berbasis *Internet of Things* (IoT) menggunakan pendekatan *Rule-Based System* yang mampu memantau dan mengendalikan suhu udara, kelembapan tanah, serta pH tanah secara *real-time*.

Penelitian menggunakan metode pengembangan sistem *prototyping* yang bersifat iteratif. Sistem dibangun menggunakan mikrokontroler ESP32 sebagai pusat kendali yang diintegrasikan dengan sensor suhu DS18B20, sensor kelembapan tanah FC-28, dan sensor pH tanah. Data sensor diproses menggunakan logika *Rule-Based System* berbasis *IF-THEN* untuk menentukan aksi pada aktuator berupa pompa air, pompa nutrisi, kipas, dan lampu *grow light*. Mekanisme *hysteresis* diterapkan untuk mencegah chattering pada aktuator. Komunikasi data dilakukan melalui protokol MQTT untuk *monitoring real-time*, sedangkan penyimpanan data *historis* menggunakan platform cloud Supabase dengan sinkronisasi waktu NTP. Pengumpulan data dilakukan melalui studi pustaka, wawancara petani pertanian, dan observasi langsung.

Hasil pengujian menunjukkan seluruh skenario uji mencapai 100% PASS. Sensor pH memiliki rata-rata *error* 3,52%, masih dalam batas toleransi 5%. Mekanisme *hysteresis* pada kontrol suhu terbukti efektif mencegah chattering dan menjaga kestabilan aktuator. Sistem penyiraman berhasil menjalankan logika siklus ganjil-genap untuk pergantian pemberian nutrisi dan air biasa, serta safety interlock saat suhu ekstrem atau pH di luar rentang optimal. Komunikasi MQTT memenuhi latensi ≤ 2 detik dengan keberhasilan kontrol 10/10 percobaan. Tanaman cabai yang dibudidayakan selama 10 minggu menunjukkan pertumbuhan konsisten dengan tinggi tanaman mencapai 40 cm dan lebar daun 6,5 cm.

Sistem otomatis berbasis *Rule-Based System* berhasil menjaga parameter suhu, kelembapan tanah, dan pH tanah dalam rentang optimal secara otomatis sehingga mendukung pertumbuhan tanaman cabai *indoor* secara stabil dan terkontrol. Integrasi IoT melalui MQTT dan Supabase memungkinkan *monitoring* dan kontrol jarak jauh secara efisien. Untuk pengembangan selanjutnya, disarankan penambahan algoritma kontrol yang lebih adaptif seperti *fuzzy logic* atau PID, sensor TDS untuk kontrol nutrisi, fitur notifikasi kondisi abnormal, serta penerapan machine learning untuk deteksi penyakit tanaman secara otomatis.

Kata Kunci: IoT, *Rule-Based System*, cabai *indoor*, ESP32, otomatisasi pertanian

ABSTRACT

The increasing demand for chili in Indonesia is not matched by stable production due to unsuitable environmental conditions such as temperature and soil moisture, as well as the shrinking of agricultural land caused by land conversion. Indoor chili cultivation has emerged as an alternative solution by enabling controlled environmental conditions. However, this approach requires an automated mechanism capable of consistently maintaining the plant's environmental parameters. This study aims to design and develop an automated system for an indoor chili pot simulation medium based on the Internet of Things (IoT) using a Rule-Based System approach, capable of monitoring and controlling air temperature, soil moisture, and soil pH in real-time.

This research applies a prototyping development. This study applied an iterative prototyping system development method. The system was built using an ESP32 microcontroller as the central controller, integrated with a DS18B20 temperature sensor, FC-28 soil moisture sensor, and soil pH sensor. Sensor data was processed using IF-THEN logic of the Rule-Based System to determine actions on actuators including a water pump, nutrient pump, fan, and grow light. A hysteresis mechanism was implemented to prevent actuator chattering. Data communication was carried out via the MQTT protocol for real-time monitoring, while historical data was stored using the Supabase cloud platform with NTP time synchronization. Data collection was conducted through literature review, expert interviews with a chili farmer, and direct observation.

Test results showed that all test scenarios achieved a 100% PASS rate. The pH sensor recorded an average error of 3.52%, within the 5% tolerance threshold. The hysteresis mechanism on temperature control proved effective in preventing chattering and maintaining actuator stability. The irrigation system successfully executed odd-even cycle logic for alternating nutrient and plain water delivery, along with a safety interlock triggered during extreme temperature or out-of-range pH conditions. MQTT communication met a latency of ≤ 2 seconds with a 10/10 successful control rate. Chili plants cultivated over 10 weeks demonstrated consistent growth, reaching a plant height of 40 cm and leaf width of 6.5 cm.

The Rule-Based System-based automated system successfully maintained temperature, soil moisture, and soil pH parameters within optimal ranges, supporting stable and controlled indoor chili plant growth. IoT integration through MQTT and Supabase enabled efficient remote monitoring and control. For future development, it is recommended to incorporate more adaptive control algorithms such as fuzzy logic or PID, a TDS sensor for nutrient control, abnormal condition notification features, and the application of machine learning for automatic plant disease detection.

Keywords: *IoT, Rule-Based System, indoor chili, ESP32, agricultural automation*