## Field Test Logs and Performance Analysis

The HydroFarmIoT system underwent multiple rounds of field testing within a real hydroponic environment using a nutrient reservoir. Each sensor such as the pH, TDS, water temperature (DS18B20), and ultrasonic water level were tested individually and then collectively within the full system. Initial calibration was performed using standard pH buffer solutions (pH 4 and 7), and TDS readings were compared against known nutrient concentrations.  
  
Live testing involved monitoring sensor values through the Node-RED dashboard, with real-time updates via MQTT. The automated pH regulation logic was validated by altering the solution to fall outside acceptable thresholds, which triggered the appropriate solenoid valve (either acidic or alkaline). This actuation successfully adjusted the pH value back to the desired range.

A screenshot of a computer

Description automatically generated

Figure 1 :Real-time sensor readings visualized on the Node-RED dashboard.

System responsiveness was measured by the delay between detection and actuation, typically under two seconds. Data was visualized on the Node-RED interface using gauges and line charts, and manual overrides were tested through toggle switches.

Plant growth was tracked over three months, with photos taken to document progress. The use of pH automation ensured a more stable nutrient environment, reflected in healthier plant roots and consistent leaf growth. No major hardware or software failures occurred during the test period, demonstrating the stability of the ESP32-based setup and the reliability of the dashboard communication.

A tall white tower with plants growing on it

Description automatically generated

Figure : Plant growth progression over three months under HydroFarmIoT monitoring.

Power consumption remained within expected limits, and all actuators operated as designed under the 12V power supply managed through the relay module. Field tests confirmed the successful integration of all components and validated the end-to-end functionality of the system under real-world hydroponic conditions.