

COMPONENTS OF AN AUTOMATIC DEHUMIDIFIER SYSTEM FOR COMMERCIAL APPLICATION

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ABSTRACT

There are already equipment available to remove moisture from controlled settings, but because of their high cost and maintenance needs, these are frequently avoided. Numerous microprocessor-based systems have been developed as a result of recent technological developments. Based on this development, a system was built around a microprocessor that can operate according to humidity and temperature values detected by a sensor. The system features a laboratory-specific design and software that allows users to adjust limit values via a touchscreen. This flexibility enables the relative humidity and temperature thresholds to be tailored for different growing media, such as sand, clay, silt, peat, and perlite, as well as for various plant species. The total cost of the system, including all components, is approximately \$350, making it an accessible option for integration into existing growing environments.

Keywords: Dehumidifier, Humidity Sensor, System Design.

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INTRODUCTION

The rapid growth of the global population, coupled with declining freshwater resources and the adverse impacts of climate change, necessitates the development of sustainable and efficient agricultural production strategies. In this context, controlled environment facilities—such as growth chambers, greenhouses, and plant factories—offer researchers the ability to apply and monitor crop stress conditions in highly regulated settings. By isolating experimental units from external environmental fluctuations, these controlled environments enable precise evaluations of individual

variables' effects on plant growth and productivity [1-3]. This level of control is particularly crucial in irrigation and water-use efficiency studies, where consistent and scientifically reliable reductions in irrigation water are required [4]. The importance of such studies is heightened as agriculture faces challenges related to desertification, soil degradation, and the need to enhance crop yields to satisfy a growing global population [5-7].

While a variety of environmental parameters—such as light intensity, photoperiod, temperature, irrigation

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scheduling, and air circulation—are typically monitored in controlled environments, the role of relative humidity is often underestimated. However, RH significantly impacts several physiological and pathological processes in plants, including transpiration, stomatal regulation, nutrient uptake, and disease development. Maintaining an optimal humidity range is essential for stabilizing the vapor pressure deficit, which directly influences evapotranspiration rates and plant water balance. Despite its importance, humidity regulation systems are frequently overlooked in agricultural research due to high costs, complex maintenance requirements, and incompatibility with small-scale research facilities. While commercial dehumidifiers are effective, they are generally designed for industrial use, posing economic and technical challenges for experimental crop growth environments [8].

To address these limitations, this study focuses on designing and implementing a low-cost, easily adaptable automatic dehumidification system specifically for controlled agricultural environments. The proposed system integrates a microcontroller, a digital temperature and humidity sensor, and a 35 cm diameter exhaust fan, all coordinated through a custom software interface [9]. A key feature is the touchscreen-based control unit, which allows users to adjust threshold values for temperature and humidity according to the needs of different crops and substrates. This flexibility enhances the system's applicability across various experimental setups. With an overall material cost of approximately 350 USD, the system offers an economically viable alternative to commercial units while maintaining accuracy and operational reliability. Consequently, it can be seamlessly integrated into ongoing research

activities in controlled environments, contributing to cost-efficiency and the reproducibility of experimental results. Furthermore, by democratizing access to humidity regulation technology, this study provides a valuable tool for researchers aiming to generate high-quality data in plant physiology and crop stress studies under controlled conditions.

MATERIALS AND METHODS

Experimental Site and Controlled Environment

The study was conducted at Electrical and Electronic Engineering Department, Presidency University, Dhaka, Bangladesh. This laboratory was specifically designed to maintain controlled environmental conditions, minimizing external factors such as wind, rainfall, and temperature fluctuations. The experimental setup was located in an enclosed growth chamber, which enabled the manipulation of environmental parameters such as light, air temperature, irrigation regime, and relative humidity. This chamber served as a test platform for the operation and validation of the automatic dehumidification system developed in this study [10-13].

Microcontroller Unit

A microcontroller Unit served as the central processing unit, operating at a clock speed of 16 MHz. It features 14 digital input/output pins, providing adequate processing capacity for sensor data acquisition and control logic.

Humidity and Temperature Sensor

A digital sensor was integrated for continuous monitoring of air temperature and relative humidity. This sensor operates within a temperature range of 0–50 °C and a relative humidity range of 20–90%, with an accuracy of ± 2 °C and $\pm 5\%$ RH. Factory pre-calibration ensures stable performance in laboratory applications [14].

Table 1: Hardware main components and their function.

Component	Role
Sensor	Temperature and humidity sensing
Microcontroller	System control
Ventilation Unit	Dehumidification process
Relay Module	Fan control
Touchscreen	Limit adjustment and display
Wires and power adapters	Stable connection

Ventilation Unit

A 35 cm diameter exhaust fan was connected to the microcontroller via a relay module. The fan expels humid air from the chamber when humidity levels exceed the user-defined threshold.

Relay Module

A single-channel 5V DC relay was utilized to control the fan's operation at 220 V AC, allowing the **Microcontroller** board to safely manage the high-voltage power supply of the ventilation system.

Touchscreen Interface

A small LCD touchscreen was implemented as the user interface. It displays real-time measurements of temperature and humidity, enabling users to set upper and lower threshold values, along with providing manual override options.

Supporting Components

Standard jumper wires, power adapters, and connectors were employed to ensure secure and stable communication between the hardware components.

Software Development and System Design

The control software was developed to read temperature and humidity data from the sensor at one-minute intervals. These measurements were then compared to user-defined threshold values. When the humidity exceeded the upper limit, the relay module was activated, automatically turning on the exhaust fan. Conversely, once the humidity fell below the lower limit, the relay disconnected the fan, helping to stabilize the chamber environment. The touchscreen interface allowed the operator to adjust the threshold values dynamically based on experimental requirements, such as the type of growing medium (sand, clay, silt, peat, perlite) or the crop species being studied [15-17]. Additionally, a manual override option enabled the fan to be turned on or off independently of the automated system when necessary. The entire system underwent validation for stability and accuracy through repeated on-off cycles and adjustments to the thresholds.

Experimental Protocol and Validation Tests

To evaluate the system's performance, a series of laboratory tests were conducted.

Functional Test

The compatibility of hardware components was assessed by operating the system in a laboratory setting and confirming the fan's real-time response to humidity changes.

Accuracy Test

The sensor measurements were cross-validated with a commercial temperature-humidity data logger (± 0.5 °C and $\pm 1\%$ RH accuracy) under identical environmental conditions over a three-day monitoring period.

Long-Term Performance Test

The system was operated continuously for several weeks with varying threshold levels to evaluate its stability, reliability, and responsiveness. Humidity and temperature data were logged at one-hour intervals, allowing for a detailed assessment of the system's ability to maintain conditions within specified ranges.

Overall, temperature values remained relatively stable between 19.5-20.5 °C, with occasional outliers exceeding 22 °C. Relative humidity was primarily maintained between 40-60%, indicating effective regulation by the system. However, sporadic deviations were noted, including unusually low RH values (3-5%), likely due to sensor misreadings or sudden environmental disturbances, such as the chamber door being opened [18-20].

Validation Against Commercial Logger

To validate the accuracy of the DHT11 sensor measurements, parallel observations were carried out using a commercial temperature-humidity logger with higher precision. The comparison revealed a strong correlation ($R^2 > 0.891$) between the Arduino-based system and the logger, although slight discrepancies were noted in relative humidity readings at extreme values.

These variations are attributed to the sensor's limited resolution, which has a tolerance of $\pm 5\%$ RH. Despite these minor differences, the results confirmed that the developed system provided sufficiently accurate measurements for research purposes in controlled environments.

Long-Term Stability and Reliability

Continuous operation of the system over several weeks demonstrated stable performance. The automatic on-off cycles of the exhaust fan effectively maintained humidity levels within the defined range, even under fluctuating environmental conditions. Cost-effectiveness was a significant advantage, as the total material cost of approximately \$350 is substantially lower than that of commercially available dehumidification units. Additionally, the low energy consumption of the fan and the simplicity of the microcontroller-based system further enhance its suitability for prolonged experimental use.

Comparison with Earlier Report

The findings of this study align with earlier reports highlighting the importance of humidity control in plant growth environments. Inappropriate humidity management can lead to excessive transpiration or increased disease incidence, while conventional dehumidification systems in greenhouses are often technically complex. In contrast, the system developed in this study offers a simpler, low-cost solution that can be readily adapted for small-scale laboratories or greenhouses. Although its accuracy is somewhat limited compared to advanced sensors, its operational performance makes it an attractive alternative for experimental applications [21].

Limitations and Future Improvements

Despite these encouraging results, several limitations should be considered. The sensor provides relatively coarse resolution, which may reduce accuracy in experiments requiring highly precise humidity

measurements. Additionally, the system currently relies solely on dehumidification through forced ventilation; future enhancements could incorporate both humidification and dehumidification functions for more comprehensive climate control. Integrating the system with IoT-based data logging and remote monitoring platforms would also enable continuous data storage, cloud-based analysis, and real-time remote control, thereby expanding its practical utility in advanced research applications [22-24].

CONCLUSION

This study details the design, development, and evaluation of a low-cost automatic dehumidification system for controlled agricultural environments. By incorporating a microcontroller, a temperature-humidity sensor, a relay module, and an exhaust fan, the system effectively maintains relative humidity within specified thresholds. Validation against a commercial logger confirmed the system's accuracy for experimental applications, while long-term operation demonstrated its stability and reliability.

The primary advantage of this system is its affordability and adaptability. With a total cost of approximately \$350, it offers a cost-effective alternative to commercial dehumidifiers, which can be prohibitively expensive for small-scale laboratories and research facilities. Additionally, the touchscreen interface allows for flexible adjustment of threshold values, making the system suitable for a variety of crops and experimental setups.

Overall, the results suggest that the proposed design provides a practical and accessible solution for researchers aiming to enhance humidity management precision in controlled environments. Future work should focus on integrating more advanced sensors, expanding the system to include both humidification and dehumidification

capabilities, and incorporating technologies for remote monitoring and data analysis. These improvements would further broaden the system's applicability in precision agriculture and controlled environmental research.

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