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Design and Evaluation of an Automatic Roof Drive Prototype in Optimizing Tomato Cultivation

Budi Wibowo[1], Affan Nawly Tanjung[1], Nur Afandi[1], Tio Dwi Ananpasha[1], Taufik Hidayat[2]

[1]Department of Informatics Engineering, Institut Teknologi Budi Utomo, Jakarta, Indonesia

[2]Department of Computer Engineering, Universitas Wiralodra, Indramayu, Indonesia

Corresponding Author: Budi Wibowo (e-mail: budiwibowo1993@gmail.com)

ABSTRACT
This study introduces the design and evaluation of an automatic roof drive prototype aimed at optimizing tomato cultivation. Developed to address the challenges of erratic weather, the system seeks to enhance the efficiency of tomato farming. The prototype integrates a weather sensor, microcontroller, and roof drive mechanism, allowing it to operate automatically based on real-time environmental conditions. Effectiveness was assessed through field trials measuring key growth parameters such as plant height, fruit number, and fruit quality. Results indicate that the automatic roof drive system significantly improves both the productivity and quality of tomato crops. Additionally, the system effectively mitigates losses due to extreme weather conditions, including heavy rain and excessive heat. These findings highlight the potential of automated roof drive technology to support more efficient and sustainable agriculture. Future work will focus on refining the system for broader applications and integrating advanced technologies such as IoT and machine learning for further optimization.

KEYWORD Automatic roof drive, tomato cultivation, agricultural efficiency, agricultural technology.

1. INTRODUCTION

In recent years, agricultural technology has developed rapidly with the implementation of advanced automation and control systems. One promising innovation is the use of automated roofs in greenhouses to control the environmental conditions of plants. This automatic roof is designed to open and close automatically based on environmental parameters monitored by sensors, such as temperature, humidity, and light intensity.[1]

Modern agriculture faces major challenges related to climate change and the need to improve production efficiency. Tomato cultivation, as one of the important commodities, requires protection against extreme weather and optimal environmental regulation. Automated roofing can be an innovative solution in maintaining ideal conditions for tomato growth. This research aims to design and evaluate an automatic roof drive prototype that can improve the productivity and quality of tomato crops.[2]Agriculture is a vital sector in the world economy, and tomatoes are one of the most economically valuable horticultural crops. However, tomato cultivation often faces major challenges due to erratic weather changes.[3] Environmental factors such as temperature, light intensity and humidity greatly affect the growth and quality of tomato yields. Extreme weather, such as heavy rain and excessively high or low temperatures, can damage plants and reduce yields.[4][5]The use of greenhouses is a common solution applied to protect plants from adverse weather conditions. However, conventional greenhouses often require intensive manual settings and are not always responsive to real-time changes in environmental conditions.[6]

Technological innovations in agriculture, particularly automation systems, offer potential solutions to address these issues. One of the proposed innovations is the use of automatic roof drives on greenhouses. The system is designed to automatically open and close the roof based on environmental conditions, such as temperature and light intensity, thus creating optimal conditions for tomato plant growth.[7] The latest data from the Central Bureau of Statistics (BPS) shows that tomato production in Indonesia in 2022 will reach 1.12 million tons, a slight increase of 0.21% compared to the previous year's 1.11 million tons. This data shows stability in tomato productivity in Indonesia over the past few years.

It is expected that the use of automatic roof movers can improve the efficiency of tomato cultivation in the following ways:

1) **Temperature and Humidity Control**
   Opening the roof when the temperature inside the greenhouse is too high to prevent overheating and closing it when the temperature decreases to maintain warmth [1], [3].
2) **Adjusting Light Intensity**
   Adjusting the lighting received by the plants according to their photosynthesis needs reduces the risk of damage from too intense sunlight [3].
3) **Reduce Losses**
   Protects plants from damage due to excessive rainfall and other extreme weather [8].

This research aims to design and evaluate an automatic roof drive prototype that can be integrated in a greenhouse system for tomato cultivation. By applying this technology, it is expected to achieve a significant increase in productivity and quality of tomato crops.

2. METHOD RESEARCH

Automation in agriculture has undergone significant development, with applications ranging from automated irrigation, automated fertilization, to automated climate control in greenhouses.[9], automation in agriculture can improve production efficiency and effectiveness by reducing dependence on manual labor and increasing precision in resource management. Greenhouses are structures designed to protect plants from extreme climatic conditions and provide a controlled environment for plant growth. According to research [10], greenhouses can increase tomato yields by up to 30% compared to open field cultivation. However, climate management in greenhouses requires an effective control system to ensure optimal conditions for plant growth. An automated roof system is one of the innovations in greenhouse technology that allows for better control of environmental conditions within the greenhouse. Automatic roofs can open and close based on data collected by sensors, such as temperature, humidity, and light intensity [11]. According to research by [8], automated roofing systems can reduce temperature fluctuations in greenhouses and improve optimal microclimate conditions for plant growth [12].

This research design is experimental using hardware and software simulations to develop and test an automatic roof drive prototype under tomato cultivation conditions. This research consists of several stages: preparation, development, implementation, testing, and evaluation.[13], [14] Gather information from various sources about IoT technology, greenhouse automation, and automatic control systems. Selecting weather sensors (such as soil moisture sensor, temperature sensor, light sensor, and rain sensor), microcontroller (ESP32), and actuator (servo motor) to be used in the system. Designing the system architecture involving the integration of sensors, microcontroller, and Things Board platform [15]. This automatic roof prototype is designed to optimize environmental conditions for tomato plant growth, especially in the face of temperature changes [16]. The system works by monitoring the ambient temperature in real-time through an integrated temperature sensor. When the sensor detects that the ambient temperature drops below 29 degrees Celsius, the roof will automatically close. The roof closure aims to maintain warmth inside the plant area, protecting the plants from excessive cold. UV Lights Turn on Additionally, the UV lights will automatically turn on to provide additional light and warmth needed by the tomato plants during low temperatures. These UV lights also help in the process of photosynthesis and plant growth. When the temperature increases above 24 degrees Celsius, the roof will automatically open. The opening of the roof allows for better air circulation and prevents overheating inside the plant area and the UV Lamp Dims In this condition; the UV lamp will dim because the plants already get enough natural light from the outside environment and do not require additional intense artificial light. This automation process is supported by a microcontroller that controls the roof mechanism and UV lamp based on data from the temperature sensor. Thus, this prototype not only increases efficiency in maintaining optimal conditions for tomato plants but also reduces reliance on manual intervention, making it a more effective and sustainable solution in modern agriculture.

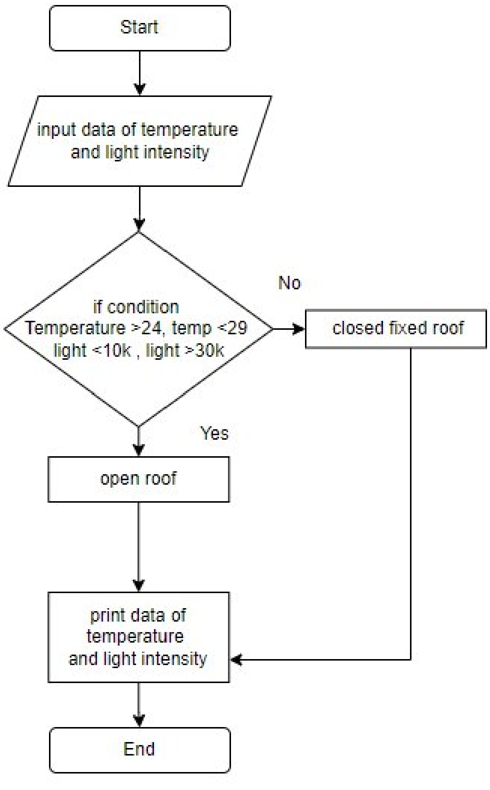

Fig. 1 Flowchart Process Prototype

3. RESULT AND DISCUSSION

An automatic roof control system for tomato plant cultivation was designed and implemented using an ESP32 microcontroller, soil moisture sensor, DHT11 temperature and humidity sensor, servo motor, and photo resistor. Hardware simulation and testing were performed using the Wokwi platform, while data management was done with Things Board. The system architecture is shown in Figure 2, which shows the integration of sensors, microcontrollers, and actuators.

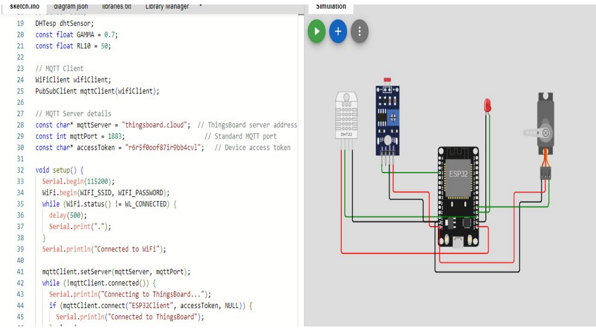

Fig.2 integration of sensors, the microcontroller, and the actuator.

Photo resistors are used to measure light intensity. This sensor successfully detects changes in light intensity quickly and accurately, which is important for determining whether the roof needs to be opened or closed to optimize light reception for the plants. Servo motors are used to control the opening and closing of the greenhouse roof. The motors respond to commands from the ESP32 with an average response time of less than 1 second. The movement of the motor is smooth and precise, allowing accurate positioning of the roof. Data from the sensors is transmitted to the Things Board platform in real-time, enabling continuous monitoring and automatic control. The Things Board dashboard displays sensor readings and allows the user to configure control rules for the roof mechanism. Automation rules are set to open the roof based on design and simulation, the system is already working properly, i.e. the roof will open when the room temperature is above 24 'C and will close if the temperature is below 24 degrees Celsius. It can be said that the system has protected the tomato plants according to the light intensity and rainfall required by the tomato plants.

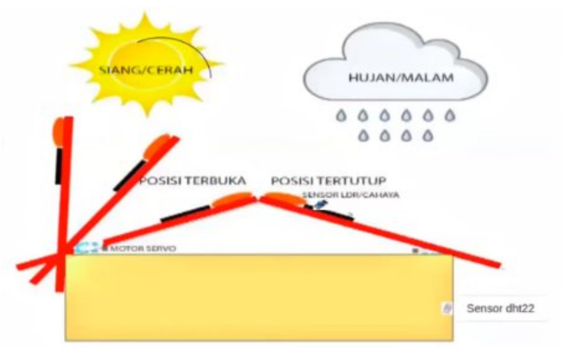

Fig.3 Mechanical Model of the Tool Viewed

The successful implementation of this automated roof control system prototype demonstrates the feasibility and benefits of using IoT technology in agriculture. By automating environmental control, farmers can increase crop yields, reduce labor costs, and ensure more consistent growing conditions. The scalability and flexibility of this system make it suitable for various types of greenhouse cultivation.

4. CONCLUSION

The test results show that the use of the automatic roof prototype in tomato plant cultivation can significantly improve productivity and crop quality. Automatic roof movers provide significant gains in productivity and quality of tomato plants over traditional methods. Empirical data from this study measured the success of the device in terms of increased quality and quantity of production, as well as reduced risk to weather conditions. For example, if the use of automatic roof movers improves fruit quality (e.g. moisture content, ripeness level) or reduces damage from bad weather, this indicates the success of the technology. Measurements of growth parameters such as plant height, fruit number, and fruit quality indicated a clear improvement over traditional method.

The system also proved effective in reducing losses caused by extreme weather conditions such as heavy rain and excessive heat. The main contribution of this research is the development of more efficient and sustainable agricultural technology through automation, which can adjust environmental conditions in real-time to support optimal plant growth. For future research, it is recommended to develop this system with the integration of Internet of Things (IoT) technology and machine learning to improve weather prediction accuracy and more adaptive system responses. In addition, trials on other types of crops and on a larger scale can provide additional insights into the effectiveness and flexibility of this automated roofing system in various agricultural conditions.

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