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Solar Powered UV Light Pest Management for Sustainable Agriculture

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Abstract

This project addresses the creation and application of an ultraviolet (UV) light system that runs on solar power for the purpose of controlling pests in agricultural environments. The main goal is to reduce insect populations that have an impact on crop output in an environmentally sustainable manner. UV lamps are powered by solar energy and are used by the system to attract and trap different types of agricultural pests. The solar-powered UV light trap's design, constructing, and testing are all included in the research. The design prioritizes increasing the attraction rate of bugs and boosting energy efficiency. Choosing the right materials and putting the solar panels, UV lights, and trapping devices together are part of the construction step. Field tests are used in testing to evaluate the system's performance in actual agricultural settings. The outcomes show that, without the use of dangerous chemicals, the solar powered UV light pest management system is successful in dramatically lowering pest populations. By using only renewable solar energy, the system reduces the environmental effect. The results imply that this innovative approach can improve agricultural sustainability and production.

1. Introduction

The agricultural industry faces significant challenges due to pests that damage crops and reduce yields. Traditional chemical pesticides, while effective, pose environmental and health risks. Pests can be prevented and eliminated using a variety of techniques, including mechanical, chemical, biological, and physical ones. Pesticides can be poisonous to a wide range of other creatures such as fish, birds, and non-target plants [1]. Numerous pests that are attracted to wheat, fruits, vegetables, and other crops are poisonous and harmful. According to a study, using an ultraviolet (UV) light bulb is the greatest and most effective approach to attract most nocturnal insect species [2]. The UV electromagnetic radiations present in sunlight is referred to as "UV light". Since its wavelength is smaller and its frequency is higher than the violet radiations present in the visible spectrum, it is known as UV, or ultraviolet radiation. The wavelengths of UV radiation range from 10 to 400 nanometers. However, the range of 100–400 nanometers is divided into three categories: UVA, UVB, and UVC. Particularly for plants, these three forms of UV light have various benefits and drawbacks [3]. The widespread use of chemical pesticides in agriculture has raised environmental concerns due to their negative impact on non-target creatures, soil health, and water quality. Additionally, the continuous development of pesticide-resistant pest populations presents a major obstacle to sustainable pest management. There is an urgent need for innovative, sustainable, and eco-friendly pest management techniques that minimize the use of harmful chemicals. Therefore, this project explores the creation and application of a solar-powered UV light system designed to control pests in an environmentally sustainable manner. By harnessing solar energy, UV lamps can attract and trap various agricultural pests, providing a chemical-free solution to pest management.

2. Overview of UV light Application for Pest Management

The ability of UV light, especially in the UV-A spectrum (300-400nm), to attract a range of agricultural pests is the foundation for the use of UV light for pest management [4]. Pest behaviour can be influenced by UV light by drawing them to a particular area where they can be neutralized or captured. By using a non-chemical approach to pest control, this technology lessens the harm that conventional pesticides cause to the environment. This idea is applied in UV light traps, which combine UV lights with trapping devices to efficiently capture pests. According to studies, UV light works especially well at repelling insects that are drawn to light sources at night, like flies, moths, and beetles [5].

2.1 Theory of Pests in Spinach Plantations

Organisms known as pests cause harm to crops, lowering their quality and value. By feeding on plants, they can inflict direct harm or indirect harm by dispersing illnesses [6]. Aphids, flea beetles, wireworms, and cutworms are common pests in spinach plantations. Pests are a big threat. There are two main types of damage they cause to crops that are growing. First, pests that consume leaves and create holes in stems, fruit, or roots are directly damaging plants. The second type of damage is known as indirect damage, in which pests harm crops indirectly by spreading bacterial, viral, or fungal infections [7].

2.2 Theory of UV Lights

UV light, when used at the right frequency and dose, can boost the production of active compounds in medical and traditional plants while also promoting a healthy growth environment. Fig.1 shows the different wavelength of the UV light. UV radiation, with wavelengths ranging from 10 nm to 400 nm, is an important portion of the electromagnetic spectrum. This section of the spectrum is not visible to the human eye, while mostly insects and birds can perceive some UV light. [8] UV light is categorized into UVA, UVB, and UVC, each with different properties and effects on pests. UV-A light is effective in attracting a variety of pests, making it a potential tool for pest management [4].

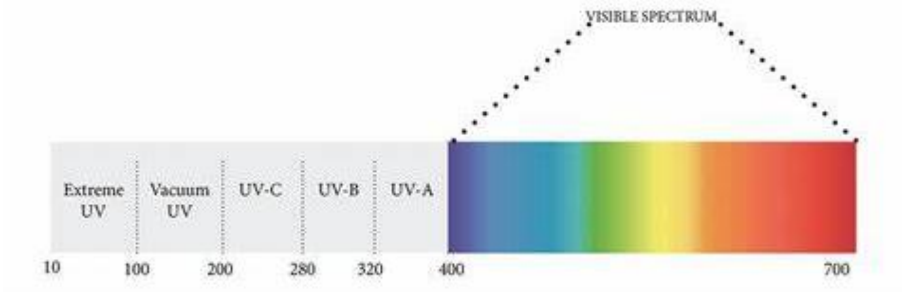

Fig. 1 *Wavelength of different UV light*

2.3 Study of UV Lights in Pest Management

Understanding the biological impact of light on insects may help in the development of techniques for using light to minimise pest activity in the fields. Insects are well recognised for flying towards light or something bright at night. The visible light wavelength for insects is determined by the spectral sensitivity of their retinas, which typically extends into the ultraviolet range, which is invisible to humans. Insect compound eyes are made up of several photosensitive components. It is widely acknowledged that insects can see UV light as an unique colour that humans cannot. UV radiation with wavelengths ranging from 315nm to 400nm is the most noticeable for insects [5].

3. Methodology

The goal is to develop the software and hardware for a solar powered UV light pest management for a spinach plant. This chapter will also outline the components and software that will be used in this project. All these resources will be used to create a project prototype. The project involves designing, constructing, and testing a solar-powered UV light pest management system. The design phase includes selecting appropriate materials and integrating solar panels, UV lights, and trapping devices. Construction involves assembling these components, while testing evaluates the system's performance in real agricultural settings.

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3.1 Flow chart process

The flowchart is utilized to aid in the development of a prototype for solar powered UV light pest management to finalize the project. It must be appropriately prepared by referring to the phase in Fig. 2. In this process of the project, the preparation of system simulation is divided into few parts which is project planning, development and simulation of hardware and data collection.

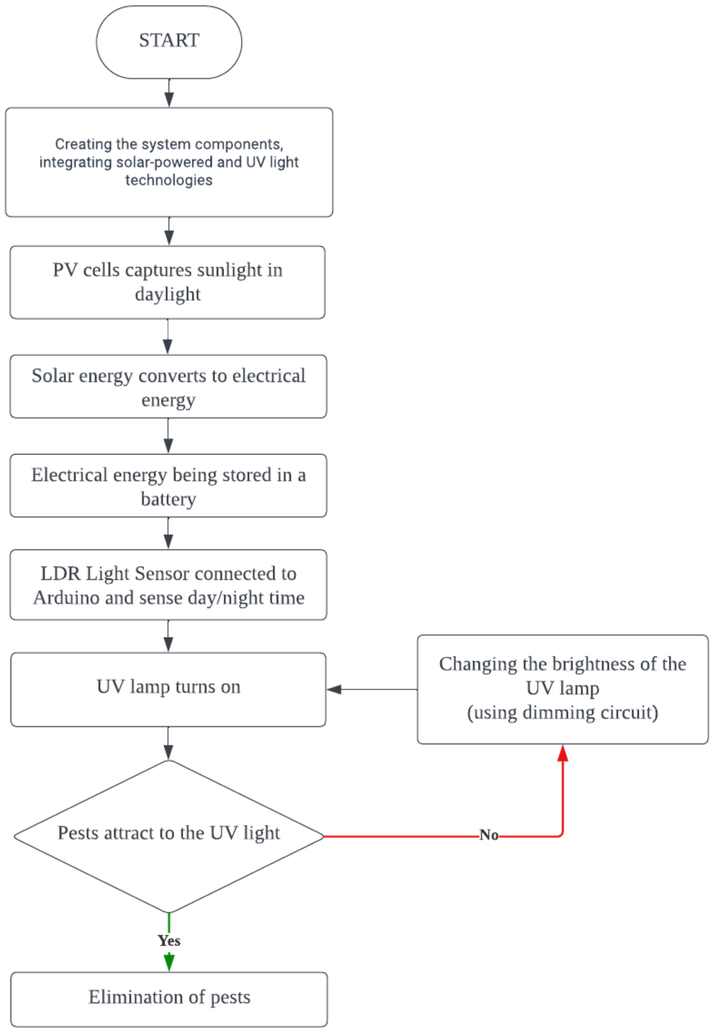

Fig. 2 *Flow chart of the project's system*

3.2 Development and Simulation of Hardware

The central component of the system is the UV lamp, which emits ultraviolet light to manage pests. The intensity of the UV light is regulated by a dimming circuit, while an Arduino board, equipped with an ESP8266 WiFi module, processes input from an LDR Light Sensor Module to adjust the UV light brightness based on ambient light levels. This configuration enables the system to be controlled remotely via IoT capabilities, allowing users to monitor performance and adjust settings as needed. Additionally, a solar charger controller regulates battery charging and discharging, prevents overcharging, optimizes battery performance, and ensures safe power output to the system. Fig. 3 illustrates the block diagram of the system, and the components used for the hardware.

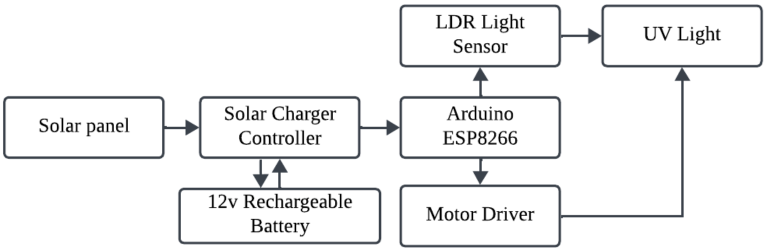

Fig. 3 *Block Diagram of the system*

3.3 Flowchart of Software Implementation

The software implementation section details the creation and operation of the software that manages the solar-powered UV light pest management system. Fig. 4 shows the flowchart of how the system will be implemented to the prototype. The software runs on an Arduino ESP8266 microcontroller, which processes sensor data, controls the UV lamp, and regulates its brightness via Blynk a mobile app that allows for remote control and monitoring of the system.

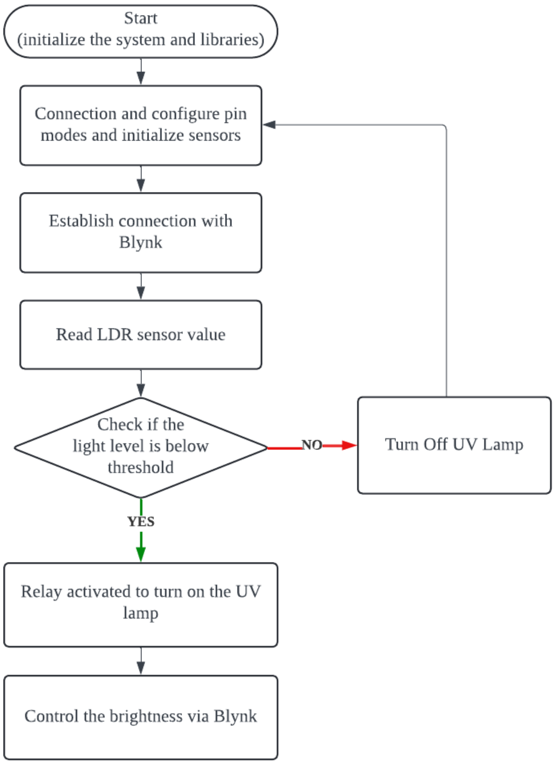

Fig. 4 *Flow chart of the software implementation's system*

3.4 Circuit Implementation

The L298N motor driver controls the brightness of the UV LED bulb. This is accomplished by regulating the voltage supplied to the lamp using pulse-width modulation (PWM) signals from the Arduino. The Arduino's digital output pins carry control signals to the L298N motor driver. These signals adjust the voltage, allowing for different brightness levels. The L298N motor driver provides fine control over the lamp's brightness, which may be changed based on ambient circumstances or special requirements to maximize pest attraction and energy usage. Fig. 5 shows the circuit connection of the components that are used in this system.

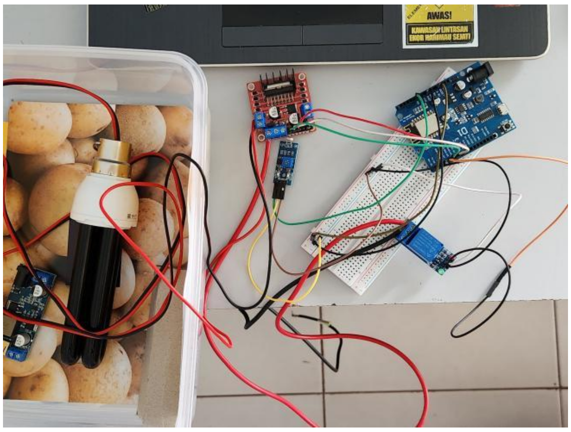

Fig. 5 *Circuit connection for the system*

3.5 Hardware Development

The Arduino system is a key component of the solar-powered UV light pest management project. It serves as the central control unit, directing the operation of the UV lights based on information from the Light Dependent Resistor (LDR) sensor and l298n motor driver. Arduino ESP8266 was used in this project as microcontroller for handling inputs and outputs. LDR Light Sensor was used to detects ambient light levels to control the UV lights. Meanwhile, motor driver was used as interfaces medium between the Arduino and UV lights. UV Lights was used as the load that is controlled based on ambient light conditions. 12V rechargeable battery was used as power supply for the Arduino and the UV lights. The final prototype of the system is demonstrated in Fig. 6.

Fig. 6 *Final prototype development*

4. Result and Discussion

4.1 UV Light Effectiveness

The UV lamp was tested for their ability to attract different pest species. The experiments indicated that the UV-A light (395 nm) was most effective in attracting nocturnal insects, confirming previous studies that UV-A light wavelengths between 315 to 400 nm are appealing to insects. The objective of this setup is to evaluate the effectiveness from different level of brightness of the UV lamp. The hypothesis of this different parameters should be having a different outcome. Low value of PWM gives a dimmer intensity for the UV lamp and will result in smaller attraction of pests. While high value of PWM gives a brighter intensity and will result in higher attraction of pests.

4.1.1 Low Brightness

The UV light was tested at low brightness settings to measure its ongoing efficiency in lowering pest populations. The value of PWM have been set up in the coding beforehand to 80 which means it is 30% of the duty cycle from L298N motor driver. Table 1 shows the conditions of the UV light for low brightness setting. Fig. 7 shows the Blynk interface for low brightness. The data collected for this parameter is by leaving the UV lamp for an hour and observe pests that have been trapped in the water and oil mixture.

Table 1 *Conditions for low brightness*

Level of brightness	Duty cycle	PWM Value
Low	30%	80

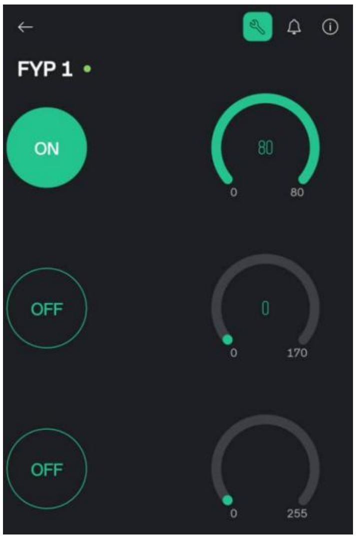

Fig. 7 *Blynk interface for low brightness*

Table 2 demonstrates that the low brightness level attracted quite a few of pests. The trap contained 468 pests for a week of observation, the most common of which were moths (228), followed by flies (145), and beetles (95). The trap successfully gathered a variety of insects, demonstrating that UV light is attractive to pests even at low brightness levels. Moths are more likely to be sensitive to UV light, even at lower levels, based on their greater abundance.

Table 2 *Summary of data collection for low brightness*

Day	Quantity of Pest Trapped
1	67
2	72
3	62
4	53
5	67
6	84
7	63
Total	**468**

4.1.2 High Brightness

The same procedure is taken from low brightness test. The UV light was tested at high brightness levels to evaluate its long-lasting effectiveness in reducing pest populations. Table 3 shows the conditions of the UV light for high brightness setting. Fig.8 shows the Blynk interface for high brightness. The value of PWM has been pre-programmed to 255, indicating that it is 100% of the duty cycle from the L298N motor driver. The data for this parameter was gathered by leaving the UV light on for an hour and observing pests trapped in the water and oil mixture.

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Table 3 *Conditions for high brightness*

Level of brightness	Duty cycle	PWM Value
High	100%	255

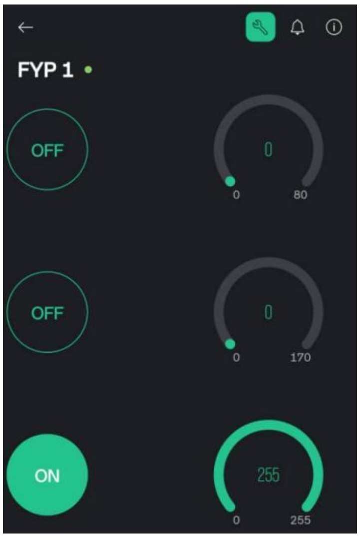

Fig. 8 *Blynk interface for high brightness*

Table. 4 indicates that an extensive number of pests were drawn to the area with higher brightness of UV light. Of the 824 pests collected in the trap for a week of observation, moths made up the largest amount (363), followed by flies (276), and beetles (185). The trap effectively captured a wide range of insects, proving that pests become more attracted to higher brightness of UV light higher brightness.

Table 4 *Summary of data collection for high brightness*

Day	**Quantity of Pest Trapped**
1	136
2	120
3	97
4	128
5	105
6	121
7	117
Total	**824**

5. Conclusion

The study successfully developed a solar-powered UV light pest management system that provides an eco-friendly alternative to chemical pesticides. By utilizing UV-A light to attract and control pests, the system significantly reduces pest populations without harming the environment. Its reliance on renewable solar energy enhances sustainability in agriculture, promoting healthier farming practices. The results demonstrate the system's potential as an effective tool for integrated pest management, contributing to both agricultural productivity and environmental conservation. First, the study established that UV radiation, especially in the UV-A range, works wonders to draw in a variety of pests, such as flies, beetles, and moths. This efficiency supports the theory that UV light can be a highly effective non-chemical pesticide substitute, offering a greener option than conventional chemical pesticides. This is a significant finding because it provides a solution to lessen agriculture's need on dangerous chemicals, supporting healthier farming methods and helping to preserve the environment.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

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