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Solar-powered pesticide sprayer using WeMos D1 Arduino-based board with Internet of Things (IoT) integration

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Abstract

This research used an experimental research design to develop a product. It aimed to create a Solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration and assess the difference with the traditional spray method. The test presented the difference between spray range, capacity to spray, internet connectivity, and delay time, utilizing a set of statistical data analysis of a t-test, percentage, and Likert scale. The prototype was also tested in farms around San Jose, Occidental Mindoro, as an agricultural project to check if it would function even in remote areas. The findings reveal that the level of effectiveness of the solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration functioned consistently across a temperature range of 29°C to 37°C and performed well under various windspeed conditions. The location where the sprayer is linked to the internet connection influences the device's internet connectivity success rate depending on the signal strength of the ISPs in each location. The Solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration only needs a simple signal that can connect the smartphone to the prototype. Signs such as 2.5G are enough based on the experiments. Using the Internet of Things for pesticide sprayer control, this study recommends automating time-based operations for broader use in areas without signal coverage. This upgrade optimizes efficiency and applicability, laying the groundwork for agricultural advancements and inspiring new applications or improvements.

Keywords: pesticide sprayer, spray range, capacity to spray, internet connectivity, delay time, traditional method

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1. Introduction

Pests are a significant problem in our agriculture, with 20% - 40% of crops damaged and almost $70 Billion worth of damage due to unwanted pathogens in the field, according to a survey conducted by Sharma et al. (2019). In the Philippines, rice is the most vulnerable crop to pests, such as rice stem borers. Agrochemicals, another name for pesticides, are often utilized to boost output, improve quality, and lower production costs in agricultural crop fields. Nevertheless, depending on pesticides to keep pests at bay can be dangerous for people or the environment because certain pesticides are pollutants. Pesticides deter pests from harming crops, but some can also impact the economy, pollution, and public health (Tudi et al., 2021).

In the Philippines, roughly 70% of farmers rely on chemicals for their primary crop protection method, and some even use pesticides made of chemicals that are restricted or prohibited. Chemical pesticide use and misuse have severely affected the environment and human health (Sanglestsawai et al., 2015). There are effective ways of spraying a pesticide depending on the temperature or time of the day. Spraying of well-known pesticides occurs during cooler times of the day, such as the morning or evening. Although using agrochemicals is a popular way of controlling pests, it can also be efficacious initially. Still, it frequently leads to an outbreak of the pest in the latter stages, and a case of pest resurgence occurs (Wang et al., 2017).

This research aimed to develop and assess the efficacy and practicality of a solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration. An automated stationary prototype that can be controlled on a smartphone can reduce labor and chances of being caught on the line of fire of the pesticide. The first modification of this product is solar-powered, which is highly abundant in today's technology and is even used by farmers. Due to the continuous global warming and high electrical bills, solar power is becoming more relevant. The sun is Earth's most plentiful energy source, creating a technological innovation in solar electricity that is inexpensive, limitless, and clean (Nemet, 2019). Using the WeMos D1 Arduino board is low on the price side of the product because it is affordable and friendly to intermediate to technically savvy people. The project aimed to develop a pesticide sprayer that is more efficient in lowering crop damage while also being automated to lessen labor work. Since the rapid growth of technology in which smartphones are almost available to everyone, adding the Internet of Things system would make a significant difference for farmers who are away or running errands but still efficiently.

Statement of the Problem - The integration of technology is pivotal for enhancing efficiency and sustainability. This study focuses on developing and assessing the efficacy and practicality of a solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration. The following questions are given particular attention in this study: (1) What is the level of effectiveness of the solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration in terms of environmental factors such as temperature and wind speed? (2) What is the level of accuracy of a solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration in terms of Internet provider connectivity in different locations and Internet sources with different Internet ranges? (3) Does the source of internet connectivity affect the delay time of the solar-powered pesticide sprayer using WeMos D1 Arduino-based board with Internet of Things integration in terms of Hotspot connection and Wi-Fi connection? (4) Is there a significant difference between a Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino-based board with Internet of Things Integration compared to traditional methods in terms of Spray range, Operation time, and Capacity to spray?

Significance of the Study - This research offers a substantial breakthrough in accurate and sustainable pesticide administration by creating a solar-powered spraying system. The study aims to create and assess the efficacy and practicality of a solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration. This breakthrough tackles critical issues in contemporary agriculture by utilizing renewable energy and integrating Internet of Things capabilities with Arduino-based control. The study contributes to creating a workable and effective method for applying pesticides sustainably and precisely, solving essential issues with environmental preservation, agricultural productivity, and farmer empowerment. This research aims to advance environmental sustainability, enhance agricultural practices, and assist in adopting and applying solar-powered sprayer systems.

To the farmers, the initiative can reduce the cost of pesticides and their harmful impacts on the environment, including eutrophication and water pollution, while assisting farmers in applying pesticides more effectively and efficiently. Additionally, this aids in raising farmers' agricultural yields and productivity. To the homeowner this technique allows homeowners to apply pesticides to their lawns and plants more successfully. This solar-powered pesticide sprayer can also benefit them if they want to cultivate crops on their lands. The research will make it feasible for manufacturers to create pesticide sprayers that are more efficient and solar-powered pesticide sprayer systems that minimize environmental damage to non-government environmental organizations. The research will pave the way for developing pesticide sprayers to enhance the country's development, which are less harmful to the environment and more effective overall. These efforts could also be sustained with the help of government organizations. To future researchers, these solar-powered pesticide sprayers are an excellent tool for aspiring researchers in the field of pest management because they can be used to test the efficacy of new pesticide sprayers, investigate the effects of pesticide application techniques on pest populations, enhance data collection and analysis on the movement of pest populations, lower costs, and labor requirements, increase safety and environmental protection, and more. With this information, pest management techniques can be enhanced and more effective.

Scope and Delimitation of the Study - This study developed a solar-powered pesticide sprayer system using a WeMos D1 Arduino-based board in conjunction with Internet of Things technology to enhance pesticide spraying efficiency to reduce crop damage caused by pesticides while simultaneously automating the process to minimize manual labor. The system was capable of dispensing pesticides anytime. Moreover, the researchers included designing and integrating an efficient mechanism to dispense pesticides, ensuring they were released precisely and controlled. This helped to ensure that the pesticides were applied evenly and that the correct amount of pesticide was used. In addition, the researchers integrated Internet of Things capabilities into the system, enabling them to monitor the amount of pesticide in the storage and notify the owner whenever the pesticide ran out of stock; however, the user was responsible for manually refilling the tank. Also, the servo motor continued to rotate even when a signal to stop was sent from the remote control. Disabling power at the circuit breaker was the only way to halt its movement. Furthermore, this study was limited by its deliberate concentration on the WeMos D1 framework, which restricted exploration of other microcontroller platforms or Internet of Things boards. The functionality and compatibility of other microcontrollers could differ significantly concerning the proposed design. Furthermore, more than one product might have been needed to cover vast agricultural regions adequately; therefore, more extensive areas required many units. The dependence on solar panels required an open area with ample sunlight for consistent operation, posing a limitation in specific environments. Additionally, due to the reliance on Internet connectivity for the Internet of Things operations, implementing this automated pesticide sprayer system was confined to areas with stable Internet access. This investigatory project was conducted in San Jose, Occidental Mindoro, during the school year 2023-2024.

2. Methodology

Research Design - This study utilized the applied experimental research design. The researchers developed and tested the effectiveness of solar-powered pesticide sprayers and their prospective ramifications on agriculture by employing experimental methodologies. The researchers conducted field trials in crop fields where randomly assigned plots were treated with either the solar-powered sprayer or a traditional spraying method. To gain the most precise responses and information, the researchers then opted to do research and observation in crop fields, which would expedite the process of gathering and acquiring information. This project aimed to develop and assess the efficacy and practicality of a solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration.

Data Gathering Procedure - The observation phase served as the primary source of data and information. The researchers acquired the information firsthand, ensuring its direct connection to the employed research methodologies. The data collection process was facilitated by meticulous observation and recording techniques. The researchers systematically gathered and compiled the requisite data through observational and experimental approaches. The utilized system and the researchers' data collection methods collectively contributed to the credibility and objectivity of the gathered data. The Solar-Powered Pesticide Sprayer effectively covered the target area using a WeMos D1 Arduino Based Board with Internet of Things Integration, with minimal overspray and even distribution. In terms of pump efficiency, the pump maintained consistent pressure and flow rate, ensuring thorough pesticide application. Moreover, precisely controlled servo motors ensured a uniform and targeted distribution of the pesticide. The reservoir's pesticide solution level was monitored by the ultrasonic level sensor. It ensured uninterrupted operation by preventing pump malfunctions and sending timely notifications when the solution level was low. Moreover, the Internet of Things integration smoothly linked the pesticide sprayer to a remote-control system, enabling users to dispense pesticide anytime, turn the sprayer on and off, and monitor system conditions from any location.

This project involved multiple stages. Stage 1 encompassed coding and assembly from November 15 to November 19, 2023, spanning four days, while Stage 2 followed a similar pattern from January 27 to January 30, 2024, but for three days. Designing took place on February 2 and February 3, 2024, lasting one day, followed by case-making from February 4 to February 6, 2024, totaling two days. Stage 3 continued with coding and assembly for three days from February 8 to February 11, 2024, and case-making from February 20 to February 29, 2024, extending over nine days. Finalizing the project occurred on March 1 and March 2, 2024, concluding in one day.

Research Process; Stage 1 Preparation and Gathering of Materials - The researchers demonstrated the materials used in making the hardware. Researchers constructed a prototype of a pesticide sprayer using a WeMos D1- ESP8266-based Arduino board, Internet of Things integration, and solar panel. To assemble these materials, researchers made online purchases, with a total cost of 5,000 Php, ensuring everything was clear in making the project. The materials used in developing the product are the following: Hose Connector. ESP8266 Node Mcu, 5v Relay Module with Optocoupler, Motorcycle Battery, Pcv Pipe, Jumper Wires, Double Pole Single Throw Switch, Hinges, Glass, Small Padlock, Heat Shrink, Servo Motor, Silicone Hose, Solar Charge Controller, Solar Panel, Submersible Mini Pump, Ultrasonic Level Sensor, WeMos D1-ESP8266 Based Arduino Board, Micro USB Cable and Pesticide.

Stage 2: Building and Development of the Project - In the upcoming stage, our initial step involved developing the coding for the product. Subsequently, the researcher constructed the schematics or blueprints for the product itself. Afterward, the researcher turned the schematics into an actual product by connecting wires and assembling all the parts. Subsequently, the researcher verified the functionality of the uploaded code with the relay, pump, and ultrasonic sensors. Additionally, the researchers assessed the voltage and amperage of each wire to ensure their compatibility with the intended specifications. Furthermore, the researchers evaluated the feasibility of controlling the system using a mobile device or a desktop computer. Subsequently, based on our observations, the researchers tested the battery's capacity to sustain the electrical demand of our product. Finally, the researchers monitored the performance of the product.

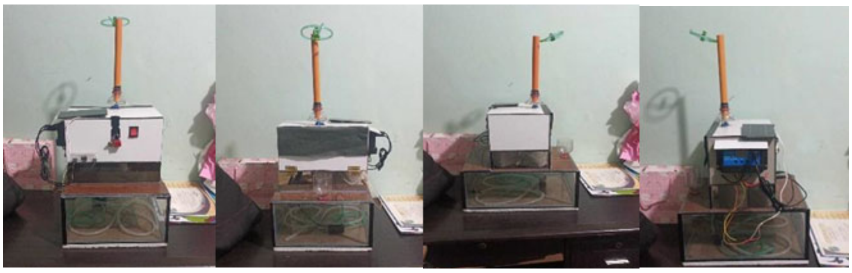

Figure 1. Actual Product of Solar-Powered Pesticide Sprayer using WeMos D1 Arduino-Based Board with Internet of Things Integration

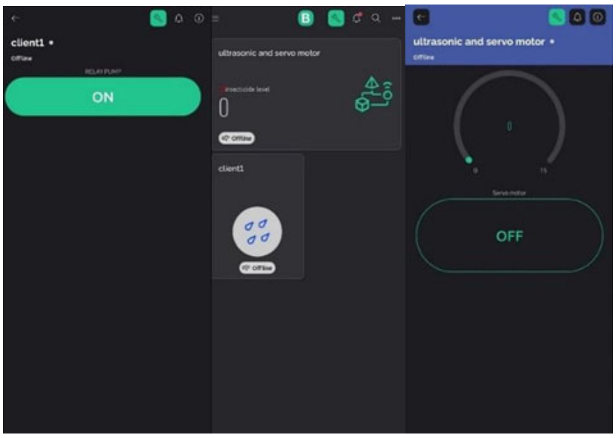

Figure 2: Blynk Internet of Things Dashboard

Figure 1 displays the side-by-side, front, and back view of the prototype, a Solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things Integration. Figure 2 illustrates the application downloaded from the Play Store. This application effectively monitors the device by controlling the water pump, servo motor, and pesticide level.

Stage 3: Experimental Stage, Observation, and Data Recording - An automated system, including a water pump for target spraying, an ultrasonic sensor to measure pesticide levels and spray height, and a servo motor for effective pesticide pumping, was first assembled by the researchers. This configuration was used in agriculture to expedite the spraying of pesticides. After that, the researchers carefully watched and examined how these parts synchronized to ensure everything worked as it should when operated by a cellphone. The study concentrated on determining the servo motor's rotational speed when pumping pesticide, using an ultrasonic sensor to track pesticide levels, and analyzing the water pump's efficiency when dispersing pesticide. The aim was to discover how this automated technology improved agricultural techniques' accuracy, usability, and efficiency.

The researchers carried out a one-day experiment from March 15 to March 16, 2024, to better understand how the product works and to quickly fix any problems that might come up. They also wanted to figure out ways to make the product better. By watching closely and studying carefully, they hoped to learn everything they could about how the product functions so they could make it even better in the future. The observation and data collection in stage 4 yielded important new information on the efficacy and long-term performance of the solar-powered pesticide system. Furthermore, additional research and development aimed at optimizing the system's capabilities and enhancing its contribution to sustainable agriculture practices were based on the data gathered.

Statistical Treatment of the Data - The researchers utilized a paired t-test, percentage, and average in this study to define the Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino Based Board with Internet with

Internet of Things Integration to the traditional method of spraying a pesticide. The percentage served as the tool for defining the percentage of how effective the Solar-Powered Pesticide Sprayer is using the WeMos D1 Arduino Based Board with Internet of Things Integration in terms of the problem statement. The average was used to determine which internet provider was more effective in different areas. The t-test was used to identify the effectiveness of the project and how it would differentiate it from the traditional manual spraying of pesticides. Zanin et al. (2022) state that when to spray insecticides and other agricultural chemicals has a big impact on the crops. The unpaired t-test served as the statistical data analysis to identify the product's work more efficiently and significantly and determined the difference between manual pesticide spraying.

3. Results and Discussions

Table 1

The level of effectiveness of the solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration in the environmental factors in terms of temperature

Trial	Morning (29°C)	Afternoon (37°C)	Evening (29°C)
1st	1	1	1
2nd	1	1	1
3rd	1	1	1
4th	1	1	1
5th	1	1	1
6th	1	1	1
7th	1	1	1
8th	1	1	1
9th	1	1	1
10th	1	1	1

Legend: (1 - functions properly ; 0 - does not function properly/ malfunction)

Table 1 displays the experiment results to assess the effect of temperature changes on the device's performance. The experiment consisted of ten trials by the researchers carried out at three different times of the day: morning (29°C), noon (37°C), and evening (29°C). The device demonstrated seamless functionality without any complications throughout all the trials, exhibiting 100% effectiveness across different temperatures. In Matzie's (2019) study, temperature is a vital factor affecting pesticides' efficacy. Different types of pesticides work best at specific temperature ranges. According to him, a pesticide is most effective when the temperature is above 50 degrees Fahrenheit. Moreover, spray losses were more significant when the temperature was low.

Table 2 provides evidence that during the ten trials, the product resulted in 100% in performance given in the three wind speed trials (windspeed #1 - 2 m/s, wind speed #2 - 3 m/s, and wind speed #3 - 4 m/s) showed the device performed effectively indicating the system's ability to control and function within the anticipated range of wind speed conditions. In the findings of Chen et al. (2021), when they conducted their study "Drift Evaluation of a Quadrotor Unmanned Aerial Vehicle (UAV) Sprayer," it is essential to highlight the importance of considering wind speed and other environmental factors when using the device to minimize drift and maximize efficiency.

Table 2

The level of effectiveness of the solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration in the environmental factors in terms of wind speed

Trial	Wind Speed #1 (2m/s)	Wind Speed #2 (3m/s)	Wind Speed #3 (4m/s)
1st	1	1	1
2nd	1	1	1
3rd	1	1	1
4th	1	1	1
5th	1	1	1
6th	1	1	1
7th	1	1	1
8th	1	1	1
9th	1	1	1
10th	1	1	1
Percentage of effectiveness	100%	100%	100%

Legend: 1 = Functioned Properly ; 0 = Did not Function Properly

Table 3

The level of accuracy of a solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration in terms of Internet provider connectivity in different locations

Trials	**Smart (Locations)**					**Globe (Locations)**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1	1	0	0	1	0	1	1	1	1	1
2	1	0	0	1	0	1	1	1	1	1
3	1	0	0	1	0	1	1	1	1	1
4	1	0	0	1	0	1	1	1	1	1
5	1	0	0	1	0	1	1	1	1	1
6	1	0	0	1	0	1	1	1	1	1
7	1	0	0	1	0	1	1	1	1	1
8	1	0	0	1	0	1	1	1	1	1
9	1	0	0	1	0	1	1	1	1	1
10	1	0	0	1	0	1	1	1	1	1
Average:	1	0	0	1	0	1	1	1	1	1
Total average:	**0.4 Poor Level of Accuracy**					**1 Very High Level of Accuracy**				

Legend: 1= Function Properly 0 = Not Functioned Properly

Descriptive Interpretation: Very High Level of Accuracy 0.81 - 1.00; High Level of Accuracy 0.61 - 0.80; Moderate Level of Accuracy 0.41 - 0.60: Low Level of Accuracy 0.21 - 0.40: Poor Level of Accuracy 0.21 - 0.40

Locations: Location1- San Isidro – Purok 3; Location2- Magbay - Purok 5; Location3- Bayotbot – Creek 1; Location4- Murtha – Hacienda Murtha; Location 5- La Curva – Purok 4

Table 3 summarizes the device's internet connectivity success rate in five locations tested with two different service providers, Smart and Globe. Each row represents the results of ten trials. In location #1 (San Isidro - Purok 3) and location #4 (Murtha - Hacienda Murtha), the device worked perfectly with both service providers during all ten attempts. However, in location #2 (Magbay - Purok 5), location #3 (Bayotbot - Creek 1), and location #5 (La Curva - Purok 4), the device only experienced connectivity problems with the Smart ISP while performing reliably with Globe ISP in all ten trials. The total average accuracy of Globe ISP is 1, indicating a very high level of accuracy, while Smart ISP received a total average of 0.4, indicating poor level of accuracy. Thus, the level of accuracy of a solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration in terms of Internet provider connectivity in different locations is found accurate in Globe service rather than Smart service provider. According to Chen et al. (2023), most are in rural locations where traditional internet service providers have minimal market share. More strong and consistent signal intensity would be preferable, particularly in isolated and underdeveloped communities. There are fewer high-speed internet connections available through rural broadband network ports. The lack of network coverage in rural areas is partly due to the necessity for increased infrastructure development. Necessary infrastructure such as network cables, communication towers, and supporting equipment are frequently needed in these locations. Topographical obstacles that impede network infrastructure development, such as steep terrain and great distances, further exacerbate the problem.

Table 4

The level of accuracy of a solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration in terms of Internet provider connectivity in different locations

Range (Meters) with 1 minute Interval	**Internet Connectivity**			
30 Trials	**Hotspot**		**Wi-fi**	
	Times it functioned properly. (in meters)	Times it did not function properly (in meters)	Times it functioned properly (in meters)	Times it did not function properly (in meters)
	27	3	12	18
Percentage of Accuracy	**90%**		**40%**	

Table 4 presents the data regarding the range of internet connectivity for both Wi-fi and hotspots, with measurements in meters. The maximum range observed for hotspots was approximately 27 meters, while the average coverage area for wifi was around 12 meters in 30 trials. The accuracy percentage for hotspots was 90%, whereas for Wi-Fi, it was 40%—this data indicates the superior accuracy performance of hotspots over Wi-Fi. Based on the study of Chen et al. (2023), Inhabitants' experiences with the Internet are adversely affected by networks in rural areas, which are frequently slower, have poorer signals, and inconsistent connections. Users may encounter varying speeds according to the subscription plans they have selected. The maximum bandwidth allotted to different plans varies frequently, which immediately impacts how quickly customers may access the network.

Table 5 indicates the two-tailed t-test of the Hotspot (variable 1) and Wi-Fi (variable 2) that consists of 1-10 meter trials in terms of delay time. The absolute computed value (t_{comp}), which is -0.257, is lower than the critical value (t_{crit}), 2.144. It is concluded that the Alternative hypothesis (H_1) is rejected, and the Null hypothesis (H_o) is accepted. The source of internet connectivity (hotspot or Wi-Fi) does not affect the delay time of the solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration. Dekel (2019) states that Wi-Fi is among today's most widely used internet-based communication technology. Its power consumption and functionality used to be significant barriers for Internet of Things developers. Furthermore, according to the findings of Ali et al. (2021), the hotspot has grown into a crucial issue in the Internet of Things-enabled Wireless Sensor Network, which is created due to the high consumption of energy by the sink nearby nodes.

Table 5

*T-test results of the source of internet connectivity in terms of the dela*y time using hotspot connection and delay time using Wi-Fi connection

	Variable 1	**Variable 2**
Mean	9.323	9.6
Variance	8.882112222	2.711111111
Observations	10	10
Hypothesized Mean Difference	0	
Df	14	
t Stat	-0.2572632	
P(T<=t) two-tail	0.800718202	
t Critical two-tail	2.144786688	

Legend: P-value ≤ 0.05 Significant; reject H_0.

Table 6

T-test results on the difference between a Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino Based Board with Internet of Things Integration compared to the traditional method in terms of spray range

	Spray range		**Operation time**		**Capacity to spray**	
	Variable 1	Variable 2	Variable 1	Variable 2	Variable 1	Variable 2
Mean	1.028	0.86	14	6.5	4831.127143	316.6666667
Variance	0.002284444	2.22222E-05	63	13	72547096.31	31027.95238
Observations	10	10	27	12	7	15
Hypothesized Mean Difference	0		0		0	
Df	9		37		6	
t Stat	11.06157229		4.057513356		1.402172747	
P(T<=t) two-tail	1.53588E-06		0.000246079		0.210423836	
t Critical two-tail	2.262157163		2.026192463		2.446911851	

Legend: P-value ≤ 0.05 Significant; reject H_0.

Table 6 presents the two-tailed t-test of the Traditional method and a Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino-based board with Internet of Things Integration in terms of its spraying range, operation time, and capacity to spray. Regarding spray range, the data is gathered through 10 trials in which both variables are tested simultaneously for more accurate experimentation. The t-test presented above depicted that the absolute computed value is 11.061 while the critical value is 2.262. Concluding on rejecting the null hypothesis while accepting the Alternative Hypothesis. It signifies that there is a significant difference on the spraying range between the Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino Based Board with Internet of Things Integration and traditional methods. Hence, the solar-powered pesticide sprayer uses a WeMos D1 Arduino-based board with Internet of Things integration and has a wider spraying range. According to Wang et al. (2017), further spraying of liquid leads to a more effective dispersion. Higher dispersion would lead to a more efficient prototype for big farm fields.

Regarding its operation time, the data is gathered through 10 trials in which both variables are tested simultaneously for more accurate experimentation. The t-test presented above depicted that the absolute computed value is 4.057 while the critical value is 2.026. Deciding to accept the alternative hypothesis and reject the null hypothesis. It shows a significant difference in the operation time between the Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino Based Board with Internet of Things Integration and traditional methods. The traditional method edges the Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino Based Board with Internet of Things Integration in terms of operation time. The traditional method can operate faster than the prototype because it is for mobile use with no connection but is for pure manual use by the user. The solar-powered pesticide sprayer uses a WeMos D1 Arduino-based board with Internet of Things integration and requires more time to operate because of Internet connectivity. The findings also proved by Vardhan et al. (2014), that the faster the prototype is to operate, the more advantage it has for a product due to its availability for immediate or emergency use. Thus, the traditional method edges the Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino Based Board with Internet of Things Integration in terms of operation time. The traditional method can operate faster than the prototype because it is mobile and has no connection but pure manual use for the user. The solar-powered pesticide sprayer uses a WeMos D1 Arduino-based board with Internet of Things integration and requires more time to operate because of Internet connectivity.

Lastly, regarding the capacity to spray using liters of water, the data is gathered through a total of 15 trials reaching 1 – 15 liters of water, in which both variables are tested simultaneously to obtain the delayed time. The traditional method got the 15-liter mark, while the prototype could only handle the 9-liter mark. The t-test presented above depicted that the absolute computed value is 1.402 while the critical value is 2.446. Opting to reject the alternative hypothesis and accept the null hypothesis. It presents that there is no significant difference in capacity to spray between the Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino Based Board with Internet of Things Integration and traditional methods. According to Fahmy & Selim (2023), a device with more capacity to spray can disperse more liquid but differs if the liquid should be sprayed more than the receiver requires. Thus, this proved that both methods could spray effectively using liters of water.

4. Conclusions

Based on the study's findings, the researcher concluded the following: The level of effectiveness of the solar-powered pesticide sprayer using a WeMos D1 Arduino-based board with Internet of Things integration functioned consistently across a temperature range of 29°C to 37°C and performed well under various windspeed conditions. The location where the sprayer is linked to the internet connection influences the device's internet connectivity success rate depending on the signal strength of the ISPs in each location. The accuracy of the internet range for the solar-powered pesticide sprayer using Wi-Fi has a limited average coverage area, while Hotspots provide a greater range and higher accuracy. There is no statistically significant difference in delay time between using a hotspot or Wi-Fi connection with the solar-powered pesticide sprayer. The solar-powered sprayer offers a significantly greater spray range compared to traditional methods. Operating the solar-powered sprayer is significantly faster than traditional methods. Lastly, the study found no significant difference in the total spray capacity that the Solar-Powered Pesticide Sprayer using a WeMos D1 Arduino Based Board with Internet of Things Integration and traditional methods can hold.

4.1 Recommendation

After examining the current investigation and findings, the researchers suggest the following topics for further exploration: This study recommends adding remote-controlled through smartphone adjustable water pressure to the sprayer to boost efficiency and usability, particularly in varying wind speeds. Farmers may adapt water pressure for wider and longer coverage, ensuring more effective pesticide application and better crop spraying results even with different wind speeds. This study recommends adding pocket Wi-Fi to the device for uninterrupted access in various locations. This update minimizes lost internet connections, boosting productivity and efficiency. Ensure reliable access and consistent performance, making the device versatile in any location. This study recommends adding a Wi-Fi repeater to the network to minimize delays and enhance internet connectivity. Experience seamless performance, access to online resources, and improved reliability and speed. Save valuable time and resources with this simple addition. This study recommends integrating extenders, spray poles, and optimal nozzles for optimal crop spraying efficiency. These additions save time and money, increase coverage, and ensure precise pesticide administration, minimizing waste and environmental harm. Maximized spraying procedures improve crop health and promote uniform application. Using the Internet of Things for pesticide sprayer control, this study recommends automating time-based operations for broader use in areas without signal coverage. This upgrade optimizes efficiency and applicability, laying the groundwork for agricultural advancements and inspiring new applications or improvements.

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