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Development and Evaluation of a High-Efficacy Solar-Powered Light Trap for Rice Black Bug (*Scotinophara Coartata*) Management

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Abstract

Rice black bugs (RBB) are a major pest causing significant yield losses in rice farms. This study investigates a novel solar-powered light trap for RBB control. The trap utilizes LEDs with different color temperatures (warm white and daylight) and incorporates an auto-response system for efficient operation. Performance evaluation over three months revealed the highest efficacy for the 50-watt warm white LED bulb (948 grams captured), followed by the daylight bulb (724 grams). However, the study found no significant difference between developing light traps with warm white and daylight LED in capturing RBBs. The trap's functionality was excellent, with low maintenance requirements. These findings suggest that the solar-powered light trap with warm white LEDs offers a promising, sustainable solution for RBB management in rice production.

Keywords

solar powered light trap, LED bulb, electrocution, auto-response system, rice black bug

INTRODUCTION

The solar-powered rice black bug trap is a light trap designed to capture rice black bugs (*Scotinophara Coarctata*) in rice farms. The rice black bug (RBB) is an invasive pest that has caused problems in rice farming and a continuous reduction in yield production. RBB is prevalent in farms without water and can be very destructive; even rice farms with sufficient water can be susceptible to this pest because they can fly and search for food in a rice field. Under favorable conditions, adult RBBs migrate to rice fields and feed on young plant leaves or sheaths. In this study, solar-powered rice black bug traps were developed, which helped prevent RBB migration and limit their population. The trap has a system that allows it to operate automatically without the operator.

Light trapping is a mechanical method used in integrated pest management (IPM) to control pests. According to Ritter et al. (2019), using traps is a better alternative to chemical pesticides as it minimizes the damage caused by pests to crops and avoids any impact on the natural fruit of certain plants. Traps are particularly effective in reducing pests, such as the RBB, without causing harm to the farmer's health or eliminating natural enemies. Several studies suggest that spraying pesticides can lead all bugs to fly to other places (Sepe et al., 2019), while excessive use of pesticides can have severe implications for the environment and human health (Rani et al., 2021). Unfortunately, some farmers misuse pesticides, leading to the mutation of variants of the RBB that are more destructive and immune to the pesticide (Sepe et al., 2019). As a result, it becomes necessary to use more pesticides to control the pests, leading to further consequences such as the emergence of other mutations or variants that require even higher dosages of pesticides or pose more significant risks to human health.

For a higher harvest and to minimize the amount of pesticide sprayed to control RBB, RBB light traps were developed. These traps are designed based on the characteristics of RBB, and prototypes have been developed using solar power and a microcontroller for automation. Studies have shown that the traps are easy to use and assemble, with only two wires needing to be connected to the batteries. However, the cost-effectiveness of the traps can vary due to the availability of certain parts (Calderon, 2017). In addition, the study of Martillano et al. (2019) focuses on creating wirelessly networked portable light traps that can communicate with each other and farmers via a mobile application. This system can track the number of RBBs caught in each trap and provide information on wind direction, light bulb status, and distance. It is recommended that scalable RF-based distance detectors and an accurate wind sensory system be used to improve accuracy. However, the availability of materials should also be considered when designing traps, as not all farmers may have the means to develop such technology.

When considering the innovation of a device based on the literature, it is essential to know the cost-effectiveness and avoid any labor-intensive tasks for the farmer, which could discourage traps. Redondo et al. (2007) reported that 11% of farmers found traps to be time-consuming since they had to monitor them overnight and dispose of the bugs in the morning. In addition, light traps, particularly those powered by electricity, are costly to operate, leading to a decline in popularity over the years (Litsinger, 2007). Another factor to consider is using water to dispose of bugs, which adds to the farmer's workload by necessitating the relocation of heavy traps. To address this challenge, electrocution could be integrated into the trap, eliminating the need for manual disposal. For the materials used, it is crucial to prioritize cost-effectiveness, given that farmers are the primary users of the device. The design should also feature a suitable lamp, lightweight materials, and a smaller area of consumption.

In this particular issue, the researcher aims to develop a solar-powered trap to address the problems of chemical pollution in farms, declining crop yields, and poorly designed traps for the RBB. The trap will be placed in the center of a rice farm currently affected by RBB. The device's brain will be the microcontroller, with an automatic open and close basin design and electrocution systems to eliminate labor-consuming tasks for end-users. The lamp of the trap will attract RBB and is a critical component in the evaluation process, requiring a suitable color temperature and power output. The solar panel and battery should provide sufficient power to operate the lamp and electrocution system. The electrocution process will utilize a Voltage Tripler device that increases the voltage of the direct current. The primary concern of this study is to develop a rice black bug trap and evaluate its performance based on its functionality, maintainability, and ease of operation. The researcher and other individuals who are experts in technology and farming will evaluate the trap's effectiveness.

METHODS

Design of solar-powered rice black bug trap

This section presents the stages in developing the solar-powered rice black bug trap as one of the light trap designs to capture RBB. These stages involved designing, estimating, and procuring necessary materials and equipment. Figure 1 presents the design of the light trap and shows the actual measurement of the device together with the different parts or systems of the trap. The trap consists of several key components meticulously assembled for efficient functionality. These components were the microcontroller, DC motor, Voltage Tripler device, photocell module, electrocution device, solar panel, and battery.

Figure 2 shows the block diagram of the solar-powered rice black bug trap with its system design and connection.

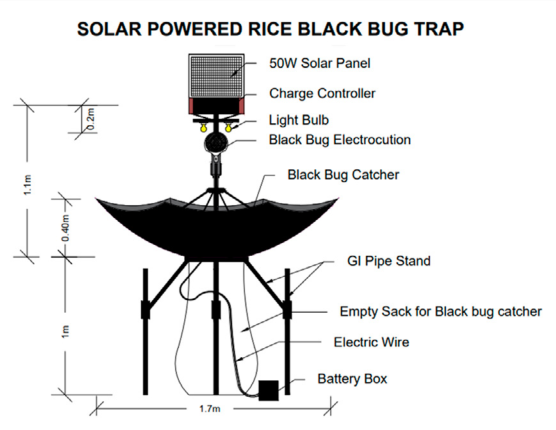


Figure 1. *Design and actual measurement of solar-powered rice black bug trap*

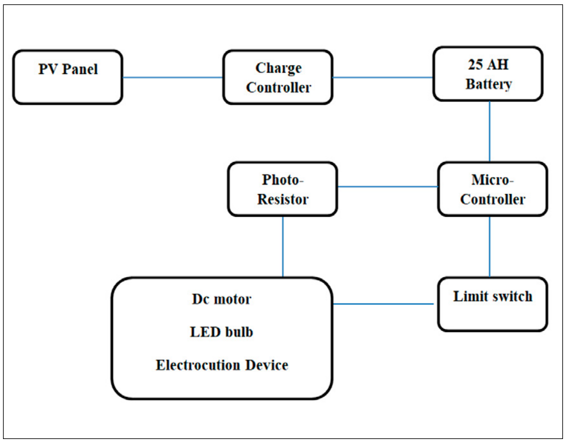


Figure 2. *Block diagram of solar-powered rice black bug trap*

List of materials needed in the study

Table 1 presents the list of materials needed in the study. The materials were used to fabricate the solar-powered rice black bug traps.

Table 1. *List of materials used in the study*

No.	Description/Specification	Unit	Quantity
1	Arduino Uno Microcontroller	unit	2
2	Monocrystalline Solar panel 50 watts	unit	2
3	25 AH Gel Type Battery	pc	2
4	DC motor 12 V	unit	2
5	round rod	length	2
6	Polyester Fabric	meter	6
7	Block Iron (BI) pipe 1"	length	3
8	Limit switch	pc	2
9	Wire 1.2 mm squared	meter	20
10	Electrode 16/70	pc	10
11	Needle	pc	1
12	Lamp 12 watts, 12V DC warm white	pc	1
13	Lamp 12 watts, 12V DC Daylight	pc	1
14	Lamp 25 watts, 12V DC warm white	pc	1
15	Lamp 25 watts, 12V DC Daylight	pc	1
16	Lamp 50 watts, 12V DC warm white	pc	1
17	Lamp 50 watts, 12V DC Daylight	pc	1
18	Solar charge controller 20 A, 24V	unit	2
19	9mm round bar	length	4

Completed Solar-powered Rice Black Bug

Figure 3 presents the developed light trap and final solar-powered rice black bug trap in close view during the day; Figure 4 shows the open view of the developed trap during nighttime. The trap was associated with an automatic control system and electrocution. The function of the light trap was to trap RBBs in rice farms. It had automatic control with an umbrella basin type, allowing the trap to open at night and close in the daytime. The operation of electrocution was also based on the opening and closing of the trap, which was "On" during the opening and "Off" during the closing. A photocell serves as an automatic sensor for opening and closing the trap.

Moreover, light traps also matter to their height and lamp in trapping RBBs. Due to the burden that this method creates, only 11% of farmers use it. To kill the black bugs, they must first shift the trap to a new site, which is difficult (Redondo et al., 2007). Furthermore, Nielsen et al. (2013) advise utilizing a 1.3-meter-tall active light trap. However, the light trap was around 2.1 meters tall and could be adjustable depending on the desired height in the collective rice field. The variation in height could be explained by the fact that, depending on the species and research method, the ideal range for luring insects with light is often between 1 to 250 meters (Martillano et al., 2019).

Figure 3. *View of the Solar-powered RBB Trap when closed*

Figure 4. *View of the Solar Power RBB Trap when open*

Testing and Evaluation

The Solar-Powered Rice Black Bug Trap was placed in the center of a rice field during testing at Barangay Panian, St. Bernard, Southern Leyte, where rice was planted 2-3 times a year. The said barangay experienced an outbreak of the RBBs and was continuously infested during the season on rice farms.

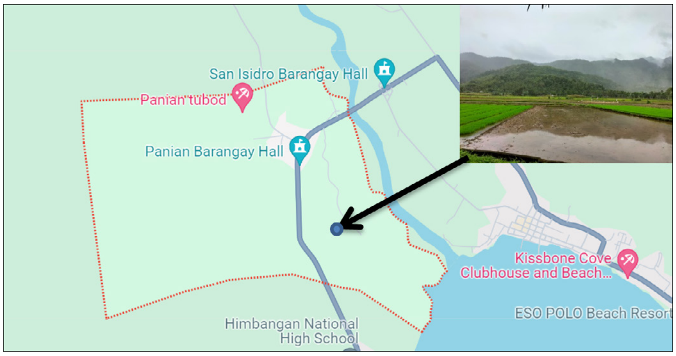


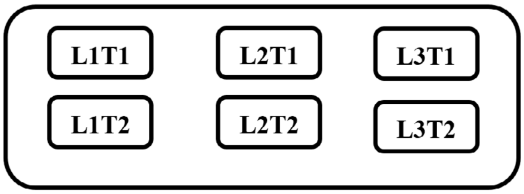
Figure 5. *Map of Panian, St. Bernard, Southern Leyte, Philippines*

This study tested various parameters to determine and evaluate the device's effectiveness in trapping RBBs. These involved different combinations of lamp color temperature and wattages designed to attract RBBs to the trap. Figure 6 illustrates the testing process involving setting up the different treatments and monitoring the number of RBBs captured. The evaluation process involved capturing RBBs in a trap and measuring the number of insects caught in grams per unit of time. The researchers weighed the captured RBBs in every treatment. The data helped determine the effectiveness of each treatment and which combination of lamps, color temperatures, and wattages worked best in attracting and trapping RBBs.

The testing was carried out on moon days, which refers to three (3) days before and three (3) days after the full moon of each month because RBBs are active during this period, as stated by Redondo et al. (2007). Adult RBBs are more engaged during this period, flying at night to find food and produce eggs. Two light traps were developed and tested over three months to test the effectiveness of the Solar-Powered Rice Black Bug Trap in trapping RBB. Treatment 1 was tested in the first month using Lamp 1 with two different LED bulbs. One bulb had a warm white color temperature and a power rating of 12 watts (L1T1); the other had a day-white color temperature and a power rating of 12 watts (L1T2). These are shown in Figure 7.

In the second month, the same light trap was used with Lamp 2, which had two LED bulbs with a higher power rating of 25 watts. One bulb had a warm white color temperature (L2T1), while the other had a Day White color temperature (L2T2), as shown in Figure 8.

Finally, in the third month, the same light trap was used with Lamp 3, which had two bulbs with a power rating of 50 watts. One bulb had a warm white color temperature (L3T1), while the other had a day white color temperature (L3T2). These are shown in Figure 9.



Legend: L1T1- 12 watts, Warm white; L1T2- 12 watts, Day light; L2T1- 25 watts, Warm white; L2T2- 25 watts, Day light; L3T1- 50 watts, Warm white; and L3T2- 50 watts, Day light

Figure 6. *Experimental treatment*

Figure 7. *L1T1 (12 watts with Warm White CT) and L1T2 (12 watts with Day White CT)*

Figure 8. *L2T1 (25 watts with Warm White CT) and L2T2 (25 watts with Day White CT)*

Figure 9. *L2T1 (50 watts with Warm White CT) and L2T2 (50 watts with Day White CT)*

This experiment aimed to determine which light trap and treatment were most effective in trapping RBB using solar power. The experiment results will help improve pest management strategies for rice crops, particularly in areas where electricity is not readily available. To ensure the accuracy of the testing, the researcher closely observed the device during its operation and asked experts to watch and observe as well. Figure 10 shows the captured rice black bug during testing. All the RBBs were collected and weighed in the morning, as shown in Figure 11. Weighing the RBBs helped determine how many were caught by the trap and allowed for a comparison of the performance of each treatment. The data collected from the trap served as the basis for determining the effectiveness of the Solar Powered Rice Black Bug Trap in attracting and trapping RBBs.

On the other hand, the researcher asked the respondents to rate the device according to their observations using questionnaires. The non-probability sampling technique, specifically purposive sampling, was used in this study; this type of sampling was selected based on the population's characteristics and the study's objective, which can help reach target respondents.

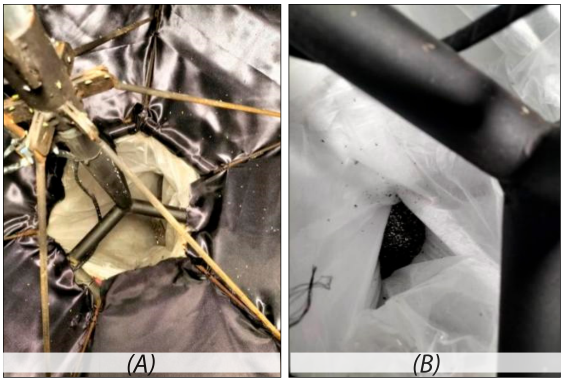


Figure 10. *Captured RBB (A) inside the Catcher and (B) inside the empty sack*

Figure 11. *Weighing of RBB*

The distributions of respondents were five engineers as an expert and 15 farmers who observed the operation of the device, with a total number of 20 respondents. The identified respondents were engineers (electrical engineers, mechanical engineers, and electronic communication engineers) who know the various functionalities of the device and a group of farmers who have experience in eliminating RBB inflection on their farms. Figure 12 shows the respondents, male and female, including the researcher, assessing the solar-powered rice black bug trap. They were observing and given a checklist to evaluate the device's performance and functionality.

Figure 12. *Respondents' observations during testing*

RESULTS AND DISCUSSION

Effectiveness of solar-powered rice black bug trap

The effectiveness of solar-powered rice black bug traps was evaluated based on the captured RBBs in terms of the LED lamps used and by the respondents' observations. The finding revealed that the light trap helped attract and trap adult Rice black bugs on the farm. This is valuable to farmers to limit and avoid risks from the toxic pesticide. Moreover, the constructed light trap is handy for RBB and other invasive nocturnal insects that damage crops.

Trapping of RBBs using LED lamp

Table 2 shows the captured RBBs using the developed light trap with LED technology. The data shows the actual weight of the RBBs trapped during the duration of testing. The light trap was tested for three consecutive months, 3 days before and 3 days after the full moon. Treatment 1 captured RBBs weighed 226 grams, treatment 2 weighed 108 grams, treatment 3 weighed 378 grams, treatment 4 weighed 416 grams, treatment 5 weighed 948 grams, and treatment 6 weighed 724 grams. Based on the data gathered, treatment 5 has the most significant amount of RBB trapped, closely followed by treatment 4.

Table 2. *Captured RBBs in grams using different LED lamp*

LED Lamp		Amount of RBB captured (grams)	
		Color Temp. 1 (Warm White)	Color Temp. 2 (Daylight)
Lamp 1	12 watts (600 lumen-1000 lumen)	226 grams	108 grams
Lamp 2	25 watts (2000-4000 lumen	378 grams	416 grams
Lamp 3	50 watts (4,500-5000 lumen)	948 grams	724 grams

Table 3 presents the effectiveness of solar-powered RBB traps in capturing RBBs using LED bulbs with warm white and daylight color temperatures. Using ANOVA in the data analysis, it was found that there was no significant difference between the developed light trap with Warm White LED and Daylight LED in attracting and capturing RBBs. The finding of this study was supported by the study of Wakefield et al. (2016), which found that there is no significant difference in the attraction of insects between the "cool-" and "warm-white" LEDs.

However, concerning the counts of the captured RBBs, this study found that warm white color temperature with a high power rating and luminance attracted and captured more RBBs than daylight color temperature with the same power rating and luminance level. Moreover, the trap is very effective when using a warm white color temperature with a higher power rating and luminance level.

According to Kim et al. (2019), physical pest management in integrated pest management (IPM) will be more effective with the introduction of modern light traps outfitted with superior light sources, such as light-emitting diodes (LEDs). Moreover, Park and Lee (2017) cited that using LED technology in light traps and IPM can potentially decrease crop loss due to agricultural pests. It proved that it is very effective even on RBB in rice farms.

Table 3. *Effectiveness of using warm white and daylight-colored temperature LED bulbs*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2261.929	5	452.386	.950	.461ns
Within Groups	17149.714	36	476.381		
Total	19411.643	41			

Functionality of the light trap

Light traps equipped with automatic components serve as effective tools for pest control, significantly reducing the workload for farmers and preventing the spread of pests (Batay-an et al., 2007). By utilizing electricity or electrocution devices, these traps efficiently reduce pest populations without requiring extensive manual labor, thus minimizing reliance on chemical pesticides and promoting environmental sustainability (Batay-an et al., 2007). The efficacy of electrocution systems is evident from respondents' feedback, indicating "Excellent" as a high rating for their effectiveness and functionality in eliminating pests like RBBs. Additionally, auto-response features further enhance the functionality of light traps by enabling them to operate autonomously, thereby alleviating labor-intensive tasks for farmers. This indicates that the light trap operates automatically based on the function that addresses the trap. It proves that developing the light trap was excellent in its functionality.

Moreover, the development of light traps with enhanced performance and maintainability underscores their importance in integrated pest management strategies (Kim et al., 2019). By optimizing their functionality and ensuring ease of operation, these traps become invaluable assets for farmers, as evidenced by the positive feedback regarding the operation and maintainability of developed solar-powered traps, underscoring as excellent as perceived by the respondents. The emphasis on cost-effectiveness and accessibility of materials for trap maintenance aligns with the need for practical solutions that farmers could readily deploy and sustain (Calderon, 2017). Thus, integrating automatic features and meticulous design considerations streamlines pest control efforts and enhances light traps' overall performance and usability in agricultural settings.

Table 4. *Functionality of the device*

Statement /Condition	Weighted Mean	Verbal Rating
Auto response	4.5	Excellent
Electrocution System	4.6	Excellent
Operation	4.54	Excellent
Maintenance	4.54	Excellent

CONCLUSION

In conclusion, the study demonstrates the efficacy of a solar-powered light trap for rice black bug (RBB) control in rice farms. The result shows no significant difference between warm white LED and daylight LED in attracting and capturing the rice black bugs in the field using the developed device. On the other hand, based on the weighed captured RBB, the trap with a 50-watt warm white LED bulb (lamp 3) captured the most RBBs, followed by the daylight bulb (lamp 3) and the 25-watt versions (lamp 2). Warm white LEDs were significantly more attractive to RBBs than daylight LEDs. Overall, the findings suggest that light traps with high luminance and warm white LEDs offer a promising and sustainable solution for RBB management, potentially reducing reliance on synthetic pesticides.

Recommendation

Based on the results and conclusions, the following suggestions are provided:

1. The LED bulbs with higher luminance levels used in the rice black bug trap could result in better capture of the rice black bug.
2. A more detailed power computation and power specification used for the rice black bug trap is advantageous in providing a better photovoltaic system.
3. The electrocution part of the device should have a wider size or range to kill more RBB.

4. Further study is recommended to measure efficiency by counting the number of bugs and considering the different factors contributing to the device's effectiveness in trapping RBB, which includes the correct setup of the RBB Trap system concerning the prevailing wind in rice fields.

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